Recycling Used Electronics

Report on Minnesota's Demonstration Project

Minnesota Office of **Environmental Assistance**

PLUG INTO RECYCLING

Principal Authors

Tony Hainault, Minnesota Office of Environmental Assistance

Douglas S. Smith, Sony Electronics, Inc.

David J. Cauchi, Waste Management Asset Recovery Group

David A. Thompson, Matsushita Electric Corporation of America

Michael M. Fisher, Ph.D., American Plastics Council

Colleen Hetzel, Minnesota Office of Environmental Assistance

Minnesota Office of Environmental Assistance

Contributors and Reviewers

Joe Aho	Maureen Hickman
David Cera	Tony Kingsbury
Patty Dillon	Kevin McCarthy
John Gilkeson	Tom Miller
Linda Headley	Doug Morris
Garth Hickle	Amy Roering

SONY

WM WASTE MANAGEMENT

Editing, Design and Technical

Paul Andre	Laurie Gustafson
Jim Behm	Glenn Meyer
Theresa Gaffey	

Panasonic

Acknowledgments

The project partners wish to thank the collection site hosts for their dedication and commitment to the project. This work could not have been done without their efforts. The project partners would also like to give special thanks to MBA Polymers for their unique technical contributions to the plastics evaluation phase of the study.

American Plastics Council

For a printed copy of this report, contact the OEA at 520 Lafayette Rd. N, St. Paul, MN 55155-4100, or to retrieve a PDF copy, visit the OEA Web site at **www.moea.state.mn.us**.

The total cost of preparing the Report on Minnesota's Demonstration Project for Recycling Used Electronics*, including staff time for the collection and evaluation of data, writing, editing and printing was approximately $44,500.*

This report was printed by a Minnesota Great Printer on 100% post-consumer recycled paper manufactured without chlorine or chlorine derivatives (PCF).

Recycling Used Electronics

Report on Minnesota's Demonstration Project

Contents

July 2001

PLUG INTO RECYCLING

This page intentionally left blank

Executive Summary

In 1999 and 2000, Minnesota's Office of Environmental Assistance (OEA) managed a public/private effort to learn more about the costs and barriers to recycling used electronic products. Electronics contain significant amounts of contaminants, including mercury, lead, cadmium, and polychlorinated biphenyls (PCBs). Cathode ray tubes (CRTs), the picture tubes from televisions and computer monitors, are one of the largest sources of lead in municipal waste. End-of-life (EoL) electronics also contribute a relatively large amount (nearly two percent and growing) to the volume of municipal waste, even though the residual material in these products has a relatively high value for recycling.

Through a demonstration project, the OEA worked with local communities and counties across Minnesota and with industry partners to collect and recycle used electronics. Each principal partner—Sony Electronics, Waste Management-Asset Recovery Group (WM-ARG), Panasonic, the American Plastics Council and the OEA—dedicated a minimum of $25,000 to the project.

The joint effort was designed to implement key aspects of product stewardship, an approach to managing products at end-of-life in which all parties who design, manufacture, sell, use and dispose of products are expected to share responsibility for managing that product when no one wants it anymore. Bearing some of the costs for managing products at end-of-life encourages manufacturers to design products differently, so that the products use less packaging, are easier to recycle and contain fewer toxic constituents. This project used the strengths of each of the five partners to develop the first large-scale multi-stakeholder effort in North America to divert used electronic products from municipal waste.

Lead in CRT glass

CRT Size	Lead
13-inch	1.0 lbs.
17-inch	1.5 lbs.
27-inch	4.0 lbs.
32-inch	6.5 lbs.

CRTs do not contain pure lead, but 22 to 25 percent of the funnel glass, by weight, is in the form of lead oxide.

Source: Sony Electronics

Objectives

By learning more about collection methods and recycling markets available for secondary materials derived from EoL electronic products, the partners hoped to be able to use the findings as a basis for future policy-making and program decisions in Minnesota and for corporate decisions by the manufacturing and recycling partners. The specific objectives of the joint effort were to:

- **Explore the economies of scale** for recycling used electronic products.
- **Evaluate high-end recovery of CRT glass and engineering plastics** from used electronic products along with best economical recycling options.
- **Evaluate costs of recycling materials** from these products by learning more about the recycling markets available for secondary materials derived from end-of-life electronics.
- **Increase electronics recycling in Minnesota** without relying solely on government funding.
- **Identify infrastructure development needs** by comparing and assessing costs and effectiveness of various collection techniques sponsored by local government and retailers.

Planning

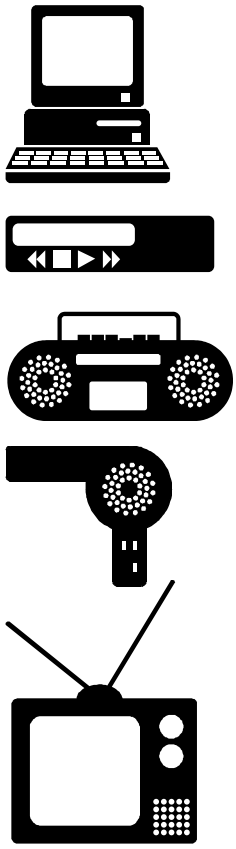
From the beginning, the collection effort was broadly targeted, including electrical as well as electronic products. Accepting "anything with a cord or a battery" hit the right mix of products and communicated a simple, clear message to the public.

The partners believed that no single collection strategy could meet the diverse needs of communities and regions in Minnesota. Through a Request For Participation process, the partners sought local sponsors for a variety of collection methods. This would make it possible to compare participation rates among various methods and to learn if some methods were more successful and/or less costly than others at capturing used products.

Once collection sites were selected, the OEA and WM-ARG (the recycler) worked with each local site host to prepare for the collection event designed for that community—establishing dates for collection events, duration of events, target audience and other relevant details.

The project targeted both electronic and electrical products — "anything with a cord or a battery" — communicating a simple, clear message to the public.

Products included electronics like televisions and computers, as well as household electrics such as kitchen appliances and hair dryers.



Results

From July 31 to October 31, 1999, residents in selected communities had a free opportunity to bring used electronics to collection sites. Collections were held at 64 sites across Minnesota, including three retail locations that volunteered to participate. In all, events were held in 32 Minnesota counties.

Participation

The estimated potential population served by these events was 1.3 million. About 9,000 people participated in collection events; 7,639 of these participants completed surveys when dropping off used electronics at collection events.

According to survey results, most people participated because they liked the idea of recycling the product and they wanted to protect the environment. When participants were asked who should pay for the safe recycling and disposal of electronics, 38 percent said manufacturers, 34 percent considered it the responsibility of consumers, 15 percent said government, 6 percent said retailers.

Survey: Who should pay for electronics recycling?

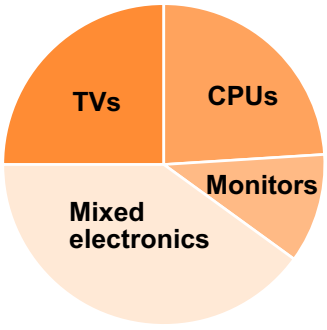
Manufacturers	38%
Consumers	34%
Government	15%
Retailers	6%

Amount of product collected

During the three-month collection phase of the project, 575 tons of used product were dropped off at collection sites—almost twice the amount partners expected. The products were separated into five broad categories, disassembled, and evaluated for scrap content and value.

An additional 125 tons of packaging (pallets, gaylord boxes, shrink-wrap and so forth) were needed to ship the product from the collection sites to Waste Management-Asset Recovery Group's processing facility in the Twin Cities metropolitan area.

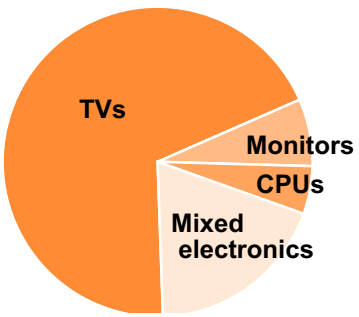
Sorting collected electronics: Broad product types



Source: Participant surveys

Quantity		Weight
25%	TVs	69%
11%	CPUs	7%
24%	Computer monitors	5%
40%	Mixed electronics*	19%

* Includes consumer electronics (telephones, fax machines, scanners) and household electronics (kitchen and bathroom appliances, radios, etc.)



Source: WM-ARG

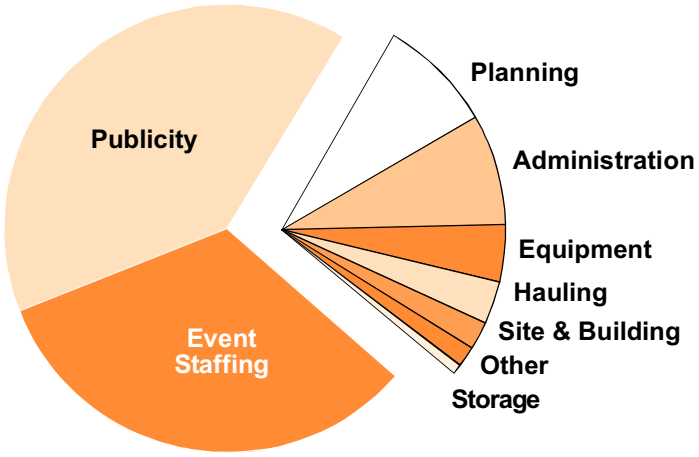
Costs

Local collection site sponsors reported spending a total of $165,843 to plan, prepare, administer and host collection events, which equals about $288 per ton of product collected. Publicity and event staffing were the largest costs incurred by hosts of collection events.

The principal partners on the project structured financing for the collection events so that local collection site hosts would not incur costs to transport old products from the point of consolidation to the processing facility, nor would they incur a charge to recycle these products. Nonetheless, the cost to collect product was significant.

Costs to local collection sites

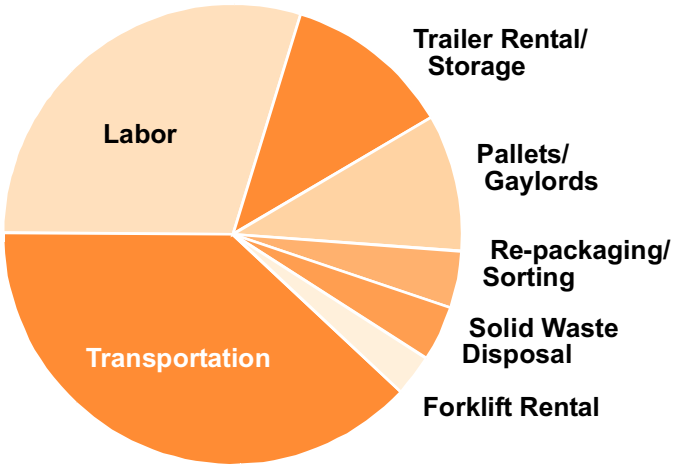
Publicity	39.7%
Event Staffing	32.6%
Planning	8.3%
Administration/Oversight	8.0%
Collection Equipment	4.1%
Hauling	3.1%
Site and Building	2.0%
Other	1.5%
Storage	0.7%



The recycler, WM-ARG, reported total operating costs of $135,000, excluding overhead and return on investment; revenues from the sale of recovered secondary materials totaled approximately $43,000. Net cost was $160 per ton to transport, process and market reusable and secondary materials. WM-ARG's largest single expenditure (38 percent) was transportation of materials from collection events to their central facility.

Costs to recycler

Transportation	38.2%
Labor	29.7%
Trailer Rental/Storage	11.8%
Pallets/Gaylords	9.6%
Re-packaging/Sorting	4.0%
Solid Waste Disposal	3.9%
Forklift Rental	2.9%



Glass recycling

In all, 45,000 pounds of glass were shipped to a glass recycler for use by a glass manufacturer; 226,000 pounds of glass were shipped to a lead smelter. Inclusive of transportation, it cost $0.025 per pound to send glass to the CRT glass manufacturer and $0.045 per pound to send glass to lead smelters to be used as a fluxing agent and for lead recovery.

While examining the cost of glass-to-glass recycling was among the initial objectives, the end market used was identified late in the project. Had this recycling option been available earlier, more glass from the project would have been recycled in this manner.

Plastics analysis

More than 31,000 pounds of plastics were shipped to MBA Polymers, Inc. in California for evaluation and processing. The plastics analysis determined that the dominant plastic resin from televisions (FR HIPS) can meet critical specification standards and can be remolded for use in new products. In other words, based on the properties tested, it is possible to segregate post-consumer engineering plastics and meet stringent quality requirements.

Plastic resins in sample

Resin	Total Sample	Television Plastics	Computer Plastics	Misc. Plastics
HIPS	56%	82%	25%	22%
ABS	20%	5%	39%	41%
PPE	11%	7%	17%	4%
PVC	3%	<1%	5%	15%
PC/ABS	3%	0%	6%	7%
PP or PE	2%	0%	3%	8%
PC	2%	1%	4%	1%
Other	<1%	<1%	<1%	2%
Unidentified	3%	5%	0%	0%

Conclusions

The following conclusions describe some of what the principal partners learned from their collaboration on the demonstration project.

Product Stewardship

Strategic voluntary partnerships can work. The demonstration project proved worthwhile for bringing public and private interests together to work toward common goals and for revealing costs and burdens of recycling used electronics to everyone in the supply chain. The project proved the value of collaboration among government, recyclers and manufacturers to find solutions for removing used electronic products from municipal waste.

Working model of shared product responsibility. The demonstration project proved the advantages of public/private collaboration to prevent the disposal of used electronic products in municipal waste. It provided direct ties to the marketplace at critical stages of work, as well as direct communication to regulatory authorities.

Costs

Minimize handling of used products. There is a high cost associated with handling used products. Reducing the number of times products must be handled from the point of collection to the point of sale as secondary material will reduce overall operating expenses.

Pilot costs are higher than the costs of a mature program. The costs to implement this one-time demonstration project are higher than would be expected under routine operating conditions. For example, many of the reported costs are one-time capital and operating expenses—costs that would otherwise not be incurred, or could be reduced substantially if collections were conducted as regularly held seasonal events or as permanent programs. While new programs often have high capital and operating costs, capital costs are reduced or eliminated and operations are made more efficient as programs mature.

Adequate funding will motivate local government participation. Well-attended public collection events proved more costly to host and required more time to prepare and staff than anticipated. Adequate funding for future events may affect decisions by local government to host or sponsor such events. Containing the cost to collect and transport used electronic products and related secondary commodities is key to developing a reuse and recycling infrastructure.

In addition, many Minnesota counties outside the metropolitan Twin Cities do not currently have full-time staff to administer existing waste-related programs for household hazardous waste, recycling, business generators of hazardous wastes, illegal dumping and other solid waste issues. Any program to address waste electronics that anticipates participation from government must provide adequate funding to accomplish its goals.

Collection methods

Dedicated "electronics-only" collection events were more cost-effective and attracted more participants than collections held in association with other waste management or recycling activities. Retail, as a collection strategy for used electronic products, was the single most successful strategy employed during the project, as a percent of total participants or as a cost per participant.

Retail stores can provide an important link in the process of moving used electronic products from consumers back to the recycling supply chain. The retail stores that participated in the pilot—Computer World (Duluth) and Circuit City (Burnsville and Maplewood)—made a significant contribution to the number of people who participated in the demonstration and the total volume of products collected.

Collection strategies used in the pilot project

Collection Strategy	Number of Participants	Number of Sites	Avg. Cost per Participant
Curbside	297	1	$19.30
Household hazardous waste sites	882	14	$69.72
Multi-facility	983	12	$68.41
Permanent recycling facility	440	6	$60.61
Retail	2,667	3	$11.75
Special collection, electronics only	1,536	12	$22.88
Special collection, multi-purpose	834	16	$26.42

Vintage study

Roughly half of televisions collected during the project were manufactured in the 1960s and 1970s and may contain PCB capacitors. Polychlorinated biphenyls (PCBs) are known carcinogens and were phased out of consumer products in the late 1970s. Materials like these in older products will affect disassembly and increase the costs to properly manage products at end-of-life (EoL).

This "vintage study" of televisions also showed that potentially 15 percent of all TVs collected were "orphan" products, that is, the manufacturer is longer in business. These orphan products pose a serious disposal challenge.

This vintage study can help future programs develop EoL strategies for used TVs, including fee structures, collection opportunities and the availability of secondary market options and costs. From a management perspective, knowing the ages and manufacturers of collected electronic products will be helpful in planning future recycling efforts.

Plastics recycling

Plastics from the study met strict specification standards required for use in the manufacture of new products. To do so economically, large volumes of these plastics must be collected and processed to meet manufacturing production schedules that typically require a monthly minimum of 100,000 pounds.

Recommendations

The pilot project was a successful collaboration between the public and private sectors. The principal partners offer these recommendations based on what they learned from the demonstration project. These recommendations can be used by public and private entities as they design opportunities to recover electronic products at end of life.

Encourage product stewardship initiatives

Industry efforts to foster voluntary and private sector recycling opportunities for used electronic products will contribute to the development of end-of-life management strategies that are environmentally and economically sustainable. These efforts must include initiatives from the design stages of products through end-of-life management strategies. Such initiatives may offer alternatives to the government mandates emerging in Europe and elsewhere.

Refine collection procedures

Collecting used electronic products is the most costly step toward their reuse and recycling. The best collection strategies will distribute this cost equitably among those who benefit from the manufacture, sale and use of these products. There will not be a single collection strategy that meets this intent, but the best collection strategies will meet local needs or will meet the needs of specific types of consumers.

Event sponsors. Fully define roles and responsibilities for all event sponsors before collections begin.

Reuse options. At events where large volumes of used product are collected, providing options for reuse will increase EoL revenues, extend the useful life of products, and benefit consumers that may otherwise not have access to products or technology.

Retail collection sites. Six steps will help retail stores interested in collecting used electronic products from consumers for reuse and recycling:

1. Define a business purpose and communicate with employees about the effort and why the store is involved.

2. Clearly communicate to customers and participants the purpose of the program and how one can participate.
3. Describe what will be done with the used products that are collected.
4. Display appropriate and visible signage at the store before and during the collection events.
5. Plan for good promotion of collection event.
6. Staff adequately for the collection event, enlisting store personnel, local government staff, recyclers and/or volunteers from local service organizations.

Reduce transportation costs

Transportation is a critical budget element for any recycling enterprise. In the demonstration project, transportation, packaging supplies and equipment to move used products from the point of collection to the processing facility cost more than anticipated, despite efforts to adequately plan for this phase of the project.

Packaging for transport—pallets, gaylord boxes and shrink-wrap—is expensive to use and offers limited opportunities for reuse. Nonetheless, some sort of packaging is necessary to reduce handling, to maximize hauling capacity and to minimize worker health and safety concerns.

- Future efforts to recycle used electronics must better identify packaging needs in advance.
- Improved packaging supplies and materials can reduce the cost to handle and transport used electronic products through the recycling chain. There is an opportunity to develop a new reusable container type to transport used electronics from the point of collection to processing sites.

On-site storage for collected product can reduce transportation expenses by taking fuller loads from collection sites to the processor.

- Large trucks employed to move product long distances should not travel with less than 60 percent of full load capacity. (The average truck during the demonstration project moved from collection sites to the processing facility at 28 percent capacity, increasing transportation costs by as much as 60 percent.)
- Address barriers to maximum loads at the earliest stages of a temporary or permanent system. Barriers may include inadequate planning, regulation, and insufficient storage capacity near the point of collection.

Spur recycling market development

Manufacturers and others in the manufacturing supply chain can spur recycling market development for CRT glass and engineering plastics by buying more of these secondary materials for new product manufacturing.

- Manufacturers can contribute to recycling market development efforts by experimenting with reclaimed raw materials from EoL electronics in new product.
- Buy recycled, including secondary materials for production and new product with recycled content.
- Increasing use of recycled materials to manufacture new products will require attention to specification standards and greater communication along the supply chain as well as within corporate structures. The flow of information must include designers, manufacturing operations, utilities and maintenance personnel and others.
- Commercially viable export markets exist for many secondary commodities and presently offer strong competition in the marketplace for EoL electronics and recovered materials including engineering plastics. Regulators, recyclers and manufacturers should consider the potential environmental and economic consequences of shipping used electronics overseas, including any long-term environmental and legal significance.

Improve processing technologies

- The collection and processing efficiencies for recycling used electronics, and the resulting costs or revenues, should be evaluated against the efficiencies for other recyclable materials and waste management systems.
- Significant progress has occurred in recent years in mechanical recycling technologies for engineering plastics and CRT glass from EoL electronics. Nonetheless, further development of recycling technologies is necessary to recover higher value from many electronic materials and components.
- Adopt clear, consistent commodity specifications, especially for post-consumer CRT glass and recovered streams of engineering plastics, to assist recovery of these secondary materials. Commodity specifications communicate clearly to recyclers about how to process material and can signal manufacturers that quality assurance will be met.

Examine regulatory barriers

Simple, common sense regulations for recycling used electronic products will be welcomed by local government, recyclers and manufacturers alike. They are an important part of developing a viable recycling infrastructure for used electronic products. Such regulations can address governments' environmental protection concerns, while simplifying regulatory operations for legitimate recyclers of used electronic products.

Educate the public

Consumers play an important role in the recycling and reuse of old electronic products. The public needs to be educated about the hazards associated with improper disposal of used electronics and the importance of recovery.

- Education efforts must also provide clear information about what people can do with used products they no longer want.
- The opportunity to reuse older electronic products is time-sensitive, and the longer products are kept or stored, the less likely that they will be reused. Therefore, education about electronic product reuse must encourage consumers to pass products on to new users or intermediaries as soon as the consumer no longer wants or uses the product.

Looking ahead

This *Report on Minnesota's Demonstration Project* describes work conducted in a specific geographic area over a defined period. The partners fully expect that readers will apply the information and data presented to markets and communities outside Minnesota.

Therefore, readers will benefit from paying close attention to similarities and differences between their circumstances and the ones described. Market prices shown in the report may be of interest, but readers are cautioned that markets for commodity values in those markets to fluctuate. The market prices available in Minnesota in 2000 may no longer be available.

Finally, the experience of this project is a useful benchmark, but it is not definitive. The partners view this effort as one of many that will be necessary in creating a viable recycling industry for used electronic products. We invite those working in the field to build on our effort from this demonstration project.

[i] It is important to note that we did not have a method to track undercounted participation. One could equate participants to households. Many waste and recycling programs, such as local government HHW programs, track participation by household. For this project, there was interest to identify total population served.

Part One
Background

In Minnesota, municipal solid waste is managed to conserve resources and to prevent pollution of the environment. In addition to aggressively promoting recycling, the state strives to remove products containing heavy metals and other undesirable substances from waste prior to incineration or land disposal. Minnesota is especially concerned with the disposal of electrical and electronic products.

End-of-life (EoL) electronics contain significant amounts of contaminants, including mercury, lead, cadmium and polychlorinated biphenyls (PCBs).[ii] These toxic materials are not a problem when consumers use electronic products, but they can create health and environmental hazards if they are not properly disposed of at end-of-life. At the same time, electronic products contain valuable secondary materials—metals and engineered plastics—that can be used by the marketplace in the production of new products.

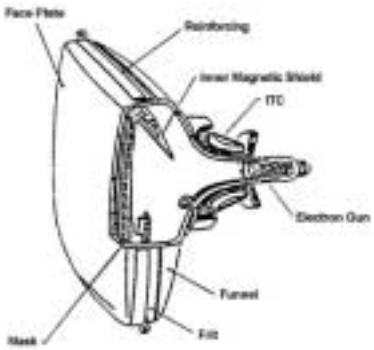
Over the last six years, Minnesota has actively looked for better management practices for used electronics at end of life. The Office of Environmental Assistance's report *Management of Waste Electronic Appliances*, (1995) developed estimates of the number of electronic appliances entering the waste stream and gathered information on the toxic and hazardous materials they contain. The report outlined management alternatives and gave recommendations for improving the management of electronic materials in wastes. Also in 1995, the Minnesota Pollution Control Agency, working in cooperation with metropolitan counties, added CRTs and circuit boards to Minnesota's Pilot Project for Special Hazardous Waste (an interim step prior to adopting federal universal waste rules).

Minnesota's Pilot Project for the Management of Special Hazardous Waste *is explained in fact sheets on the MPCA's Web site. http://www.pca.state.mn.us/waste/pubs/business.html*

Toxics in electronics

Cathode ray tubes (CRTs). The picture tubes from televisions and computer monitors are among the largest sources of lead in municipal waste. A recent model 27-inch television may contain nearly four pounds of lead. Older products may actually have more, such as lead in face plates (the front viewing panel of a CRT). Perhaps the most significant lead in CRTs is in the glue, or frit, that holds together the face plate and funnel glass of color monitors.

Figure 1-1. Anatomy of a cathode ray tube (CRT)



Significant amounts of lead can be found in a CRT's funnel glass and the frit—the glue that holds together the panel (face plate) and funnel glass of color monitors.

CRTs do not contain pure lead, but nearly one-fourth of funnel glass (22-25%), by weight, is lead oxide.

Sources: Panasonic, Sony Electronics

CRT Size	Lead
13-inch	1.0 lb.
17-inch	1.5 lb.
27-inch	4.0 lb.
32-inch	6.5 lb.

Printed wire boards. Part of the circuitry in electronic products, printed wire boards are the next largest source of lead in municipal waste, principally from the soldering on these components. Printed wire boards may contain chromium, mercury, cadmium and other metals and compounds. Heavy metals and other constituents of these products increase the cost to properly manage them if disposed of in general municipal waste.

Batteries. Electronic products also often contain batteries—nickel-cadmium, alkaline, mercuric oxide, silver oxide, zinc oxide, lithium, carbon-zinc—many of which are a concern to waste management officials when these batteries are disposed of in household trash.

Plastics. Plastic housings and cables used in electronics often have additives or stabilizers that contain heavy metals. Older TV plastic housings are laminated and cannot be recycled.

A growing volume of end-of-life electronics

The OEA is interested in the conservation and sustainable use of resources and is concerned about the growing pressure on existing disposal options in Minnesota to keep electronic products out of the garbage. Electronic products with cathode ray tubes, such as televisions and computer monitors, contain lead and other heavy metals that are toxic if released into the environment. Products containing CRTs are considered the single largest source of lead in Minnesota's municipal waste, containing 5-8 pounds of lead per unit. They also contain valuable glass, metals and plastics that can be used to make new products, rather than wasted.

A recent study by the National Safety Council's Environmental Health Center found that 20.6 million computer monitors became obsolete in 1998, and that only 11 percent of those products were recycled.

Increasingly rapid technological innovations mean people want to replace their electronic equipment more often. A 1999 study by the National Safety Council estimates that nationally, nearly 500 million computers will become obsolete between 1997 and 2006. Most old electronic products are either in storage or are thrown in landfills rather than recycled.

A 1999 composition analysis of Minnesota's municipal solid waste (MSW) indicated that end-of-life electronics contribute approximately two percent to MSW in the state. Fieldwork for the study overlapped slightly in time and place with the electronics recycling demonstration project. It is not believed that this overlap affected the results of the composition study, but the fact that people had a one-time opportunity to recycle used electronics during the waste composition study may have reduced the amount of electronic products in the overall composition of the waste that was evaluated.

The OEA and SWMCB estimate that there are presently about 3.5 million television sets, and 1.5 to 2.0 million computer monitors in homes businesses in Minnesota. There are an estimated 900,000 units sold each year, and that figure is probably growing with each year. While many of these units are in use, many are unwanted or unusable, and all of them will one day require management at end-of-life.

In 2006, television broadcasters will complete the transition of switching from analog to digital transmission signals, as required by the Federal Communications Commission. While that date may be subject to change, the replacement of analog television with High Definition TV (HDTV) *will* occur. Once completed, consumers will have to buy a "conversion box" to attach to an analog TV to continue to receive transmissions or replace the analog set with a new digital one. This conversion of conventional technology will be the most dramatic change for consumer products since the switch from radio to television. Solid waste professionals have concerns that it will result in a significant amount of electronics waste.

This rapid rise in the number of computers, televisions and other electronic items becoming obsolete represents a substantial quantity of material that contains hazardous and toxic materials. This will place tremendous pressure on waste management systems not only in Minnesota, but throughout the United States and overseas. At the same time, the scrap from used electronic products commands a relatively high price in secondary markets, which means it has good value for recycling. For these reasons, it makes sense to remove these products from municipal waste.

Product stewardship

An innovative approach to resource conservation, **product stewardship** seeks to increase the recovery and recycling of products through partnerships between government and industry and provides incentives for the redesign of products to reduce toxicity and facilitate recycling. Minnesota, through its Office of Environmental Assistance (OEA), is the first state in the country to develop and implement a product stewardship policy.

Product stewardship places responsibility for addressing the environmental impacts of products throughout their life-cycle on the parties who produce, sell and use products, and holds that those with the greatest influence over the environmental impacts of the product have the greatest responsibility to address those impacts. In particular, product stewardship calls on manufacturers to share in the financial and physical responsibility for recovering and recycling products when people are done using them. When manufacturers share the costs of recycling products, they have an incentive to use recycled materials in new products and to design products to be less toxic and easier to recycle, incorporating environmental concerns into the earliest phases of product design.

OEA's partnership with Sony, Panasonic, Waste Management-Asset Recovery Group and the American Plastics Council to conduct the electronics collection and recycling project is one part of the OEA's product stewardship initiative for electronics. The electronics demonstration project employed models for collecting and recycling used electronics in which manufacturers, retailers, recyclers, government and consumers each played an important role. Government and industry are using the results of this project—an evaluation of costs and benefits of different collection and recycling methods—to help guide ongoing efforts to develop a long-term product stewardship program for used electronics.

Project partners

In the fall of 1998, Minnesota's Office of Environmental Assistance (OEA) began planning a public/private effort to learn more about the costs and barriers to recycling used electronic products. In 1999, the OEA launched an innovative demonstration project to evaluate methods for capturing and recycling used electronics from residential waste in Minnesota. The project, which concluded in 2000, strategically melded three related goals of the OEA: product stewardship, recycling market development and toxics reduction. By documenting costs and revenues related to recycling used electronic products diverted from municipal waste, the OEA wanted to develop specific information to encourage and motivate voluntary and private efforts to recycle these products. Similarly, the electronics industry sought to identify EoL management strategies that are environmentally and economically sustainable and may offer alternatives to the government mandates emerging in Europe and elsewhere.

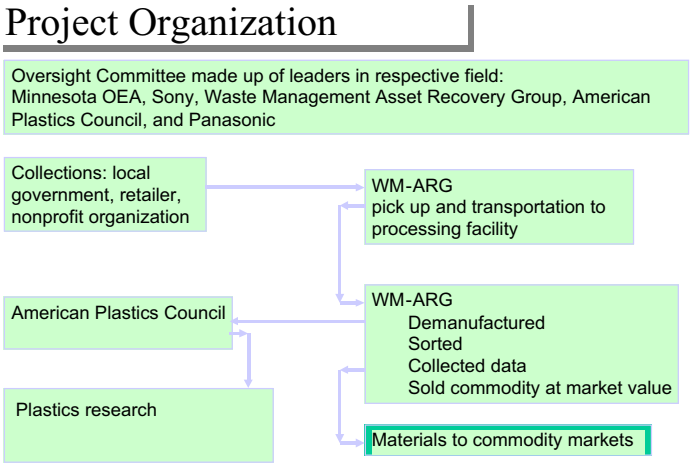
Minnesota's efforts to promote product stewardship for used electronic products rest in the concept of sharing responsibility with manufacturers and others to collect and recycle EoL products. The OEA believes that a private sector infrastructure can be developed to manage EoL electronics that would offer the most efficient way to recover these materials and keep them out of municipal waste. A product stewardship recovery model also provides incentive to manufacturers to design products to be less toxic and more reusable and recyclable.

The OEA believed that a successful electronics recycling demonstration project must involve representatives from both the public and private sectors to achieve optimal planning, scope, results and follow-through. The OEA sought voluntary initiative from industry to help address environmental and economic concerns about the disposal of used electronic products in municipal waste. By working collaboratively on a defined project,

each participant would gain unique insights into approaches to problem solving and priorities for addressing issues of concern to all parties.

The partnership for the demonstration project evolved over several years from interactions among various stakeholders associated with the computer and electronics sector, especially manufacturers and the OEA. Sony Electronics Inc., Waste Management-Asset Recovery Group (WM-ARG), Panasonic, the American Plastics Council (APC) and the OEA committed time and talent to the project in addition to a minimum contribution of $25,000. Throughout this report, these five organizations are referred to as the project partners or principal partners. (See Appendix A for further description of project partners.)

Figure1-2. Flowchart of demonstration project



Discussions among the OEA and its industry partners focused on specific strategies to divert products from waste that would promote reuse and recycling of these products. The discussions explored:

- **Collection and recycling.** The roles of various parties—manufacturers, state and municipal governments, retailers, recyclers and nonprofits—to collect used electronic products.
- **Economical processing methods.** Reduce handling for preparing secondary materials for market.
- **Recycling market development.** The role of government and industry in developing markets for secondary materials derived from these products once processed.
- **Design initiatives.** Efforts by industry to reduce the use of hazardous materials in products and to spur recycling by making products easier to recycle and by using post-consumer glass and plastics in new products.
- **Regulatory initiatives.** Identify opportunities to increase recycling by reducing current barriers to the movement of used products.

Reliance on private recycling companies was an additional aspect of the project that appealed to the corporate partners. Many manufacturers have been concerned that implementing a company-sponsored recycling program for used consumer products would detract from core business activities. Private recycling companies that can manage the growing volume of used electronic products provide an alternative model for recycling that remains in the private sector.

The project partners designed the demonstration project with a shared vision of the overall problem of waste electronics and the specific goals to be accomplished by the effort. The project used the strengths of each of the five partners to develop the first large-scale, multi-stakeholder effort in North America to divert used electronic products from municipal waste.

The partners agreed to the following goals for the partnership:

- *All participants bring something to the table.*
- *All project information be shared.*
- *Commitment to evaluate opportunities and barriers for life-after-project.*
- *Commitment to share information and lessons learned with other states, manufacturers, recyclers, municipalities, suppliers and others.*

Project Objectives

The ultimate goal of recycling is to make better use of resources and to remove, from municipal waste, products that are potentially harmful to the environment. Too often, however, c*ollecting materials for recycling* is mistaken with *fully recycling* those materials. Instead, it is just the first stage of a much larger process of separation, dismantling and selling secondary materials to markets that sell them to manufacturers who then return these commodities to the production cycle of new products.

Through the demonstration project, the partners hoped to identify ways to recycle used electronics without relying solely on taxpayers to pay for that effort. In planning the project, the partners set out not just to track the costs for collecting used electronics from the residential sector, but also to systematically identify recycling options for secondary material streams generated from demanufacturing these products.

The primary objectives of the joint effort were to:

- **Explore the economies of scale** for recycling used electronic products.
- **Evaluate high-end recycling of CRT glass and engineering plastics** from used electronic products along with best economical recycling options.
- **Evaluate costs of recycling materials** from these products by learning more about the recycling markets available for secondary materials derived from end-of-life electronics.
- **Increase electronics recycling in Minnesota** without relying solely on government funding.
- **Identify infrastructure development needs** by comparing and assessing costs and effectiveness of various collection techniques sponsored by local government and retailers.

High-end recycling *refers to the use of recovered materials in the production of new products in a manner consistent with the original purpose of the material, also referred to as closed-loop recycling. High-end recycling commands a better price for secondary materials in the market place and has the potential to be a significant source of revenue to recyclers. See Figure 2-1.*

The project partners wanted to explore all aspects of recycling used electronics and to evaluate ways to share costs and responsibilities for recycling these products. By quantifying the specific costs and revenues associated with collecting and processing used electronic products, the project partners sought to identify ways to manage these costs and revenues in the future. In doing so, they hoped to encourage greater efforts to recycle these products—products that have significant resource value at end-of-life and which pose a significant threat to the environment.

Through the demonstration project, the public/private team specifically wanted to:

- Identify needs and opportunities for existing infrastructure, especially for collecting, processing, marketing and utilizing secondary materials from used electronics.
- Gather data that could be used to improve the recycling infrastructure for used electronic products in Minnesota and elsewhere.
- Evaluate the costs, efficiencies and public preference for a variety of collection events or techniques sponsored by public and private entities.
- Determine costs of transportation, processing and disposal of waste.
- Evaluate opportunities to reduce the cost of managing televisions and computer monitors to recyclers and to increase revenue potential for secondary materials through sales to commodity or reuse markets.
- Compare the cost and/or revenue to the recycler for marketing CRT glass to a primary or secondary lead smelter (referred to as glass-to-lead recycling) to the cost of recycling CRT glass back into CRT glass (referred to as glass-to-glass recycling).
- Evaluate opportunities for high-end recycling of engineering plastics back into original product by analyzing the ability of recovered plastics to meet specification standards for new product, thereby increasing markets and improving price for these plastics.
- Examine the difference between the value of the material collected and the costs of collecting, processing and marketing that material for a private recycler.

Building upon previous studies

In designing the demonstration project, the project partners drew upon the experience of previous efforts to remove used electronics from municipal waste. The partners evaluated other electronics recycling programs and pilots, including:

- Efforts by Hennepin County, Minnesota.
- Two reports published by the Common Sense Initiative (CSI) of the United States Environmental Protection Agency (U.S. EPA) that described[iii] and analyzed[iv] municipal recycling efforts.
- A 1998 retail collection pilot conducted in Minnesota.[v]
- Work conducted by the American Plastics Council and MBA Polymers, Inc, to evaluate the composition of engineering plastics collected from municipal sources.[vi]
- A report on a retail pilot conducted in San Jose, California in late 1997[vii]

Based on these studies, the partners wanted to explore the question, "Could the cost of recycling these products be reduced by increasing the amount of material collected and processed?" The project partners wanted to direct the attention of their work toward the economies of scale for recycling.

The Minnesota project sought to build upon these previous efforts, especially their recommendations for further study:

1) **Pursue economies of scale for collection, transportation and processing.[viii]** By emphasizing these specific concerns, the project partners attempted to learn more about opportunities and barriers to recycling old electronic products. Collection, transportation and processing efforts for the project were designed to evaluate optimal volumes.
2) **Improve information available about recycling markets for secondary scrap from old electronic products.** The recycling market development work was designed to evaluate alternative processing techniques by comparing methods to recycle glass from cathode ray tubes and to analyze the potential to return high-valued post-consumer engineering plastics from electronic equipment to new electronic products.

Retail Pilots in 2000

Two reports now available describe single-event retail pilot collections conducted in 2000.

Washington County, Minnesota teamed with Best Buy, Panasonic, Sharp and WM-ARG in September. Web site: www.co.washington.mn.us/pubhlth/pubcatn.html.

The Mid-Atlantic Consortium of Recycling and Economic Development Officials (MACREDO) teamed with CompUSA in October.
http://www.libertynet.org/ macredo/eprprj.htm.

Part Two
Planning Phase

Once the partners identified specific questions they sought to answer from the project, they worked to maintain a narrowly directed focus for the project—evaluating end-of-life electronics recycling.

Targeting consumer electronics for recycling

The OEA estimates that perhaps half of all used electronic products in municipal waste in the United States is generated by residents, yet relatively few electronic products have been collected and recycled from residential sources. Opportunities available to businesses to properly manage used electronic products do not adequately address the consumer product waste stream, and may be less accessible for businesses outside of major metropolitan areas. The partners wanted to challenge assumptions about the volume of residential electronics that could be collected and processed in a timely, efficient and cost-effective way.

They chose to focus the project on used electronic products generated by residents because these products:

- Contain large amounts of identifiable contaminants such as lead in CRTs and circuit boards.
- Are not regulated under the federal Resource Conservation and Recovery Act.
- Are less uniform than business-generated products and therefore more costly for recyclers to collect and process.
- Are similar to other household reusable and recyclable materials because they are a relatively large portion of municipal waste, are recoverable, and have relatively high value as secondary material.
- Are currently costly to recycle or manage separately from municipal waste and are therefore difficult to capture as a separate material stream.
- Are generally not collected for recycling in Minnesota at this time.
- Existing electronics recycling services are mostly directed toward business generators who are regulated by current law.

Among collection opportunities in Minnesota for household electronics, most are in the Twin Cities area. For instance, Hennepin County has accepted used electronics since 1992 (from residents only) through its extensive household hazardous waste program; and many communities now contract with electronics recyclers to accept old televisions and other products at spring and fall clean-up events, generally for a fee. Curbside collection in the city of Minneapolis has also been part of the Hennepin County program since late 1997.

Electronics from businesses

Despite generally restricting participation at collection events to residents, small businesses were included in a limited number of collection events. This was done, among other reasons, to test if products from businesses might improve the general value of material collected and reduce the total disassembly time for the recycler. Old products from businesses tend to have more value, are often already aggregated and are generally more uniform which means that they can be processed in less time than products discarded by residents. Some local collection site hosts were also eager to include small businesses.

Given these reasons, small businesses were included at two collection sites in less-populated parts of the state where site hosts, responding to local pressure, were eager to expand participation. In addition, Hennepin County collected products only from small businesses.

Small businesses, schools, churches and small nonprofit organizations are perceived, in some instances, to have more difficulty managing EoL electronic equipment than large businesses and institutions.

Excluding repair and reuse

In order to maximize what could be learned about the dynamics of recycling used electronics and the secondary markets specific to this product stream, the partners excluded *reuse* of used electronics from the project. While the partners support reusing used electronic products, repair and reuse were considered to lie outside the primary objective of the project—evaluating collection methods and costs of *recycling* used electronics.

Nonetheless, the partners did not anticipate the relatively large number of computers and computer monitors that met the requirements for reuse (were fully functional and not that outdated), especially for overseas reuse markets. During the processing phase of the project, the partners reconsidered reuse options. See "Marketing the Secondary Materials Streams" in Part 4 for discussion of reuse options.

Specific research

The principal partners wanted to learn more about the following aspects of collecting and recycling used electronic products from the household sector.

- **Factors that motivate collection hosts.** What factors influence public and private entities in deciding to collect used electronic products from consumers? Are they strictly cost factors, or are there other factors that may motivate this decision?
- **Consumer participation.** Will anyone come to collection events? Are people aware of the disposal hazards of used electronic products? Does that awareness motivate them to recycle the product instead of throwing it away with their trash? Who do they think should pay to manage these products when nobody wants them anymore?
- **Costs to process products.** The project had two goals relevant to processing the used electronic products. First, most of the used products collected were to be recycled, so the partners wanted the products sorted, broadly categorized, then disassembled as efficiently as possible in order to arrive at good cost data for managing the product stream.

  The project partners encouraged WM-ARG to evaluate any processing activity that could result in cost savings in managing the product stream. The partners agreed to give great flexibility to WM-ARG to make decisions based on cost without compromising the recycling and proper management of these products.

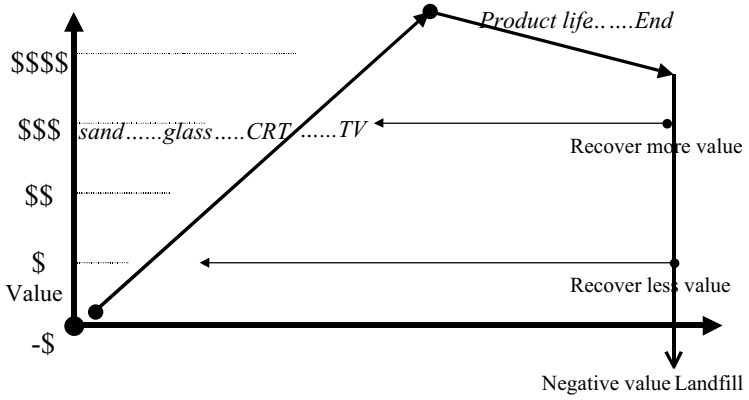
  Since the project team decided to collect general household electronics, they knew they would get many small used products that were mostly plastic and metal. Thinking about how to handle this product stream as little as possible, the recycler decided to send most of this product category to a large shredding operation to evaluate the efficiency of separating the metal and plastic in that manner.

- **Evaluating processing efficiencies and techniques.** A second goal ran counter to cost savings, in some regard, because the project partners wanted to evaluate new ways to process material that might lead to greater efficiencies in the future. In doing this, the project risked adding cost to the processing effort without learning new, more cost-effective methods to accomplish the task. In consultation with MBA Polymers, the partners also chose to sort engineering plastics by commodity types and color to see if this would be beneficial to further processing by MBA Polymers.
- **Market analysis and material sales of the secondary material streams.** The project partners wanted to use existing markets for the material removed from the products collected in order to learn as much as possible about the materials and to keep costs low. Yet the partners also wanted to explore new secondary markets and to compare costs of different market strategies for the same material, such as the cost to recycle CRTs in a glass-to-glass loop compared to glass-to-lead smelting. Glass-to-glass recycling returns old CRT glass back into new CRTs and a few other acceptable commodities, such as glass shielding from radiation in hospital x-ray labs and filaments in incandescent light bulbs.

  The partners chose to evaluate plastics and glass in this manner because engineered plastics have the greatest potential to add value to a recycling process at EoL and glass poses the greatest opportunity to reduce costs at EoL (see Figure 2-1).

Figure 2-1. Value-added potential for secondary materials

Not all recycling is the same. Original process characteristics of secondary materials have the potential to increase the price of secondary materials paid by markets because they retain these characteristics and therefore add value to the manufacturing process.



Selecting products to collect

The partners chose to target any electronic or electrical product with a cord or battery, expanding the collection effort to include electrical as well as electronic products. Accepting "anything with a cord or a battery" communicated a simple, clear message to the public and also made it easy to collect products with nickel-cadmium and other batteries that contain heavy metals.

Products accepted at the events included TVs, computers, household goods and small kitchen appliances. Flyers and advertising literature for the collection events included a list of acceptable and unacceptable products.

Large appliances, or "white goods," such as washing machines and refrigerators, were excluded from the project because they have been banned from disposal in Minnesota since 1988 and an efficient collection infrastructure currently exists for these products in the state. Microwave ovens were excluded because by law, they are considered large appliances in Minnesota. Air conditioners were excluded because the recycler was not permitted to evacuate Freon. (See Appendix C.)

The partners wanted to test the hypothesis that the value of some products, such as small electronic and electrical products made primarily from engineering plastics, steel and other easily recycled metals, might help to offset the cost of managing other items, such as CRTs in televisions and computer monitors. Waste Management-Asset Recovery Group (WM-ARG), also wanted to evaluate the feasibility of shredding small electronic appliances, such as telephones and cell phones, which contain precious metals, copper and steel. WM-ARG anticipated that if enough of these smaller appliances were collected, reducing the time and cost of dismantling would increase the residual value of metals in these smaller products and help offset the cost of recycling CRTs.

Products Accepted at Collections

- *TVs*
- *VCRs*
- *Stereo equipment*
- *Phones*
- *Vacuum cleaners*
- *Small appliances (blenders, toasters, answering machines, etc.)*
- *Computer monitors*
- *Computer central processing units or hard drives (CPUs)*
- *Computer keyboards*
- *Computer printesr*
- *Fax machines*
- *Scanners*

Selecting collection sites

Like many states, Minnesota has large urban centers, smaller urban communities, rural communities and long distances between hub cities. Half of the state's 4.8 million residents live in the metropolitan Twin Cities (Minneapolis, St. Paul and suburbs), the sixteenth most-populated metropolitan area in the United States. In contrast to uniform statewide programs, Minnesota has encouraged counties and local communities to design recycling and household hazardous waste programs to fit with local practices and needs in an effort to better serve all residents of the state.

The project partners wanted to serve rural as well as urban residents of Minnesota. While serving residents far from the processing site would increase costs, it would also meet multiple objectives and perhaps provide more realistic results. Partners recognized that all costs must be considered by the project.

The partners believed that no single collection strategy was likely to meet the diverse needs of communities and regions in Minnesota. Therefore, through the Request For Participation (RFP) process (described below), they sought local sponsors for a variety of collection methods. This would make it possible for the project to compare participation rates among various methods and to learn if some methods were more successful and/or less costly than others at capturing used products.

Request for Participation

In February 1999, the OEA issued a Request for Participation (RFP) in the State Register to solicit sponsors to host collection activities for used electronics products. The RFP described what the partners were looking for from potential collection site sponsors and what they, in turn, could expect from the OEA and its partners. The RFP encouraged flexibility for site sponsors to champion collection strategies that could lead to successful collection events.

Copies of the RFP were mailed to potential applicants, including representatives from local government, members of OEA's advisory boards, representatives from the business community and other potentially interested parties. Each collection site administrator was encouraged to craft a collection scenario that would be most successful in meeting local needs. Once all applications were received, the partners evaluated them for completeness, a general sense of understanding of the project, the variety of collection strategies proposed, geographic representation throughout the state, rural and urban participants, and so forth.

Barriers to participation

The OEA talked to many possible applicants during the RFP process. Along with all of the reasons why local authorities wanted to participate in the project, there were also relevant reasons why they chose not to participate. Chief among these was the concern that a local community would find it difficult to replicate the collection in the future without continued financial assistance, which was not assured. These communities did not want to start a program for residents that they could not maintain.

Many communities expressed concern that the cost to participate would be too high, even with assistance for event publicity, transportation from the collection site and processing. Concern was also expressed about regulatory issues, including issues about collecting the products, storage of material on site and potential liability. Regulatory issues were addressed directly by the Minnesota Pollution Control Agency (MPCA). The partners considered concerns about future collection opportunities, costs to participate and regulatory issues as valid reasons why communities would choose not to participate in the project.

Site Finalists

Nine regional collection areas, encompassing 64 collection sites, were selected to participate in the project based on the ability of these areas to enhance project results by providing geographic and population diversity and a variety of collection strategies. These sites ranged from single-county or city collection efforts to coalitions of rural counties.

Preparing for collection events

The OEA and WM-ARG worked with each local site host to prepare for the collection event designed for that community—establishing dates for collection events, duration of events, target audience and other relevant details. Numerous meetings were held with individual site hosts; and an organizational meeting for the entire team, including all collection hosts and principal partners, was held in St. Cloud on June 29, 1999. Each regional collection group host was represented at this meeting, except for Circuit City, which joined the effort in late August 1999. The Minnesota Pollution Control Agency participated and presented attendees with a regulatory perspective on the project.

The OEA mailed each local collection site host a packet with the following:

- Safety recommendations. (See Appendix C.)
- A list of accepted materials.

- Two fact sheets, one for residents and one for businesses, to inform everyone who brought products to collection events about proper disposal options for electronic products.
- A program cost and tracking form to ensure uniform reporting of expenses, staff requirements, etc. to the OEA upon completion of collection activities.
- Surveys to administer to everyone who brought used electronics to collection events.
- Media assistance (described in the publicity section).

Some aspects of the collections, such as safety procedures, would be uniform for all sites. Other activities, such as education, advertising and staffing, depended on the site and the kind of event planned.

Safety procedures

Safety procedures were developed in consultation with Sony, Panasonic, WM-ARG, Hennepin County and U.S. EPA. The partners found no existing standard safety procedures for collecting used electronic products from the general public. The procedures developed common sense rules for lifting and storing heavy and bulky items. Of the two retail sites involved in the project, only Circuit City actively participated as a drop-off site for used products. When Circuit City employees were involved in accepting used products from the public, they were advised to follow Circuit City's standard lifting procedures.

Logistics plan and packaging requirements

WM-ARG prepared a logistics plan for each collection site and mailed it to the contact person for each site to ensure proper communication during collection events. This plan included the date(s) and location(s) for each event, and names and phone numbers that WM-ARG would use to contact the site.

All material was to be loaded into 48-foot trailers placed in gaylord boxes (durable cardboard boxes measuring four feet on each side) set on pallets, and that the boxes be double stacked. (Some sites close to the processing facility loaded material directly into roll-off containers).

The plan recommended that all sites have access to a forklift and a palletjack, and that all boxes should be marked with the location, date, pre-assigned bill of lading number and source of material (business or residential). The logistics plan included pre-printed bills of lading that included a call number to arrange pick-up with WM-ARG.

Education

The OEA, the MPCA and representatives from local government collaborated in preparing two fact sheets on what to do with old electronic products—one for residents and one for businesses.

Because used electronic products discarded by households are exempt from hazardous waste laws, it seemed that separate fact sheets for households and businesses would provide clearer information and the best education possible. Businesses must evaluate the hazardous nature of electronic products and consider managing them separately from waste whereas households are not required to do this in Minnesota at this time.

Estimating participation

In order to help organizers plan staffing needs at events and for the recycler to plan transportation needs for removing material from sites, the partners tried to estimate how much material would be collected. The estimates relied on actual participation rates from previous efforts, including Hennepin County, and estimates developed by U.S. EPA's Common Sense Initiative (CSI)[ix] in a report that analyzed and compared pioneering community electronics recycling efforts. Participation rates were expressed as pounds collected per person per

population in the community of the collection event. Estimates ranged from 0.22 to 1.39 pounds per person per population for the CSI calculation, and 0.22 to 0.77 for the Hennepin County calculation.

Participation at these previous events varied significantly between one-day events and collection events held regularly or over many days. In addition, the U.S. estimates seemed high compared to estimates for Hennepin County, which had operated a permanent program to collect used electronics from residents since 1992. Hennepin County's program includes both permanent facilities and one-day collection events. Using these crude extrapolations based on population in the areas to be served by the project, the partners expected to get between 250 to 300 tons of material during the project.

This compares to other efforts at that time:

- Hennepin County, Minnesota collected 262 tons in 1996, and 366 tons in 1997[x].
- Union County, New Jersey collected 225 tons between October 1996 and August 1998.[xi]
- Massachusetts, which had just begun a statewide collection effort, collected 179 tons in FY1999; 714 tons in FY2000, and 1,390 tons in the first 6 months of FY2001. Massachusetts banned disposal of products containing CRTs in April 2000[xii].

Data-gathering tools

The partners wanted to learn from the work that was done during the project and from the people who participated in each event. With this in mind, two specific data-gathering tools were developed to try to capture information that would be useful to future efforts to recycle used electronic products.

Cost and tracking survey

The OEA designed a cost and tracking form to collect both quantitative and qualitative information from administrators at each collection site. The partners were especially interested in learning specific costs incurred in preparing and hosting the collection events from local sites.

Other information was considered equally critical to understanding the success and shortcomings of each collection event, and for evaluating cost data. This included hours spent staffing an event, the number of staff used at each event and the types of publicity used. The survey also offered site administrators a chance to note what worked well and what did not work and to give recommendations for future efforts. With information from the survey, project partners expected to be able to compare data among the different sites.

Participant survey

The project partners also designed a questionnaire to be given to all participants bringing old products to collection events. Participants at all events were asked to complete the survey to help event coordinators and the principal partners learn more about how people learn about such events and what motivates them to participate. The partners also wanted such a survey to be brief—five to eight questions and no longer than a single-sided page.

The survey sought to collect information such as:

- What kind of publicity worked best to get participants to events.
- Who participants thought should pay to properly manage these old products.
- How many and what kind of products did each participant bring to collection events.
- How many CRTs did participants have remaining at their home or business.

The partners wanted any survey of participants to be consistent among the collection sites to allow for comparisons among participants at the collection events. Uniformity was ensured by providing each site with enough surveys to give to all possible participants. This survey also served as an inventory of all participants.

Publicity

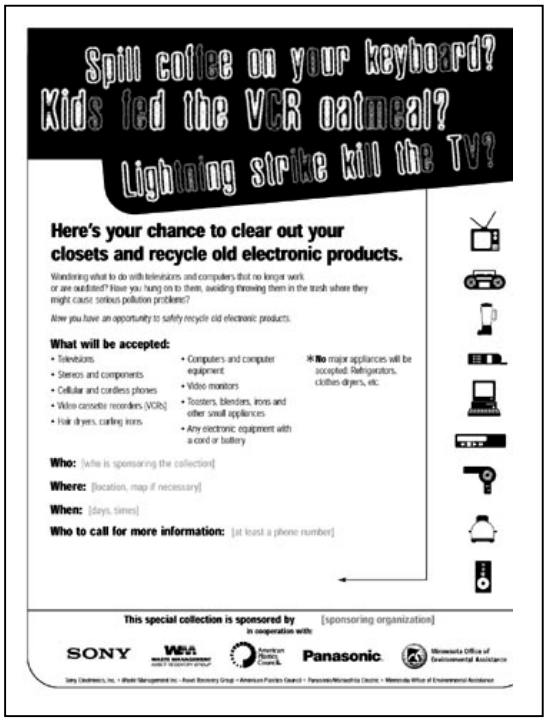
Publicity was tailored to local markets in the communities where collection events were held. In rural areas and in the cities of Duluth and St. Cloud, information was distributed to whole communities. For example, in Duluth, where an eight-day event was held in the parking lot of Computer World, a local retailer, the team administering the collection effort pursued a wide range of publicity options, including radio and television talk shows. In smaller communities, collection hosts alerted residents about the effort through radio announcements and newspaper ads.

Promotions logo

In the metropolitan Twin Cities, where 18 collection events were held, publicity was carefully targeted in segments of cities and communities to motivate strong, but not overwhelming, participation. Hennepin County, which hosted an event just for small businesses, had some concerns that a large publicity effort would reach businesses in the surrounding six or more metropolitan counties. Similar concerns were shared in other metropolitan Twin Cities communities where collection events were held.

An example of clip art

Hennepin County discreetly notified local businesses by describing the collection opportunity in a bulletin on waste-related topics that the county uses to communicate with its business community. In the city of St. Paul, in Washington County and at the two Circuit City locations, publicity was directed to very specific audiences in and around the community hosting the event. In the case of the two Circuit City stores that accepted material during the month of October, advertising was carefully tailored to prevent customers from bringing used products to other Twin Cities Circuit City stores which were not participating in the project.



Generic flyer

The OEA provided participating local governments with limited financial assistance for publicity, up to $5,000, and prepared standard media tools to be used by collection site hosts. The materials were designed to be tailored to meet the needs of specific sites as well as to help standardize the message received by the public throughout the state. These tools included:

- Radio ads and taglines for radio
- Logo
- Press release
- Generic op-ed piece
- Slogans and tag lines for other uses
- Clip art
- Formatted newspaper ads
- Suggested language for brochures
- Flyer design and text
- Generic poster
- Web site for communicating to potential participants as well as to site administrators

Promotional Web site

In addition to publicizing local collection efforts, the partners wanted to attract media attention to the overall project. However, in several conference calls on the subject, the principal partners found it difficult to agree on a strategy for pursuing press—some wanted to pursue press attention during the collection effort, others wanted to wait until they had results to report. A strategy was developed well after the collection events were completed, allowing each partner to solicit media attention independently. This was much more successful since those partners interested in press attention in the project were

free to pursue it.

Sony Electronics and the American Plastics Council were most active in sharing results. For example, Sony pursued print and broadcast attention and was instrumental in creating interest in the project by *The Wall Street Journal*, which lead to a story published July 18, 2000. Similarly, APC developed interest in the project by the Buy Recycled Business Alliance (BRBA), a group of companies that works with the National Recycling Coalition to promote better recycling practices by America's businesses. The BRBA was instrumental in developing a cover wrap for the July/August 2000 issue of the *Harvard Business Review* which also highlighted the demonstration project.

THE WALL STREET JOURNAL.

MARKETPLACE

Where TVs Go When They Die

As Junked Electronics Pile Up, Threatening Environment, Some States Crack Down

By Evan Ramstad
Staff Reporter of The Wall Street Journal

MINNEAPOLIS—On the third floor of an 84-year-old downtown warehouse here, two dozen workers wielding hammers and drills are ripping apart television sets. After reducing the sets to rubble, they sort wires, plastic, wood and circuit boards. "We run it like a TV-repair shop in reverse," says one of the workers, Yusuf Mustafaa.

The methodical destruction is one way of dealing with an increasingly difficult—and potentially dangerous—problem: the nation's mounting pile of electronics trash.

With sales of TVs, wireless phones, computers and monitors at record levels, consumers are junking their outmoded models by the carload—replete with harmful metals, such as nickel in batteries and lead in TV tubes. The refuse is expected to grow in this decade as consumers replace generations of televisions with new digital models.

Keeping the cast-off electronics out of landfills is a slow and costly process that hasn't yet won widespread support, but environmentalists and regulators have been making some progress. In April, Massachusetts banned public disposal of TVs and computer screens, urging residents to take advantage of an ad hoc network of charities and recyclers. Florida and Connecticut are considering the same thing. Japan and some European nations also regulate the disposal of electronic goods.

Some parts of Minnesota have been recycling TVs for years. But the state hasn't imposed such a ban on disposal, officials say, because it doesn't want to adopt a statewide regulation without an economical process that entices manufacturers and waste companies to share costs. "No single one of us is going to take on this burden alone," says Sherry Enzler, director of the state's Office of Environmental Assistance.

Still, Hennepin County, Minnesota's largest, has been recycling TVs since 1992 and holding curbside collection in Minneapolis since 1997, which makes it easy for homeowners. "It's so convenient," says Jennifer Bachman, who disposed of one of her four TVs last month when it didn't sell at a garage sale.

But the effort costs the county about $1 million a year, or $20 a TV, says Mike Brunell of the county's environmental office. Last year, about half the cost went to PPI Industries, a nonprofit, job-training organization that runs the dismantling operation in the downtown warehouse.

On a recent day at the warehouse, Mr. Mustafaa wheeled a four-foot-tall carton of electrical wires away from a noisy room where men were taking sets apart with drills and hammers. Earlier, he loaded 44 similar cartons of TV tubes into two semi-trailers for shipment to a lead smelter. Last year, the crew took apart 911 tons of products, mostly TVs. Hennepin County paid a lead smelter about $300,000 last year to take the glass tubes. The smelter then separates the lead and sends the glass for its own use.

Last fall, Minnesota's Office of Environmental Assistance tried a bigger program, joining **Waste Management** Inc. and the U.S. units of **Sony** Corp. and **Matsushita Electric Industrial** Co. to collect electronics gear in 11

Please Turn to Page B6, Column 1

In an experiment *last fall, Minnesota, Waste Management, Sony and Matsushita jointly collected discarded TVs, PCs, but the three-month program (photo above) encountered problems of economics*

Wall Street Journal article published July 18, 2000

Part Three
Collection Activities and Results

Collection events for recycling used electronics were held in selected communities around Minnesota from July 31 to October 31, 1999. Collection events ranged in length from one day to two months and were held either as special events or in cooperation with permanent programs. Although the project targeted household electronics, some events included items from businesses.

Collection Events

Nine regional groups cooperated to sponsor 64 collection sites throughout Minnesota. Collection sites were geographically distributed throughout the state (see Figure 3-1) and included rural and urban populations. Hosts for collection events included a non-profit organization, retail stores, public and private recycling facilities, government-sponsored household hazardous waste programs, and other county, city and township governments. Some of these groups had prior experience collecting used electronic products from households, but most were undertaking this kind of effort for the first time.

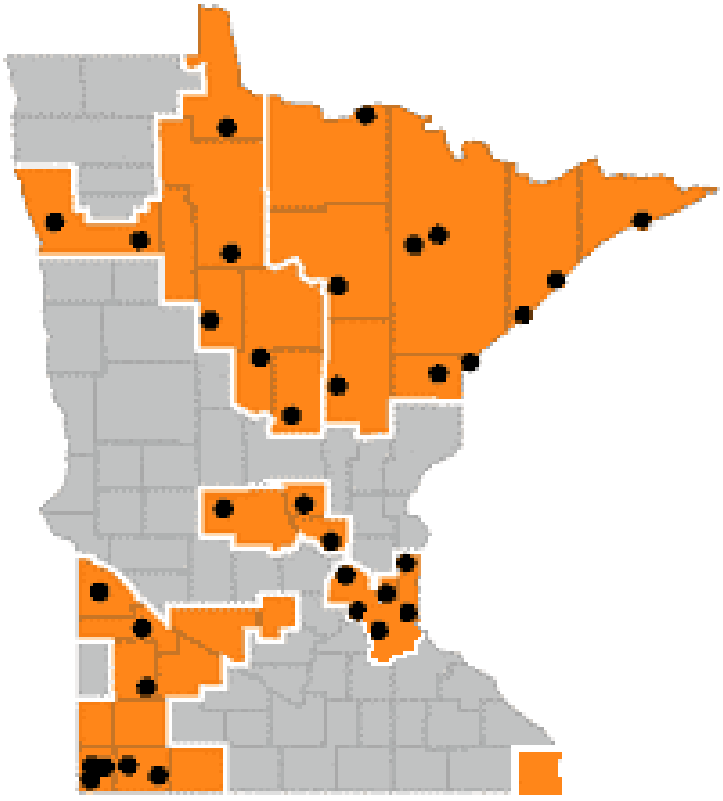
Most of the sites limited services to residents, but a few sites allowed small businesses to participate as well. All but one site accepted used products without a fee—one urban collection event in Hennepin County which was held exclusively for business generators charged a nominal fee. The private sector partners believed that businesses would manage the products correctly if properly informed. Small businesses and institutions that brought products to collection sites were given a fact sheet prepared by the Minnesota Pollution Control Agency describing the regulatory status of used electronic products from businesses and institutions.

See details on each collection site in Appendix B.

More than 25 percent of Minnesota residents (approximately 1.3 million people) had access to collection sites and events hosted during the three-month demonstration project.

Electronics collection site in Duluth, Minnesota.

Figure 3-1. Regions of Minnesota where residents had access to electronics recycling collection events



Shaded areas highlight counties in which collection events were held.

Collection Results

- Collection events occurred from July 31 to October 31, 1999.
- 64 sites (retail, curbside, HHW, drop-off events) in 9 regions.
- Service to 1.3 million residents.
- Approximately 9,000 people participated in collection events.
- 7639 people completed a survey.
- Of these, 89% reported they were residents, 6% reported they were businesses, 1% reported they were both, and 4% did not respond.
- 575 tons of used electronics collected.
- Of the material collected, based on the participant survey, 72% was residential, 21% was from businesses, 2% was both and 5% did not answer.
- Based on 7639 completed surveys by participants, the average participant brought 151 pounds of product and more than 3 items to an event.
- The average weight of a TV collected during the project was approximately 90 pounds—the single heaviest item.

Table 3-1. Collection site profiles for demonstration project

Site Hosts	Sponsors and Participants at Collection Sites	Target Generator	Collection Method	Event Schedule
Neighborhood Energy Consortium (NEC)	Ramsey County, City of St. Paul	residents	one-day clean-ups in eleven city neighborhoods	August 21 to October 16
Arrowhead Region: St. Louis County with six counties, WLSSD and three business	Counties: Aitkin, Carlton, Cook, Itasca, Lake, Koochiching, St. Louis. Computer World, MPCA, OEA (regional office), North Shore Mining, Waste Management, Inc., Western Lake Superior Sanitary District (WLSSD)	residents	up to eight-day events in seven counties at multiple sites, including recycling drop-off, HHW, transfer stations, landfill, retail parking lot	August
Hennepin County	Hennepin Transfer Inc, (HTI) subcontractor	small businesses or institutions that are not small or large quantity generators of hazardous waste (SQGs or LQGs)	one-day event at two drop-off sites in county	August 2 and October 4
Houston County	Houston County	residents	drop-off at five staffed county sites	Saturdays and Mondays in August and September
Washington County	Advanced Environmental Technical Services (AETS) subcontractor, City of Cottage Grove, Forest Lake and Scandia Townships	residents	drop-off at HHW satellite collections in four communities	July 31, August 21, September 11 and September 18
Northwest Counties	Counties: Beltrami, Cass, Clearwater, Crow Wing, Hubbard, Lake of the Woods, Polk. Businesses: Northern Lighting, Magnuson Trucking	residents and small businesses or institutions that are not SQGs or LQGs (these are defined directly above in Hennepin)	drop-off at transfer stations and selected drop-off events	locations in seven counties from August 16 through September.
Southwest Region	Counties: Jackson, Lac Qui Parle, Lyon, Murray, Nobles, Pipestone, Redwood, Renville, Rock, Yellow Medicine	residents	variety of collections from single-day to month-long events, mostly tailored to local HHW or recycling activity traditions, including curbside	various dates in ten counties, mid-August through September
Circuit City stores	Corporate headquarters, regional offices and two retail locations. Dakota and Ramsey Counties, City of Burnsville	residents	Drop-off at retail site, either at service counter in store or at trailer in parking lot on weekends	month of October during regular business hours
Tri-County Solid Waste Management Commission	Counties: Benton, Sherburne, Stearns	residents	One-day events at highway garage and transfer stations in cities of Elk River, St. Cloud and Foley, and in rural Stearns County.	Thursdays in September

Collection methods

The collection methods varied from site to site, which allowed the partners to compare different strategies for collecting used electronics from residents to see if some strategies were more successful or cost-effective than others. Activities such as requesting participants to complete a survey and the types of products that would be accepted were held constant at each site.

One-day and multi-day drop-off events

These were collection events held specifically to collect used electronic products. A defined target population was informed about the events in advance using utility bill inserts or selected media, such as neighborhood newspapers and, in some cases, television and radio. On specified dates and times, the public could bring obsolete products to specified sites. The sites were generally logical places for events, such as a municipal garage, city hall, and other public locations. More than 20 collection sites in the project evaluated this method for collecting used electronics from residents.

Drop-off opportunities at household hazardous waste (HHW) sites

These events, held at permanent or mobile HHW sites, collected used electronics in conjunction with an event to collect other household hazardous wastes, such as paint, oil and pesticides. One dozen events of this kind were sponsored during the project, ranging in length from one day to one month.

Hennepin County also sponsored two one-day events in two locations as part of its regularly scheduled once-a-month events for small businesses that generate less than 22 gallons of hazardous waste per month (very small quantity generators). The county did not check the generator status of businesses that brought used electronics to the events, although they did check generator status for businesses dropping off hazardous wastes. Small businesses were charged a $5 per unit fee to participate (a unit was defined as a television or a computer, including the monitor, CPU and peripherals). The fee was collected by WM-ARG.

Drop-off at other permanent facilities

These 18 events were held at garbage transfer stations, permanent recycling centers and landfills. The partners evaluated the use of existing public facilities as sites to collect used electronics. Permanent recycling centers typically do not collect problem wastes or non-recyclable materials. Garbage transfer stations and landfills, in addition to accepting municipal waste from waste haulers, often accept waste and other items from individuals (self-haulers), including problem wastes and items banned from disposal such as major appliances or tires.

Neighborhood clean-up events

Neighborhood clean-up events are generally held once or twice per year, in the spring or fall, and accept items from residents that are generally difficult to get rid of and that people do not mind storing until an opportunity to recycle or dispose of them is made available. These items may include major appliances, unwanted furniture, yard and tree waste. Some clean-up events also collect problem materials and household hazardous wastes. Generally it is the community that decides in advance what is accepted. These events are typically one day only, often for just a few hours, and are restricted for use to residents of a defined geographic area. There were 16 of these events.

Retail collection sites

Two electronics retailers at three locations participated in the project. These retailers provided limited labor and support to collect used electronics. The retail sites were restricted to residential use. Businesses were given the MPCA fact sheet and a list of local recyclers with whom they could contract for service.

- **Computer World.** The collection event at Computer World in Duluth was staged in the store's parking lot during eight days in August and was staffed primarily by local government personnel. The site is centrally located and turnout was heavy.
- **Circuit City.** Two Circuit City stores in the metropolitan Twin Cities area (one in Maplewood and one in Burnsville) collected used electronics during the entire month of October. Products were collected during the week by Circuit City staff at the service desk. On the weekends, collections were staged in the parking lots with a truck provided by WM-ARG and staffed by government volunteers and Circuit City employees.

Circuit City has ten stores in the metropolitan Twin Cities and initially considered hosting collection events at each of these sites. In discussion with the project partners, Circuit City chose to restrict its participation to two sites after considering the potential response from the public if the events were widely publicized throughout the metropolitan area.

Curbside pick-up

Curbside collection is a common way to collect garbage and recyclable materials from residents. Redwood County in Southwest Minnesota conducted a curbside collection for used electronics from residents. The single event was held over four consecutive days. (The city of Minneapolis provides curbside collection of televisions and computer monitors to residents as part of its comprehensive recycling and waste collection services. This program was not included in the demonstration project).

Control site

The County Recycling Administrator of Houston County, in rural southeastern Minnesota offered his program as a rural control site for comparison to other collection activities conducted during the project. For several years, the county has collected used electronics at five recycling drop-off centers with the intent of removing these products from municipal waste before it is managed at a waste-to-energy facility in La Crosse, Wisconsin. The collected used electronics are then typically landfilled. For two months during the project, no advertising was done and used electronics were accepted at the drop-off sites, just as they usually were.

Collection results

This section describes and analyzes results from collection events, including amount of products collected, results from the participant survey and costs of collecting products. The information is based on data gathered from the participant survey, the cost and tracking form completed by site administrators, and results provided by WM-ARG.

Amount of used electronics collected

During the three-month collection phase of the project, 575 tons of used electronics—almost twice the amount the partners expected—were dropped off at collection sites. More than 24,000 products were collected according to responses to the participant survey.

Small quantities of air conditioners and microwaves were brought to collection events and, as a rule, were accepted from participants. Microwaves were processed by the recycler and air conditioning units were transferred to a licensed recycler.

In addition, it took 125 tons of packaging and shipping material, such as pallets, gaylord boxes and shrink-wrap, to properly handle and ship the old electronics from collection sites and consolidation points to the Waste Management-Asset Recovery Group (WM-ARG) facility in Inver Grove Heights.

Participation

The estimated potential population served by these events was 1.3 million[xiii]. About 9,000 people participated in collection events; 7,639 of these participants completed surveys when dropping off used electronics at collection events. For purposes of this report, only those participants who completed a participant survey are included in the data below.

Estimating Total Participation

The project did not have a method to track undercounted participation. Nonetheless, we developed an estimate of total participation based on the participant survey and the work done by the recycler. Survey participants completed 7,639 surveys on which they reported bringing 7,044 televisions to collection events. WM-ARG processed 8,649 televisions from the project sites.

$$\frac{\text{reported TVs delivered to sites}}{\text{total TVs processed by recycler}} = \frac{\text{completed participant surveys}}{\text{estimated total participation}}$$

$$\frac{7{,}044}{8{,}649} = \frac{7{,}639}{X}$$

Where "X" equals 9,380, which can be rounded to 9,400, or 9,000, to use only one significant digit. For purposes of calculations in this report, however, we have used 7,639 to represent total participation.

Table 3-2. Participation by location

Collection Area	Number of Participants	Percent of Total	Number of Products per Participant
Aitkin	90	1.2	5.30
Beltrami	44	0.6	*
Carlton	198	2.6	4.85
Cass	212	2.8	*
Circuit City	1000	13.1	3.54
Clearwater	50	0.7	*
Cook	79	1.0	4.20
Crow Wing	152	2.0	*
Hennepin	98	1.3	*
Houston	34	0.4	1.35
Hubbard	93	1.2	*
Itasca	48	0.6	3.31
Jackson	121	1.6	*
Koochiching	153	2.0	3.63
Lac Qui Parle	36	0.5	5.44
Lake	30	0.4	2.90
Lyon	100	1.3	3.01
Murray	15	0.2	3.07
NEC	708	9.3	2.97
Nobles	93	1.2	3.61
Pipestone	91	1.2	3.58
Polk	229	3.0	*
Redwood	297	3.9	3.85
Renville	22	0.3	5.23
Rock	78	1.0	3.94
St. Louis	208	2.7	5.39
Tri-County	1161	15.2	4.70
Washington	513	6.7	3.31
WLSSD	1667	21.8	3.19
Yellow Medicine	19	0.2	5.95
Total	**7639**	**100.0**	

* Sites that accepted products from businesses.

Houston County, the control site, had only 10 percent of the anticipated participation as estimated using Minnesota's calculation (0.77 pounds/person/population) and only 5 percent of the participation using the CSI estimate (1.39 pounds/person/population).

Business and residential participants

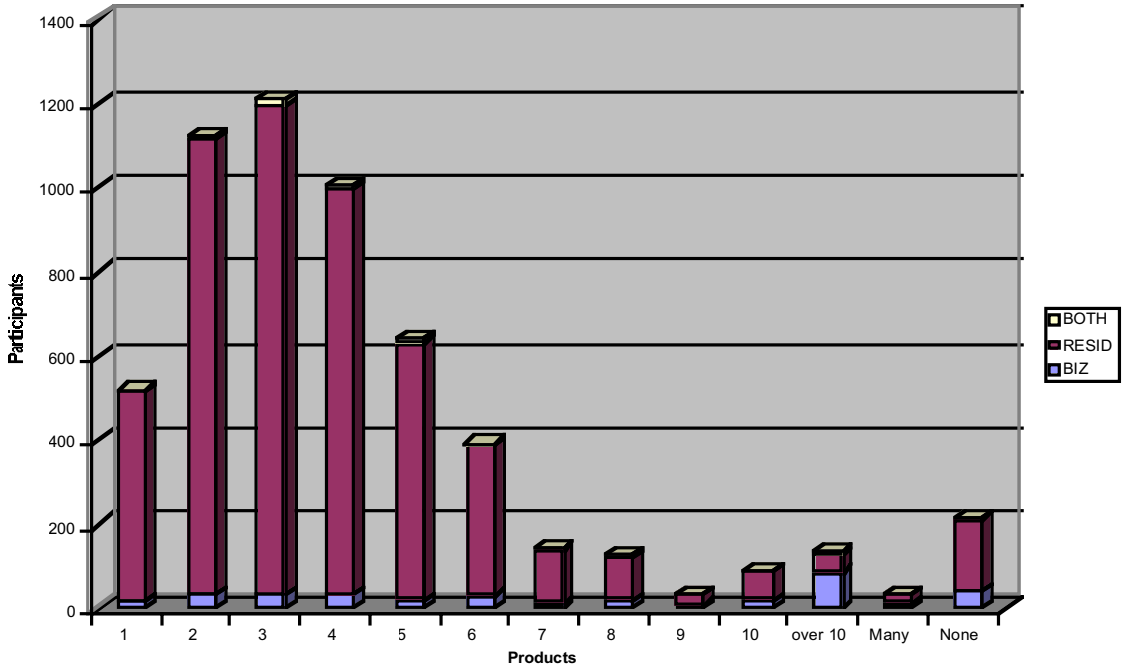
Residents accounted for 89 percent of all participants completing a survey, and businesses accounted for six percent. Of the rest, one percent said they were both and four percent did not answer the question. Based on the survey, 72 percent of material collected was from residents, 21 percent was from businesses, two percent was from both and five percent did not answer.

The fact that businesses brought more material, as a percent of all material collected, is consistent with the expectation that when businesses generate used electronics, they generate larger and more uniform volumes of old products. It may also suggests that among businesses and institutions that participated in the project, many were aware that these products should be managed separately from waste and recognized the opportunity to properly manage the product stream during the project.

Average participant

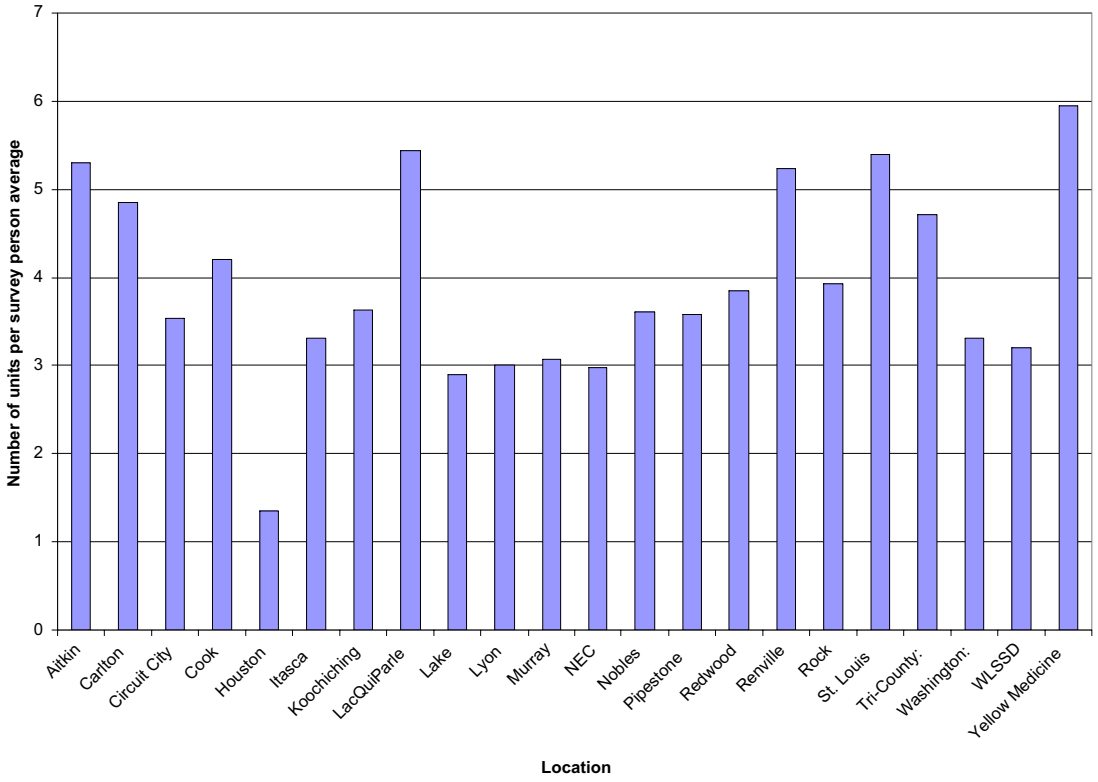
The average participant delivered more than three used products—151 pounds—to collection events. Figure 3-2 shows the numbers of products per person delivered to collection events.

Figure 3-2. Number of products per participant brought to collection events



The average participant in the project brought more than three items to a collection event.

Figure 3-3. Number of units per person



Average weight per participant may have been inflated for a variety of reasons. Among them, small businesses and institutions tended to bring more material to events than residents, and businesses accounted for at least 21 percent of all material collected, although they accounted for less than eleven percent of participants.

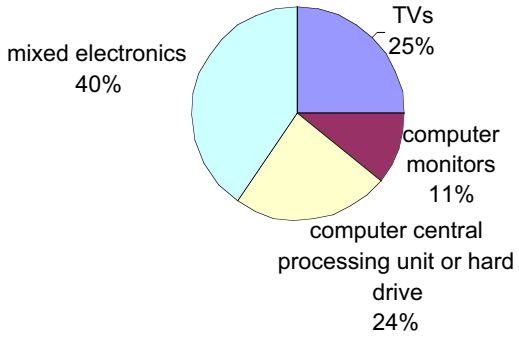
Some collection site sponsors made efforts to collect old products from seniors and other residents who had difficulty attending events. In these cases, collected products were either not recorded, or multiple households were recorded on a single form. Some residents were also known to have delivered used products to collection events from neighbors and families, yet reported these quantities on a single survey form.

Participant Survey Results

In all, 7,639 people completed a participant survey at a collection event during the demonstration project. This survey measured attitudes about recycling used electronic products and recorded details about each respondent, such as how they learned about the event (see survey, Appendix C).

Two questions on the survey attempted to measure volume of product per participant. Figure 3-4 shows responses to the question, "What items did you bring in today?" This question was followed by two boxes with lists of product types to make it easy for participants to either check or write in a tally for the appropriate products. Interestingly this question had the highest rate of non-response—1,600 people did not answer this question. Those who chose to answer the question brought an average of more than three products to the event.

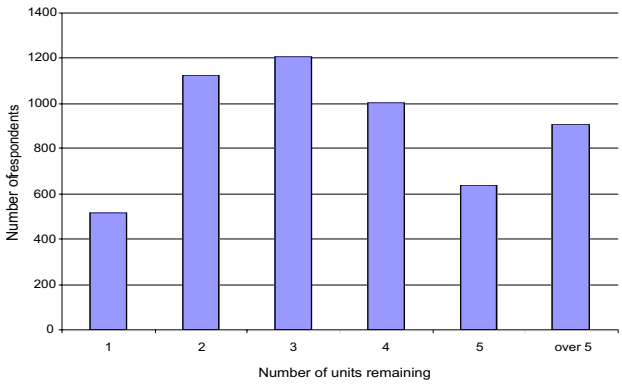
Figure 3-4. Product categories as a percentage of total number of collected electronics



Units collected, expressed as a percent of four broad product categories, based on responses to the participant survey. Mixed electronics includes consumer and household products.

Figure 3-5 shows responses to the question, "How many computers and TVs do you have (total —at your home or at your business)?" This was an attempt to find out, among participants, how many more CRT-containing devices they had at home. According to the response to this question, the average person who attended a collection event had more than three computers and televisions at home.

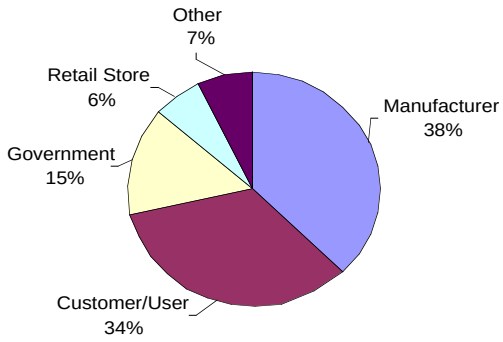
Figure 3-5. Number of computers and TVs at home or business



According to survey results, people participated primarily because they liked the idea of recycling the product and they wanted to protect the environment. When participants were asked who should pay for the safe recycling and disposal of electronics, over two-thirds said it is the responsibility of the manufacturers or consumers. See Figure 3-6.

Participant response to the question of who should pay to properly manage harmful products can be interpreted in several ways. The large number of responses to the categories "manufacturer" and "consumer" can be interpreted to mean the respondent does not distinguish between these categories. The broad distribution of the response can be taken to indicate support among respondents to product stewardship programs that are based on shared responsibility for the cost of managing such products separately from municipal waste.

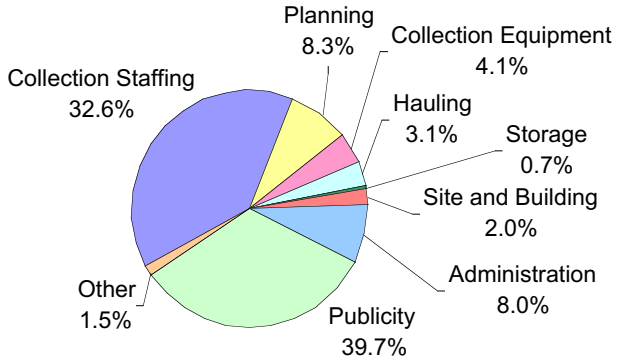
Figure 3-6. Survey: Who should pay for electronics recycling



Costs to collection site hosts

Local collection site sponsors reported spending a total of $165,843 to plan, prepare, administer and host collection events. This is the equivalent of about $288 per ton (see Figure 3-7). The principal partners on the project structured financing for the collection events so that local collection site hosts would not incur costs to transport old products from the point of consolidation to the processing facility, nor would they incur a charge to recycle these products. Nonetheless, the cost to collect product was significant. Counties used available funds for current projects, recycling programs and HHW programs. Of the total amount, the OEA provided about $25,000 in direct assistance to help defray advertising costs. Indirect assistance included transport packaging, transportation of products from the collection site and processing and recycling of the material.

Figure 3-7. Costs to local collection sites



Publicity and staffing costs made up 72 percent of the total costs to the collection hosts.

Activity	Actual Cost	Percent
Administration	$13,194	8.0%
Equipment for events	$6,865	4.1%
Hauling to consolidate material	$5,074	3.1%
Other	$2,517	1.5%
Planning	$13,698	8.3%
Publicity	$65,877	39.7%
Site and building	$3,338	2.0%
Staffing at events	$54,045	32.6%
Storage	$1,235	0.7%
Total	$ 165,843	100%

Table 3-3: Comparison of site costs per survey respondent

Location	Total Cost	Number of surveys completed	Cost per Survey Respondent
Tri-County	$20840	1161	$18
Redwood	$5733	297	$19
Cook	$4060	79	$51
Jackson	$1298	121	$11
Cass	$4781	212	$23
Itasca	$1345	48	$28
Renville	$1702	22	$77
Murray	$1850	15	$123
Carlton	$5719	198	$29
Clearwater	$1720	50	$34
Lac Qui Parle	$801	36	$22
Yellow Medicine	$1418	19	$75
Houston	$748	34	$22
Nobles	$4501	93	$48
Rock	$2782	78	$36
Lyon	$2015	100	$20
Crow Wing	$3970	152	$26
Polk	$1982	229	$9
Pipestone	$1452	91	$16
Koochiching	$2163	153	$14
Washington	$5375	513	$10
Hubbard	$5785	93	$62
Circuit City	$11272	1000	$11
NEC	$11030	708	$16
WLSSD	$20389	1667	$12
Lake	$6497	30	$217
Hennepin	$21287	98	$217
St. Louis	$9420	208	$45
Aitkin	$1195	90	$13
Beltrami	$4237	44	$96

Costs per survey respondent ranged from less than $10 to more than $200. The cost comparison can be influenced by low turnout at an event and high overhead costs.

Evaluating participation by site, as in Table 3-3, the impact of participation on cost is apparent. Here, the concept of "economies of scale" for collection activities becomes clear. The more rural sites and the less attended sites, often but not always the same, tend to be much more expensive on a per participant basis. Sites with a high total cost, such as the Tri-County (collection events in and near St. Cloud) and WLSSD (Western Lake Superior Sanitary District—the collection event in downtown Duluth) had a relatively low cost per survey participant. Conversely, sites with low to moderate total program costs, such as Yellow Medicine, Lake and Hubbard, with low participation, experienced high cost per survey respondent.

More efficient means of collecting used electronic products will be required in less-populated areas to achieve cost-effective programs. The types of activities that might help include storing material locally to achieve significant volumes before shipment to a processing facility, promoting reuse locally, conducting collection efforts in conjunction with other activities, utilizing volunteers, operating in cooperation with nonprofit or community-based programs, and so forth.

Conclusions about costs

Costs to implement this one-time demonstration event are higher than would be expected under routine operating conditions. Many of the reported costs are recognized as more typical for a one-time event or for costs associated with new program activity. In other words, they

were costs that would otherwise not be incurred or could be reduced substantially if collections were conducted as regularly held seasonal events or as permanent programs. Costs for new programs are often higher. As programs mature, capital costs are reduced or eliminated and operations are made more efficient.

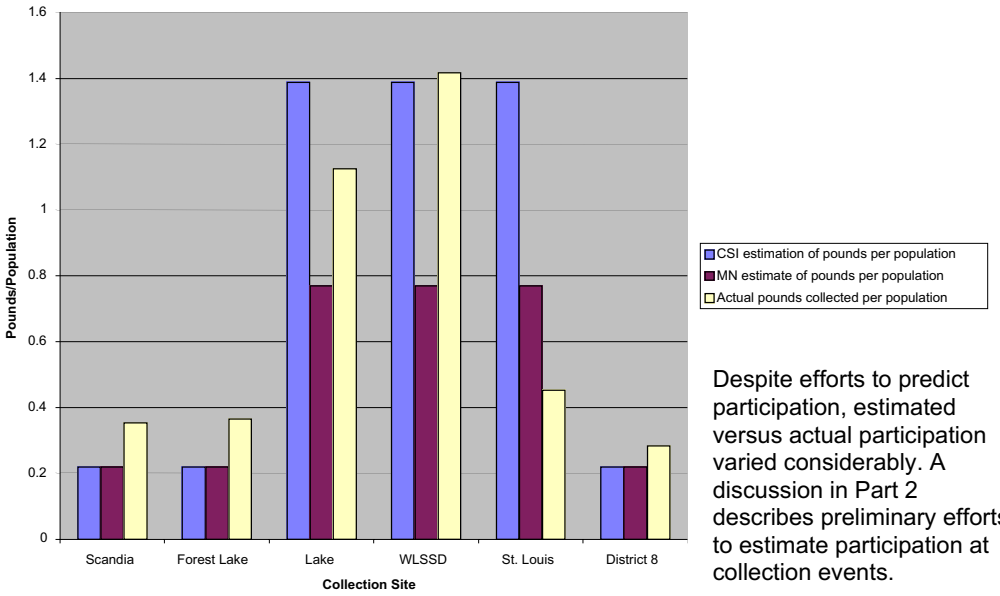
The most costly activities for event collections were publicizing events (39 percent) and staffing them (33 percent). While it is unlikely that changing staffing patterns could significantly reduce the cost to staff future events, conducting publicity in conjunction with existing activities could yield large cost savings for future efforts. By including electronics collections in on-going publicity and education campaigns, costs to publicize future collection efforts can be substantially reduced.

Other cost savings must be evaluated on a case-by-case basis. In the project-sponsored events, planning and administration costs were high because this was a new effort for most site administrators. These costs can be expected to fall as event hosts become more familiar with the routine of collecting used electronics. On the other hand, storage and equipment costs may remain constant or rise.

Estimated versus actual amounts collected

Given initial efforts to estimate volume of material that would be collected during the project. Figure 3-7 compares estimated volumes to actual volumes for several sites. At the time estimates were made, planners for the project were inclined to accept the Minnesota estimates over the CSI estimates as the better indicator of potential participation, which suggested there would be slightly fewer participants and material collected than the CSI estimates.

Figure 3-8. Estimated versus actual pounds collected per population at selected collection sites



Despite efforts to predict participation, estimated versus actual participation varied considerably. A discussion in Part 2 describes preliminary efforts to estimate participation at collection events.

Of the sites in Figure 3-8, participation was significantly overestimated only at the St. Louis County events. These weeklong collections were held at the county landfill and transfer station and are less strategically located for residential drop-off events. St. Louis County is the largest county in the state with a significant rural population. The county is also home to the city of Duluth, Minnesota's fourth largest city. The eight-day collection event sponsored by the Western Lake Superior Sanitary District (WLSSD) was conveniently held in a retail parking lot in downtown Duluth and participation surpassed all expectations. Publicity for collection events in the entire Arrowhead region (WLSSD, St. Louis County and six additional counties) was consolidated in advertising and interviews. Given a choice, residents selected the more convenient locations.

Conversely, participation was as much as 50 percent higher than either estimate at the one-day HHW collection events in Scandia and Forest Lake Townships, sponsored by Washington County, and at the one-day fall clean-up event in District 8 of the city of St. Paul, sponsored by the Neighborhood Energy Consortium.

Overall, while planners for the demonstration project anticipated collecting 250 to 300 tons of used products, in aggregate, the project actually collected 575 tons of used electronics. It is clear from these efforts to predict participation and thereby volumes that better estimating methods need to be developed. Good estimates are valuable to planners who need to arrange people to staff events and trucks to haul material from collection sites to processors.

The impact on this project was to significantly add to the cost to transport and process material since so many more products were collected than originally anticipated.

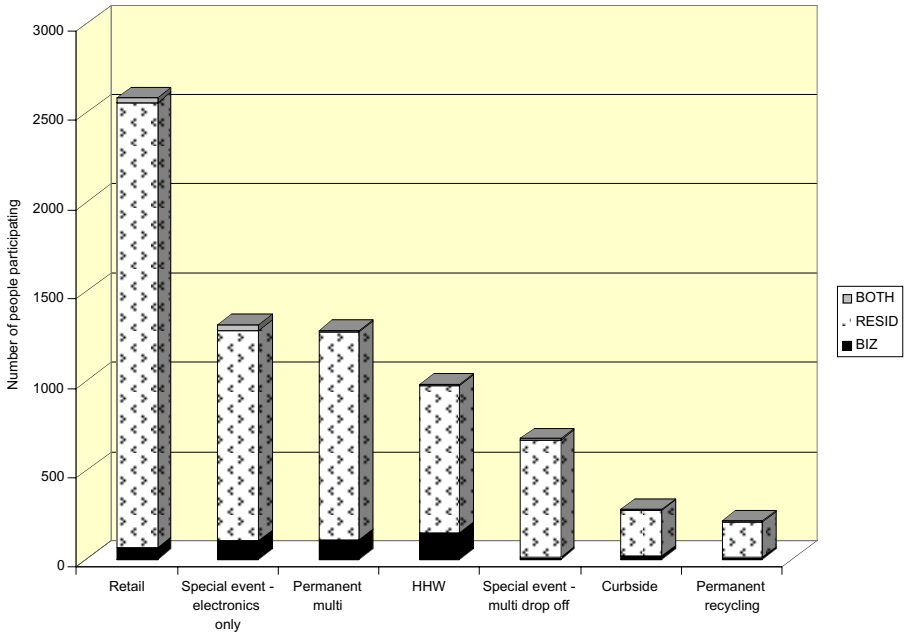
Transportation that is not scheduled in advance must be arranged for at the last minute, usually at higher per unit cost. Arranging temporary storage for used product prior to a collection event, either as a contingency plan or as part of normal procedure, can also relieve some of this cost.

As programs develop and the public perceives less urgency to utilize any given collection opportunity, participation rates may level off. This may be what was observed in Houston County, the control site, where collections proceeded as usual and participation was considerably lower than at sites that publicized a unique recycling opportunity.

Comparing collection methods

There was a strong effort in designing the demonstration project to develop as many different collection scenarios as possible to provide an opportunity to compare the various strategies. The intent was to try to measure differences in participation rates, operating costs and volumes of products collected per participant.

Figure 3-9.Types of collections held in Minnesota



Metropolitan Twin Cities compared to Greater Minnesota

There were 18 collection sites in the greater metropolitan area of Minneapolis and St. Paul and 46 sites in Minnesota communities outside of the metropolitan area. Publicity for collection events in the Twin Cities was strictly limited to targeted neighborhoods, in an effort to control participation and keep it to manageable numbers of participants. Thirty percent of all survey respondents came to a Twin Cities event. On the other hand, publicity at events in the rest of the state blanketed television, radio and newspapers in whole communities. In Duluth, 1,667 participants completed surveys and in St. Cloud, 1,536 participants completed surveys.

Collection events held in conjunction with HHW collection activities

Collection events held in association with HHW collection events or permanent HHW sites accounted for 13 percent of all participants during the demonstration project and 14 percent of all material collected during the project. The general public was inclined to participate in used electronic collection events held in conjunction with HHW programs. This type of event was among the most expensive collection methods tested. These higher costs were generally related to greater staffing requirements and possibly to fixed costs at the site.

Table 3-4. Comparison of collection strategies

	Number of Participants	Percent of Participants	Number of Sites	Average Cost Per Participant
Curbside	297	3.9%	1	$19.30
Household hazardous waste sites	882	11.5%	14	$69.72
Multi-facility	983	12.9%	12	$68.41
Permanent recycling facility	440	5.8%	6	$60.61
Retail	2,667	34.9%	3	$11.75
Special collection, electronics only	1,536	20.1%	12	$22.88
Special collection, multi-purpose	834	10.9%	16	$26.42
Total	7639	100.0%	64	

Retail, as a collection strategy for used electronic products for recycling or reuse, was the single most successful collection strategy during the project both as a percent of total participants and as a cost per participant. Collection events held in association with other waste or recycling collections attracted fewer participants than events that only collected electronic products, which were also more cost-effective.

Impact of retail collection sites

Retail stores (Computer World in Duluth and the two Circuit City stores in the Twin Cities suburbs of Burnsville and Maplewood) had a significant impact on participation and the amount of material collected during the project. Thirty-five percent of all participants brought used electronics to one of three retail sites during the project.

The August event in the parking lot of Computer World was sponsored, organized and conducted by the Western Lake Superior Sanitary District. Participants completed 1,667 surveys at the Duluth collection event during eight days in August.

The Circuit City collection events in October were sponsored by Circuit City Stores, and were planned and conducted with assistance from WM-ARG and the OEA. Significant publicity assistance was provided by the City of Burnsville, Dakota County and Ramsey County. One thousand participant surveys were completed at Circuit City stores during the month of October.

Comments from surveys completed by participants at retail locations were very positive and revealed that participants considered it a very convenient way to dispose of used electronics. Several participants also noted that they felt that the environmental values that Circuit City was promoting would influence where they would shop for appliances. Other customers said that they were coming to purchase new equipment and liked the idea of dropping off their old products while shopping for new products. Among respondents, 75 of 1,000 indicated that they came to Circuit City for the first time as a result of the collection project.

Despite positive feedback from customers on the survey, Circuit City's internal tracking devices led them to believe that the project had a negative impact on general customer satisfaction in the two stores that collected used electronics during October 1999. Management had concerns that the needs of customers wanting to buy new product were neglected while employees collected used products from participants in the project. Circuit City reported that customer complaints were noticeably higher in these two stores during the collection effort than in previous months.

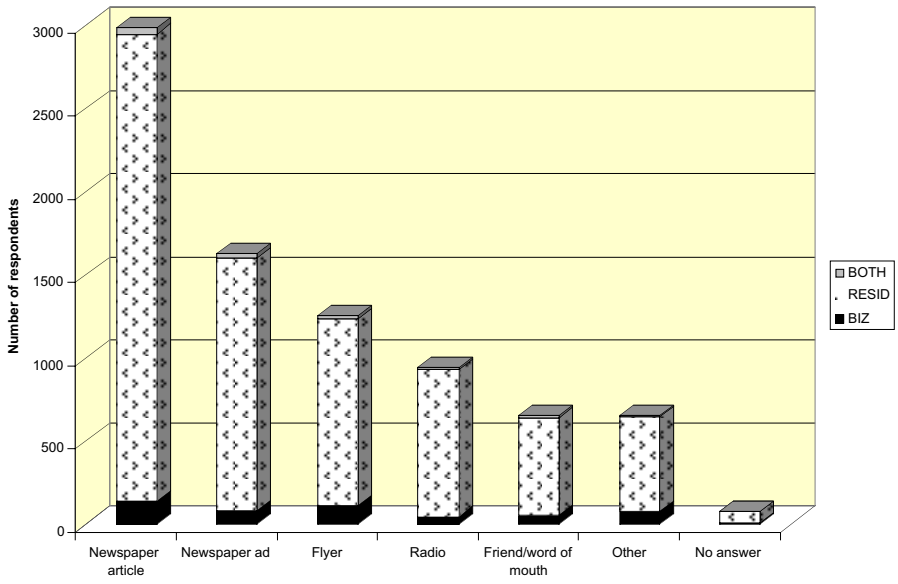
Circuit City chose not to post signs or instructions about the collection effort in the participating stores. Customers participating in the collection event had to ask store personnel to learn details about the collection effort. This was difficult for customers and staff, and was mentioned by respondents on surveys several times. Future retail operations should plan to display appropriate and visible signage if conducting collection events for used electronics.

Impact of publicity

Comparing collection events among those that used at least four media tools and those that used fewer than four media tools reveals a significantly higher participation rate among sites using more tools to advertise collection events. Media tools could include four or more of the following: flyers, radio Public Service Announcements (PSAs), radio advertisements, radio talk shows, newspaper ads, newspaper articles, television ads, television PSAs and television talk shows.

The participation rate for all events was 0.57 people per population base in the area of the event (the overall household participation rate was 1.4 households per area). The participation rate for collection events that used four or more media tools was 0.85 people per population base (the household participation rate was 1.95 households per area). Collection sites that used fewer than four media tools had a participation rate of 0.53 people per population base (the household participation rate for these sites was 1.34 households per area).

Figure 3-10. How did participant hear about collection event?



Part Four
Product Management and Results

The OEA and Waste Management-Asset Recovery Group worked with collection site hosts to manage the product once it was collected. WM-ARG shipped 700 gross tons of material (product and packaging) from the various sites to its central processing facility in Inver Grove Heights, Minnesota.

Many sites required temporary storage at or near collection sites prior to shipping to the central processing facility. In some cases, product was shipped directly to the processing site the day of collection. Generally, this decision was made based on distance to the processing facility and an estimate of the time it would take to collect enough material to warrant shipping.

Shipping products to processing center

Early on, the project partners recognized that getting the collected product from the collection sites to the processing center would be one of the costliest parts of the project. WM-ARG worked with the collection sites to design opportunities to aggregate material, from multiple sites if necessary, and to combine as much hauling as possible.

Packaging

The used electronics required 125 tons of packaging (pallets, gaylord boxes, shrink-wrap and so forth) to ship product from collection sites to the processing facility. Packaging can reduce the cost to manage used electronic products by simplifying the transportation of bulky items as well as large volumes of small products. Packaging was used to:

- reduce breakage of CRTs and other products
- maximize use of transport space
- reduce the amount of time spent handling material
- simplify handling
- reduce product handling both at the point of collection and by the processor
- make it easier and faster to process material once it arrived at the processing site
- prevent injuries

Gaylord boxes were used to transport electronics

This study found that the most economical way to ship and prepare the televisions, monitors and CPUs was on pallets, bound by shrink-wrap. All other products were best managed by placing them in gaylord boxes.

Initially sites were asked to supply gaylords and pallets, and were offered reimbursement for gaylord boxes that were not returned. It was difficult for many of the collection sites to provide these packaging materials and WM-ARG made separate deliveries of packaging to these sites prior to collection events. In most cases, WM-ARG provided gaylord boxes (durable cardboard boxes that measure four cubic feet), pallets and shrink-wrap, as necessary.

Transportation to processing site

The recycling company staged trailer trucks at designated drop-off points. The staging sites were useful to keep collection sites stocked with trucks to fill, and to keep collection sites clear in cases when large volumes were collected and it made sense to move full trucks off the site. Once prepared for shipment, product was either loaded into 20-foot and 48-foot trucks or roll-off containers. In general, roll-off containers were used at one-day collection events held relatively near the WM-ARG processing facility, and trucks were used for multi-day events or events farther away.

Product to be loaded into trucks was packaged at the time it was collected. Trucks were important at multi-day events to protect the used products from the weather, to prevent vandalism and to discourage the curious from looking through boxes of old products. Trucks were also used to store products locally, when possible, to maximize truck capacities and transportation distances.

Material placed in roll-off boxes (generally, metal open-top containers that can hold ten or twenty cubic yards for transporting bulky material) was generally loaded directly, not pre-packaged, and achieved the highest density for transport. However, it took extra time at the recycling facility to sort and separate the contents. Roll-offs were expedient to use at busy collection sites, but resulted in more breakage and were more difficult and less safe to unload at the processing facility.

Inspection and Inventory

When the material arrived at the processing facility, WM-ARG staff took a light and heavy weight of each truck on arrival to determine the gross weight of used products and identified the source of each shipment. Heavy weight is the weight of truck loaded with product; light weight is the weight of the empty truck. The difference is the weight of the product.

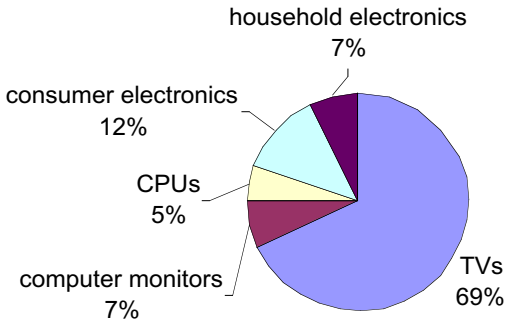
The recycler then unloaded each container and conducted an inventory.

WM-ARG sorted the used electronics into five categories and weighed them (see Table 4-1):

- televisions
- monitors
- personal computers, including keyboards, mice and hard drives
- consumer electronics, including telephones, fax machines and scanners
- household electronics, including small kitchen appliances, hairdryers, curling irons, radios and so forth

The recycler referred to this process as “sorting raw material” since the primary value in these old products was now defined by the scrap value of the secondary materials that would be culled from them during and after disassembly. It was also at this time that WM-ARG conducted a vintage assessment and brand analysis on televisions.

Figure 4-1. Product categories as a percentage of total weight of collected electronics



Weight of units collected, expressed as a percent of five broad product categories, reported by the recycler.

Table 4-1. Inbound electronics products delivered to central processing facility

Product Category	Type of Products	Tons	Percent of Total (w/o packaging)	Percent of Total (with packaging)
Televisions	1960 through 1990s vintages	390	67.9%	55.7%
Consumer electronics	Telephones, radios, facsimiles, handheld electronics, stereos, all other personal electronics	70.5	12.3%	10.1%
Household electronics	Microwaves, curling irons, small kitchen appliances,	43	7.4%	6.1%
Computer monitors		41	7.1%	5.9%
PCs	CPU's and peripherals	30.5	5.3%	4.3%
Total without packaging		575		
Packaging	Gaylord boxes, shrink wrap, pallets	125		17.9%
Total		700	100.0%	100.0%

Quantity and type of products shipped to WM-ARG

Televisions accounted for more than half of the 700 gross tons shipped for processing. During the three-month pilot effort, 8,649 TVs were collected and processed. Televisions totaled 390 tons, with an average weight of 90 pounds per TV.

Interestingly, packaging was the next largest item by weight at 125 tons, followed by consumer electronics at 70.5 tons. Table 4-1 shows that if packaging is removed from the equation, the distribution by product type looks somewhat different. Televisions account for 67.9 percent—or more than two-thirds—of the total, followed by consumer electronics at 12.3 percent, household electronics at 7.4 percent, computer monitors at 7.1 percent, and personal computers and components at 5.3 percent.

Although they were not included in the pilot, a small number of microwaves and air conditioners were brought to collection events. The recycler processed the microwave ovens. Air conditioning units were transferred to a licensed recycler.

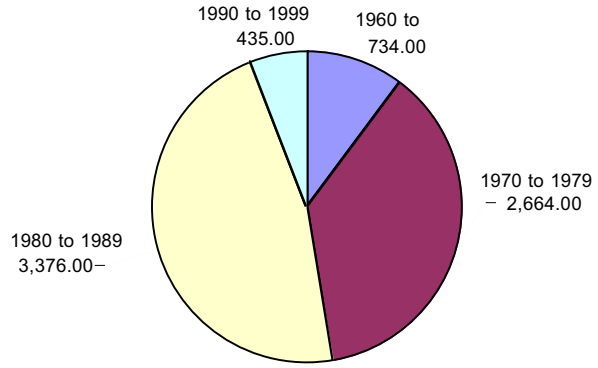
Vintage study of televisions

Shortly after the project began, WM-ARG began a vintage analysis of the collected televisions that would reveal the age of televisions in the disposal stream as well as the predominant manufacturers of those televisions. At that stage of processing, 1,440 televisions had already been processed, but WM-ARG recorded the model year and manufacturer for the remaining 7,209 televisions delivered to the processing site before dismantling the product (see Figure 4-2).

Roughly half of all televisions collected during the study were from the 1960s and 1970s. This is significant because capacitors containing regulated polychlorinated biphenyls (PCBs)—known carcinogens—were phased out of televisions in the late 1970s and early 1980s. Materials like these in older products will affect disassembly and increase the costs to properly manage products at end-of-life.

Seventeen brand names accounted for more than 85 percent of all televisions collected. Of the other 15 percent (other manufacturers), many of the manufacturers no longer exist. These orphan products pose a serious disposal challenge. If future plans for recycling televisions include working with the manufacturer, the problem of these "orphan products" must be addressed. This vintage study can help future programs develop EoL strategies for used TVs, including fee structures, collection opportunities and the availability of secondary market options and costs.

Figure 4-2. Vintage of televisions, by decade



Manufacturers	1960s	1970s	1980s	1990s	Total	Percent of Total
Zenith	186	606	552	50	1394	19.34%
RCA	170	517	521	67	1275	17.69%
Other manufacturers (70)	89	357	560	52	1058	14.68%
GE	43	190	219	30	482	6.69%
Sony	39	79	170	75	363	5.04%
Panasonic	49	130	164	16	359	4.98%
Sears	34	133	171	7	345	4.79%
Magnavox	28	120	157	34	339	4.70%
Sylvania	33	136	142	6	317	4.40%
Montgomery Wards	13	58	123	19	213	2.95%
Radio Shack	4	84	114	7	209	2.90%
JC Penney's	7	63	102	3	175	2.43%
Sharp	16	38	103	13	170	2.36%
Emerson	14	23	69	33	139	1.93%
Quasar	3	49	58	1	111	1.54%
Goldstar	5	36	58	5	104	1.44%
Toshiba	1	25	42	12	80	1.11%
Samsung	0	20	51	5	76	1.05%
Total	734	2664	3376	435	7209	100.00%

Demanufacturing used products for recyclable materials

After the electronics were separated into product categories, WM-ARG demanufactured the used products for recyclable materials. Products at the site were generally manually taken apart. Demanufacturing involved disassembling the electronics, removing hazardous materials, sorting them into secondary materials categories and weighing each secondary materials category.

These categories included:

- plastics
- copper yokes
- steel breakage
- packaging material for resale
- reusable products for export
- power supplies
- high- and low-grade printed circuit boards
- insulated copper wire
- steel and other metal structural components
- scrap for export
- CRT glass
- waste (mostly wood and plastic)

By dismantling these products into their constituent parts, the used electronics were transformed into scrap that has value in secondary markets. From the perspective of the recycler, these "raw materials"—the whole electronics products—were transformed into bulk commodity finished goods for a consumer market (otherwise referred to as scrap bound for scrap markets). WM-ARG completed this processing work in early March 2000.

Secondary materials results

The following section describes the types of secondary materials derived from products collected during the project, the percent of these materials by broad product categories and the markets where these materials were sold.

Of all component categories, steel breakage (the steel parts and chassis from computers and other electronic products) made up the largest share of this material, at 180 tons (25.7 percent). CRTs exceeded packaging slightly, at 135.5 tons (19.3 percent). More than 80 percent of the CRT glass was shipped to a lead smelter and the remaining CRT glass was shipped to a glass-to-glass recycler in Ohio.

Packaging, including pallets, gaylord boxes and shrink-wrap, accounted for the next largest volume of material at 125 tons. Efforts to reduce the use of this much packaging would require packing protocols and possibly specially-designed packaging to simplify transport. It would be cost-effective for large-scale efforts to recover used electronic products from consumers to pursue this.

Seven additional items made up less than 40 percent of the remaining materials. The largest category of these was 92 tons of solid waste sent to a landfill, which was mostly old wood and plastic laminated television chassis. Other waste included wood and plastics from other products, such as stereos and speaker cabinets. Copper smelters consumed 41.5 tons of printed circuit boards, which represented nearly six percent of all secondary materials, and 23 tons of copper-bearing materials. Engineering plastics accounted for 30.5 tons of the outbound materials, or 4.4 percent. These plastics, sent to MBA Polymers in Richmond, California, are discussed in detail later in Part 4. Finally, there were two export categories. "Export reusable" amounted to 4.5 percent, or 31.5 tons, and refers to computer monitors and personal computers that were shipped to reuse markets overseas. "Export scrap" amounted to 41 tons, or 5.9 percent of all outbound materials, and included plastic and metal that was

sorted and sold to brokers. This represented much of the mixed household electronics and some of the consumer electronics.

Some materials were sold, including plastics, glass from CRTs, copper-bearing and precious metal-bearing materials, non-ferrous metals and ferrous metals. Others, including the packaging and some whole parts, were reused. Still others were sent to the landfill as solid waste.

Table 4-2. Secondary materials derived from materials shipped to WM-ARG

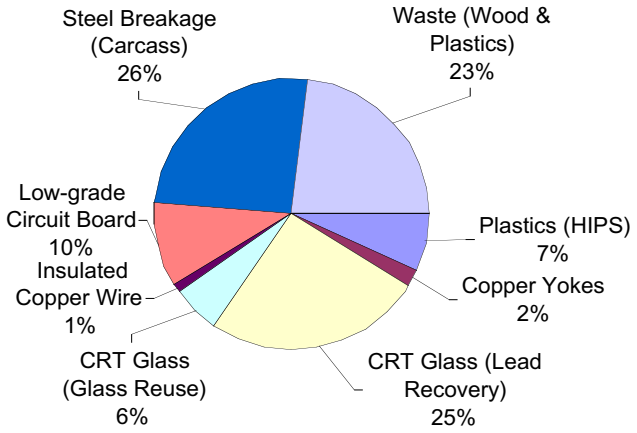
Material	Tons	Percent of Total	Destination
Plastics	30.5	4.4%	MBA Polymers or export
CRT glass to lead	113	16.1%	Lead smelter
CRT glass to glass	22.5	3.2%	CRT manufacturer
Printed circuit boards	41.5	5.9%	Copper smelter
Copper-bearing materials	23	3.3%	Copper smelter
Steel breakage (ferrous)	180	25.7%	Steel mill
Export reusable	31.5	4.5%	Component recovery
Export scrap	41	5.9%	Export scrap processor
Solid waste	92	13.1%	Landfill
Subtotal	575	82.1%	
Packaging	125	17.9%	Reused
Total	700	100.0%	

Secondary materials from televisions

The demonstration project collected 8649 TVs, totaling 388 tons (776,312 pounds) and representing 68 percent by weight of all products collected during the project. Average weight of a TV collected during the project was approximately 90 pounds, the single heaviest item brought to collection sites.

Of the secondary material dismantled from the televisions, CRTs made up 31 percent—the largest single commodity. There was slightly more steel breakage than waste, each accounting for roughly a quarter of all material. Additional commodities bound for raw material markets with relatively high value included copper yokes (two percent), insulated copper wire (one percent), engineering plastics (seven percent high-impact polystyrene), and low-grade circuit boards (ten percent), which all represent revenue to the recycler. The large volume of waste is attributed to old wood consoles, laminated plastic housings and other plastic housings contaminated with paint and/or metal that were common in the 1970s and 1980s.

Figure 4-3. Secondary materials derived from dismantled televisions



Commodity Recovered from TVs	Pounds	Value to Recycler	Gross Revenue	Consumer (End Market)	End Market Value	Gross Revenue
Plastics (HIPS)	53,152	$0.060	$3,189.12	Export Plastic Consumer	$0.125	$6,644.00
CRT Glass (Lead Recovery)	199,350	$(0.045)	$(8,970.75)	Lead Smelter	$0.030	$5,980.50
CRT Glass (Glass Reuse)	45,000	$(0.025)	$(1,125.00)	CRT Manufacturer	$0.085	$3,825.00
Low-grade Circuit Boards	78,500	$0.125	$9,812.50	Copper Smelter	$0.250	$19,625.00
Insulated Copper Wire	7,455	$0.120	$894.60	Copper Smelter	$0.250	$1,863.75
Copper Yokes	15,094	$0.115	$1,735.81	Copper Smelter	$0.230	$3,471.62
Steel Breakage (Carcass)	198,300	$0.020	$3,966.00	Steel Mill	$0.045	$8,923.50
Waste (Wood & Plastics)	179,461	$(0.030)	$(5,383.83)	WM Landfill	$(0.010)	$(1,794.61)
Total	776,312					
Gross Revenue per Pound		$0.005			$0.063	
Gross Revenue			$4,118.45			$48,538.76
Labor Cost			$(23,600.00)			
Packaging Supplies			$(3,200.00)			
Net Revenue per Pound		$(0.029)				
Net Revenue			$(22,681.55)			

CRT glass sent for reuse as CRT glass (glass-to-glass recycling) represented considerable savings to the recycler, confirming the principal partners' speculations on this possibility during the planning stages of the project. In fact, as markets for glass cullet expand, CRT glass in a glass-to-glass loop may represent revenue to a recycler, or at the very least, would represent significantly reduced expense. Future efforts to recycle CRTs that take full advantage of this cost savings will add value to recyclers by reducing the cost to manage products containing CRTs.

Abbreviations for Plastic Types

HIPS = High-Impact Polystyrene
ABS = Acrylonitrile Butadiene Styrene
PPE = Polyphenylene Ether
PVC = Polyvinyl Chloride
PC/ABS = Polycarbonate/Acrylonitrile Butadiene Styrene blend
PP = Polypropylene
PE = Polyethylene
PC = Polycarbonate

Secondary materials from computer monitors

Computer monitors are relatively newer consumer products than televisions; this is reflected in the kinds and quantities of commodities derived from the disassembled product. Evaluating the secondary commodities derived from monitors collected during the project (and excluding whole monitors sold for reuse, described as "export reusable" in Figure 4-4), what may seem like the same product type as televisions reveals a remarkably different secondary commodity profile.

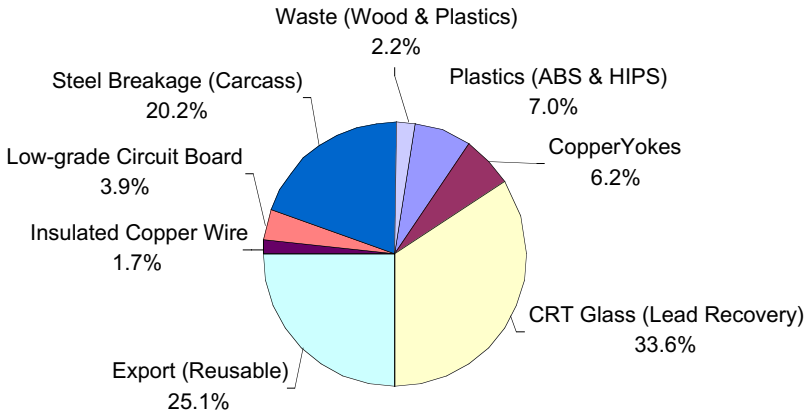
Comparing results from the project for televisions and monitors, TVs contain more waste than monitors, while monitors have a higher percentage of CRT glass and engineering plastics than found in TVs (See Table 4-3).

Table 4-3. Comparison of secondary materials from TVs and monitors

	Monitors	TVs
Waste	3%	23%
CRT Glass	46%	31%
Plastics	9%	7%

Plastic housings recovered from computer monitors (5,650 pounds) represent the second largest volume of plastics recovered by product type in the study. Monitor housing plastic represents 9.4 percent of the recovered monitor scrap. In preparing plastics to be sent to MBA Polymers, Inc., these plastics were combined with 656 pounds of plastics from computer housings, 3.7 percent of the total CPU scrap, prior to shipment. CRT glass from monitors was processed and shipped to a lead smelter before the glass-to-glass market was identified, otherwise it, too, would have been recycled in a glass-to-glass loop.

Figure 4-4. Secondary materials from computer monitors



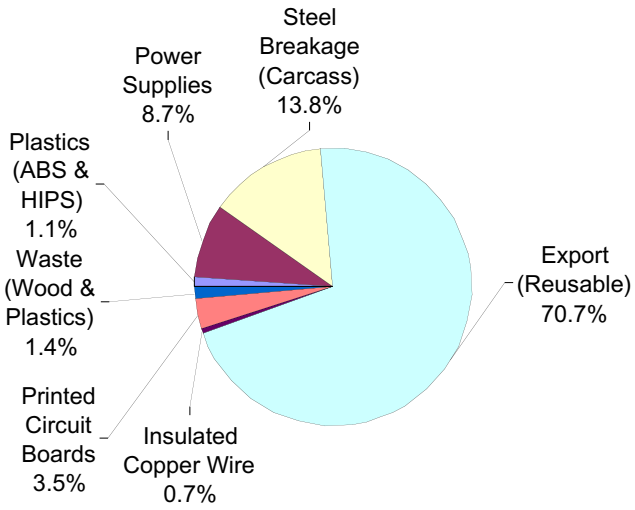
Commodity Recovered from Computer Monitors	Pounds	Value to Recycler	Gross Revenue	Consumer (End Market)	End Market Value	Gross Revenue
Plastics (ABS & HIPS)	5,650	$0.060	$339.00	MBA Polymer	$0.125	$706.25
Copper Yokes	5,011	$0.115	$576.27	Copper Smelter	$0.230	$1,152.53
CRT Glass (Lead Recovery)	26,977	$(0.045)	$(1,213.97)	Lead Smelter	$0.030	$809.31
Insulated Copper Wire	1,340	$0.120	$160.80	Copper Smelter	$0.250	$335.00
Low-grade Circuit Boards	3,150	$0.125	$393.75	Copper Smelter	$0.250	$787.50
Export (Reusable)	20,150	$0.055	$1,108.25	Component Recovery	$0.155	$3,123.25
Steel Breakage (Carcass)	16,188	$0.030	$485.64	Steel Mill	$0.045	$728.46
Waste (Wood & Plastics)	1,777	$(0.030)	$(53.31)	WM Landfill	$(0.010)	$(17.77)
Total	80,243					
Gross Revenue per Pound		$0.022				$7,624.53
Gross Revenue			$1,796.43		$0.095	
Labor Cost			$(2,407.29)			
Packaging Supplies			$1,300.00			
Net Revenue per Pound		$0.009				
Net Revenue			$689.14			

Secondary materials from personal computers

Here, the term "personal computer" refers to the central processing unit (CPU). For the purposes of recycling used commodities for this project, computer peripherals, such as keyboards and mice, were managed as consumer electronics.

Personal computers have relatively high value for disassembly and commodity sales to secondary markets in North America. Printed circuit boards in PCs were worth ten times more than the value of low-grade circuit boards from CRT devices, televisions and other electronic products. High-value secondary commodities make up a greater portion of the product, including 30 percent power supplies, more than two percent insulated copper wire, 12 percent high-grade circuit boards and 47 percent steel breakage. "Export reusable" amounted to 70.7 percent and refers to personal computers that were shipped to reuse markets overseas.

Figure 4-5. Secondary materials from personal computers



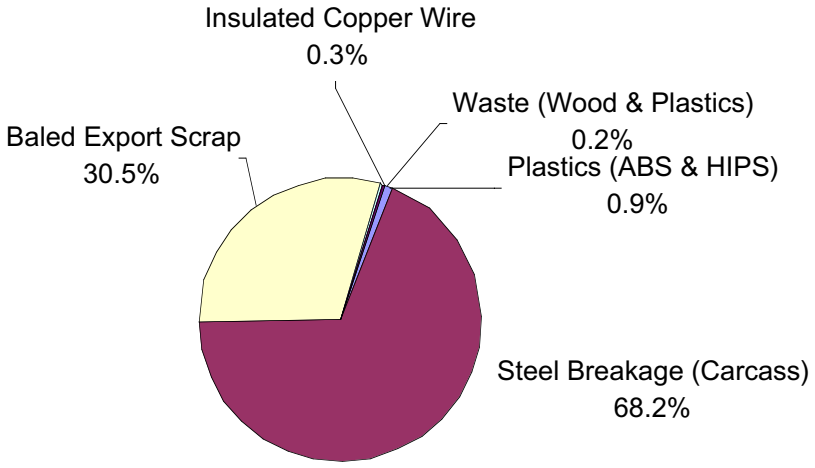
Commodity Recovered from Personal Computers	Pounds	Value to Recycler	Gross Revenue	Consumer (End Market)	End Market Value	Gross Revenue
Plastics (ABS & HIPS)	656	$0*	$0	Export and MBA Polymers	$0.125	$82.00
Power Supplies	5,271	$0.115	$606.17	Copper Smelter	$0.230	$1,212.33
Export (Reusable)	42,822	$0.100	$4,282.20	Component Recovery	$0.180	$7,707.96
Insulated Copper Wire	405	$0.135	$54.68	Copper Smelter	$0.250	$101.25
Printed Circuit Boards	2,145	$1.250	$2,681.25	Copper Smelter	$1.800	$3,861.00
Steel Breakage (Carcass)	8,357	$0.030	$250.71	Steel Mill	$0.030	$250.71
Waste (Wood & Plastics)	875	$(0.030)	$(26.25)	WM Landfill	$(0.010)	$(8.75)
Total	60,531					
Gross Revenue per Pound		$0.130			$0.218	
Gross Revenue			$7,848.75			$13,206.50
Labor Cost			$(1,815.93)			
Packaging Supplies			$550.00			
Net Revenue per Pound		$0.109				
Net Revenue			$6,582.82			

* The American Plastics Council paid to ship material to MBA Polymers. WM-ARG incurred no transportation costs and received no revenue for this material.

Secondary materials from consumer electronics

Consumer electronics include telephones, radios, fax machines, handheld electronics, stereos, scanners and all other personal electronic products. For the purposes of sorting commodities for the recycler, they also include computer peripherals such as mice and keyboards. Steel breakage made up 68 percent of the secondary materials from consumer electronics, and nearly one third, or 31 percent, was primarily mixed resin plastics. Both were sold as baled scrap for export. These products produced small quantities of waste, insulated copper wire and engineering plastic (HIPS) that was easily separated as a single resin commodity. This 1,200 pounds of engineering plastics was sent to MBA polymers for further study.

Figure 4-6. Secondary materials from consumer electronics



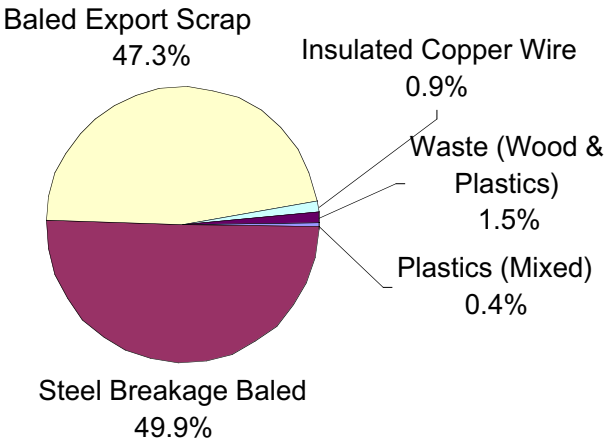
Commodity Recovered from Consumer Electronics	Pounds	Value to Recycler	Gross Revenue	Consumer (End Market)	End Market Value	Gross Revenue
Plastics (ABS & HIPS)	1,200	$0	$0	MBA Polymer	$0.125	$150.00
Steel Breakage (Carcass)	95,690	$0.020	$1,913.80	Steel Mill	$0.045	$4,306.05
Baled Export Scrap (plastics)	42,822	$0.020	$856.44	Export Scrap Processor	$0.085	$3,639.87
Insulated Copper Wire	405	$0.135	$54.68	Copper Smelter	$0.250	$101.25
Waste (Wood & Plastics)	250	$(0.030)	$(7.50)	WM Landfill	$(0.010)	$(2.50)
Total	140,367					
Gross Revenue per Pound		$0.020			$0.058	
Gross Revenue			$2,817.42			$8,194.67
Labor Cost			$(2,105.51)			
Packaging Supplies			$2,100.00			
Net Revenue per Pound		$0.020				
Net Revenue			$2,811.91			

Secondary materials from household electronics

Household electronics include microwaves, curling irons, hairdryers, vacuums and small kitchen appliances such as can openers and mixers. As a group, these products contained less metal and more plastic than the category defined as consumer electronics. After minor disassembly, products that were mostly plastic were baled for export.

WM-ARG recovered 350 pounds of mixed plastics from household appliances and shipped them to MBA Polymers for limited evaluation. This represents 0.4 percent by weight of commodities recovered from household electronics.

Figure 4-7. Secondary materials from household electronics



Commodity Recovered from Household Electronics	Pounds	Value to Recycler	Gross Revenue	Consumer (End Market)	End Market Value	Gross Revenue
Plastics (Mixed)	350	$0	$0	MBA Polymer	$0.125	$43.75
Steel Breakage Baled	41,741	$0.020	$834.82	Steel Mill	$0.045	$1,878.35
Baled Export Scrap	39,565	$0.025	$989.13	Export Scrap Processor	$0.085	$3,363.03
Insulated Copper Wire	750	$0.135	$101.25	Copper Smelter	$0.250	$187.50
Waste (Wood & Plastics)	1,250	$(0.030)	$(37.50)	WM Landfill	$(0.010)	$(12.50)
Total	83,656					
Gross Revenue per Pound		$0.023			$0.065	
Gross Revenue			$1,887.70			$5,460.12
Labor Cost			$(1,254.84)			
Packaging Supplies			$600.00			
Net Revenue per Pound		$0.015				
Net Revenue			$1,232.86			

Table 4-4. Secondary materials from all product categories

Secondary Material	Televisions		Computer Monitors		Personal Computers (CPUs)		Consumer Electronics		Household Electronics	
	Pounds	Percent	Pounds	Percent	Pounds	Percent	Pounds	Percent	Pounds	Percent
Copper yokes	15,094	1.9%	5,011	6.2%						
CRT glass (glass-to-glass)	45,000	5.8%								
CRT glass (lead smelter)	199,350	25.7%	26,977	33.6%						
Export (reusable)			20,150	25.1%	42,822	70.7%				
High-grade circuit boards					2,145	3.5%				
Low-grade circuit boards	78,500	10.1%	3,150	3.9%						
Insulated copper wire	7,455	1.0%	1,340	1.7%	405	0.7%	405	0.3%	750	0.9%
Plastics (ABS & HIPS)			5,650	7.0%	656	1.1%	1,200	0.9%		
Plastics (HIPS)	53,152	6.8%								
Plastics (mixed)									350	0.4%
Baled export scrap (Plastic)							42,822	30.5%	39,565	47.3%
Power supplies					5,271	8.7%				
Steel breakage, baled	198,300	25.5%	16,188	20.2%	8,357	13.8%	95,690	68.2%	41,741	49.9%
Waste (mostly wood and plastics)	179,461	23.1%	1,777	2.2%	875	1.4%	250	0.2%	1,250	1.5%
Total, all commodities, in pounds	**776,312**	**100.0%**	**80,243**	**100.0%**	**875**	**100.0%**	**140,367**	**100.0%**	**83,656**	**100.0%**

Marketing the Secondary Materials Streams

A principal assumption of the project was that secondary materials have different values depending on the end-user of the scrap commodity. The project sought to evaluate these differences for some of the scrap, depending on whether it was sold to low-end or high-end markets.

- High-end markets capture some of the added value from previous processing inherent in the scrap, reducing the energy and labor required to make new finished goods from the secondary material (see Figure 2-1). High-end markets include product manufacturers. Brokers may represent either market sector.
- Low-end markets are those reclaiming raw materials such as smelters and raw material refineries.

The partners chose to evaluate engineering plastics and CRT glass for recycling in high-end secondary markets. Engineering plastics have the greatest potential to add revenue to a recycling process for EoL electronics, while CRT glass poses an opportunity for the greatest reduction in costs for managing EoL electronic products. Consumer markets for recyclers consist of copper and lead smelters, CRT glass manufacturers, plastics manufacturers, auto shredding operations, mixed plastic processing operations, international reusable markets, landfills and local non-ferrous and ferrous consumers and brokers.

WM-ARG tracked information on the cost to process the products and the secondary materials and noted the value these materials had in the scrap markets as secondary materials. It's important to note that secondary materials are traded as commodities, and as such, prices will fluctuate. Nonetheless, the information provides a good sense of the residual value of used electronic products.

Speculating on future prices for specific secondary materials makes it possible to consider future uses for those materials. Over time, the value from reusing and recycling used electronics should begin to equal or exceed the cost to collect, transport and refurbish or recycle these products. Improving the market disposition for refurbished products, CRT glass and engineering plastics offers the best hope for accomplishing this in the future.

CRT glass recycling

CRT glass recovered in Minnesota has traditionally been managed in a glass-to-lead loop at various smelting operations. The primary CRT glass-to-glass recycling markets that return CRT cullet to the CRT manufacturing process are located on the east coast of North America and in Japan. Comparing the cost of glass-to-glass recycling against glass-to-lead recovery was one of the objectives of the project.

Glass from CRTs collected during the project was sold to two markets: a traditional smelting market for glass-to-lead recycling and to an intermediary processor working with CRT manufacturers to remanufacture the glass back into CRTs—a glass-to-glass loop.

Glass-to-glass. A smaller portion of all glass managed by the project (22.5 tons) was shipped to Dlubak Glass, a processor supplying the CRT glass manufacturing industry with post-consumer CRT cullet. If all CRT glass from the project had been managed for glass-to-glass recycling, the recycler would have lowered expenses by $4,526.

Glass-to-lead. Most of the CRT glass from the project (113 tons) was transferred directly to primary lead smelters at a net loss of $0.045 per pound, including transportation. CRT glass provides lead smelters not only with a source of lead, but also with a source of silica, which is used as a fluxing agent in the furnace. North American copper smelters are also large consumers of CRT glass where the glass is used as a fluxing agent. Nonetheless, transportation and material preparation at the smelters exceeds the monetary value of silica and lead.

WM-ARG reported net costs of $90 per ton, or a total of $8,971, to manage CRT glass in a glass-to-lead loop. This represented the single largest material processing expense incurred by

WM-ARG. CRT glass managed in a glass-to-glass loop, on the other hand, cost a net $50 per ton, or a total of $1,125, representing a significant savings to WM-ARG for the glass-to-glass recycling effort.

CRT glass cullet that can meet manufacturers' specification standards is a more valuable commodity to the CRT manufacturing industry than CRT glass is to the smelting industry. This management strategy warrants further evaluation for its potential to add value to future electronic product recycling efforts and to reduce recycling costs.

Precious metals recovery

Precious metals like gold, silver, platinum and palladium are recovered from printed circuit boards found in electronic products. Copper smelters separate the precious metals from other parts of the circuit board and compensate the recycler accordingly.

See Figures 4-3 to 4-5 for details on value of circuit boards.

Nearly 42 tons of printed circuit boards from the project were sent to a copper smelter, generating revenues of $12,887, or about $0.154 per pound. Project data show that all but 2.6 percent of these circuit boards were low-value boards from televisions and computer monitors. The copper smelter paid $1.25 per pound for the high-grade circuit boards removed from personal computers and only one tenth that amount for low-grade circuit boards from all other products.

Auto shredder operations

Products that were considered to have the least commodity value from the mixed household electronics and consumer electronics sorts were sent to an auto shredder for mechanical separation. This was done to test the potential of recovering better prices from secondary markets by mechanically separating metals and plastics. If this were the case, then future recycling efforts would utilize this processing technique. An auto shredder—a mixed ferrous metal recovery operation—is typically used to process old automobiles and large appliances such as refrigerators and washing machines. The experiment proved that it was not worthwhile to separate and process these product streams separately. The resulting shredded material had no additional value unless it was separated, but separation would eliminate any potential cost savings from use of the technique.

Reuse options for PCs and monitors

A portion of the collected monitors and CPUs was sold to overseas markets for potential reuse, repair or component recovery. Overseas markets paid a net $0.10 per pound for CPUs and a net $0.55 per pound for computer monitors, which was a greater return than domestic metal recovery markets. Although this management option was not intended to be included in the project, it became clear by the condition of much of the computer equipment collected that reuse markets would pay more for the product and reduce the recycler's labor costs for disassembly. There were 10.1 tons of monitors sold for reuse for revenue of $1,108, and 21.4 tons of CPUs sold for reuse for revenue of $4,282.

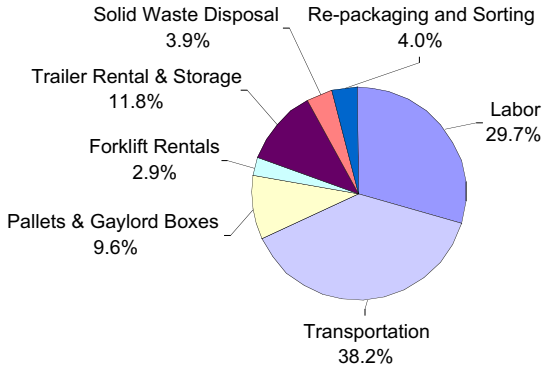
There is high demand from overseas markets for older personal computers. Seventy percent of the CPUs collected during the project were sold to export markets. In general, CPUs shipped from the project were sold to markets that disassembled them for component recovery. Computer monitors sold to export markets were more likely to have been reused or refurbished for resale.

Costs to transport, process and market finished product

Electronics recyclers are in business to aggregate used electronic products and disassemble them into secondary materials: glass, plastic, metal and so forth. These raw materials that recyclers remove from electronic products are the secondary materials or "finished products" the recycler can sell back into the marketplace. These end markets include smelters, raw material refineries, brokers, processors and product manufacturers. The difference between the cost to create the finished product and the revenues the recycler can get for the secondary materials is the profit or loss associated with the recycling effort.

During this demonstration project, WM-ARG collected consumer electronics and household electronics to see if these items would help offset the cost incurred to manage other products, such as CRT-containing products. In addition, consumer electronics and mixed electronics were kept separate to see if the components of one product group would be more valuable than the components of the other. WM-ARG experimented with these items to evaluate how to best maximize value from the various product streams and concluded that separating the two streams added only modest value.

Figure 4-8. Costs to recycler



Operation	Cost	Pounds	Cost per Ton*
Labor	$42,176		$73.35
Transportation	$47,105		$81.92
Pallets & Gaylord Boxes	$13,659		$23.76
Forklift Rentals	$4,104		$7.14
Trailer Rental & Storage	$16,746		$29.12
Solid Waste Disposal	$5,508	183,613	$9.58
Re-packaging and Sorting	$5,628		$9.79
Sub-Total	$134,926		$234.65

All variable costs associated with this project are as listed in this table. The breakdown for costs incurred at the WM-ARG processing facility did not include fixed overhead costs including Sales, General Administration, Facility cost or Management cost.

*Based on the 575 tons of used products collected during the collection phase of the project.

Net processing costs, excluding transportation, equipment and storage were about $93 per ton. That averages about $4.20 per 90-pound television.

WM-ARG reported total operating costs of $135,000, excluding overhead and return on investment; revenues from the sale of recovered secondary materials totaled approximately $43,000. Net cost was $160 per ton to transport, process and market reusable and secondary materials. WM-ARG's largest single expenditure (38 percent) was transportation of materials from collection events to their central facility.

Analysis of plastics by MBA Polymers, Inc.

During the demanufacturing process, WM-ARG separated the plastics into three basic categories:

- plastics from televisions (primarily housings which are mostly black in color).
- plastics from computers (monitor housings, CPU housings, and peripherals which are mostly light colored).
- plastics from miscellaneous electronics (all other communication and household electronic goods which are typically mixed color).

To help control for quality, American Plastics Council (APC) and MBA Polymers asked WM-ARG to exclude TVs with high levels of lamination and/or high levels of obvious coatings. Older TV sets with simulated wood grain covers were disposed of as waste due to the known difficulties of cleaning and purifying this problem waste plastic. They also excluded monitors with large amounts of metal coatings, but left metal attachments (such as screws and molded-in metal inserts) and labels intact.

As Table 4-2 shows, 30.5 tons (61,000 pounds) of plastics were collected and separated in this manner. That represents 4.4 percent by weight of the total quantity of outbound materials (including discards).

Of the 61,000 pounds of outbound plastics, more than 31,000 pounds were shipped to MBA Polymers for characterization and further study. The remaining plastics from dismantled TV housings were sold into the export market at about five cents per pound, and the rest of the plastics were discarded as waste along with wood from old televisions.

Recycling and evaluation

In total, 31,588 pounds of plastics were shipped to MBA Polymers. Plastics from televisions made up 54 percent of the sample, computer plastics made up 38 percent, and miscellaneous plastics was 8 percent. MBA Polymers, Inc., is a durable plastics processor and technical research facility in Richmond, California. With input from APC, MBA Polymers began evaluating selected engineering plastics in July 2000 and completed work on baseline data of the plastics three months later. This included an initial characterization, pre-processing, plastic-plastic separation, and finally, extrusion, molding and material testing.

Plastic-plastic separation is a processing technique that separates plastic resins based on manufacturer and market interest.

In addition to evaluation of the material properties and applications for these engineering plastics, MBA Polymers also prepared a mechanical specification sheet on the resulting batch. It was the experience of the partners that many product design engineers are not interested in experimenting with used plastic unless a physical properties specification sheet is available to review. (The American Plastics Council is evaluating a mixed stream of the non-television, non-computer plastics in a separate but related study.)

Separation and identification

The entire sample—100 percent of each category—was accepted for further processing. MBA put the plastics through a dry process designed to reduce size and remove metals. During this first process, about 10 percent of the sample was removed as metal, fluff or fines. These are contaminants that reduce the value of the finished product. Metal is sometimes attached to engineering plastics, especially on older products, fluff is lightweight contaminant that cannot be used, such as paper or plastic, and fines are small dirt particles or other contaminants that are undesirable in the final product. Then the plastics went through proprietary separation processes to produce discrete streams of plastic. An additional 5 percent of the sample was removed as contaminants during the separation process, leaving a total of 27,301 pounds of plastic for characterization.

Next, MBA identified the plastics by resin type using equipment developed, in part, with APC support. MBA was able to identify eight different basic resins (see Table 4-5). In the total sample, HIPS was the predominant resin at 56 percent, followed by ABS at 20 percent and PPE at 11 percent. The quantity of those resins varied within product categories. HIPS was clearly

the predominant resin in television plastics, whereas ABS was the predominant resin in both computer and miscellaneous plastics.

Table 4-5. Plastic resins in sample sent to MBA Polymers

Plastic Resin	Percent of Total Sample	Television Plastics	Computer Plastics	Miscellaneous Plastics
HIPS	56%	82%	25%	22%
ABS	20%	5%	39%	41%
PPE	11%	7%	17%	4%
PVC	3%	<1%	5%	15%
PC/ABS	3%	0%	6%	7%
PP or PE	2%	0%	3%	8%
PC	2%	1%	4%	1%
Other	<1%	<1%	<1%	2%
Unidentified	3%	5%	0%	0%

Plastic resin separation

Another goal of the project was to determine whether individual plastic resins could be separated into discrete streams that could be marketed for high-end applications. MBA chose to focus on the most abundant resin in the sample, flame-retardant television HIPS.

MBA used a proprietary separation process on the entire sample of television plastics. This process yielded a nearly pure stream of 8,215 pounds of flame-retardant HIPS. This represented 67 percent of the HIPS in the sample. MBA believes that this yield would increase with experience using and separating the material.

While similar separation tests were not performed on other resins, MBA maintains that, given sufficient quantities, it should be possible to separate television and computer plastics to yield high-quality ABS and PPE. Engineering plastics used in housings (PC and PC/ABS) could also be targeted from the computer stream.

Abbreviations for Plastic Types

HIPS = High-Impact Polystyrene
ABS = Acrylonitrile Butadiene Styrene
PPE = Polyphenylene Ether
PVC = Polyvinyl Chloride
PC/ABS = Polycarbonate/Acrylonitrile Butadiene Styrene blend
PP = Polypropylene
PE = Polyethylene
PC = Polycarbonate

Extrusion and material testing

A final goal of the project was to develop a specification sheet for HIPS to determine if it could be used in high-end applications. To that end, MBA dried, extruded and pelletized the recovered HIPS, then injection-molded test bars and tested properties. Table 4-6 shows the results of those tests and compares the melt flow rate, impact strength, tensile strength, and density of post-consumer T-HIPS with three similar virgin resins currently on the market. The results of these tests show that several properties of flame retardant HIPS from recovered residential televisions are comparable to virgin resins. This suggests that recycled HIPS could be used in similar applications given a consistent quantity and quality of supply.

Table 4-6. Test results for recovered flame retardant HIPS (including comparisons with select virgin resins)

Resin	Melt Flow Rate[1] (200/5.0) (g/10 min)	Notched Izod Impact Strength[2] (ftlb/in)	Tensile Strength[3] (psi)	Density (g/cm^3)
HIPS	7.5	1.5	3100	1.15
Dow Styron 6515	7.5	2.8	2800	1.16
BASF ES 8120	6	2	3500	1.15
Huntsman PS 351	6.5	1.7	4000	1.16

Test results for post-consumer HIPS for melt flow rate, impact strength, tensile strength and density, as evaluated by MBA Polymers, Inc. Plastic sample was from products collected during the Minnesota demonstration project.

[1]This is a measure of how easy it is for the molten plastic to flow at a given temperature (200 degrees Celsius in this case) under a given load (5.0 kg in this case).

[2]This is a measure of how much energy is required to break the material. The plastic is notched to ensure that breaking energy is concentrated on one location on the specimen.

[3] Tensile strength is the greater of tensile strength at yield, which refers to the stress beyond which a material will irrevocably deform or the tensile strength at break, which refers to the stress on a material just prior to breaking.

Comparisons to previous research

APC has done considerable research in the area of durables recovery over the past eight years. It is also responsible, in large part, for the development and testing of several types of identification and separation technology used in the analysis done by MBA Polymers for the demonstration project. While numerous reports have been written on various components of APC's research, its recent report, *Plastics from Residential Electronics Recycling: Report 2000,* is probably the most comparable to this project. It involved characterizing plastics from electronics recovered in 1998 by Hennepin County, Minnesota, from its residential collection program.

Table 4-7. Comparison of plastics sample from demonstration project to sample from Hennepin County

Plastic Resin	Percent of Project's Total Sample	Percent of Hennepin County Total Sample
HIPS	56%	59%
ABS	20%	20%
PPE	11%	16%
PVC	3%	<1%
PC/ABS	3%	<1%
PP or PE	2%	3%
PC	2%	<1%
Other	<1%	2%
Unidentified	3%	0%

Therefore, it makes the most sense to compare the results of that previous work with the results of this more current study.

What do comparisons to previous research reveal?

- **Better sample.** The current project tested a much larger sample—31,000 pounds compared to 3,000 pounds—and, thus, is statistically more representative of which plastics can be found in used consumer electronics.
- **Better sorting.** MBA Polymers accepted 100 percent of the current plastics sample but only 35 percent of the previous sample, due in large part to the excellent job WM-ARG did of sorting plastics to meet MBA's specifications, choosing to export or discard plastics that did not meet specifications prior to shipment. If all demanufacturers work similarly to meet market specifications, it should improve the viability of recycling plastics from recovered electronics.
- **Different product types.** The distribution by product type was quite different. In the current project, television plastics made up a much smaller portion of the sample (54 percent compared to the previous 67 percent) and computer plastics made up a much larger portion (38 percent compared to the Hennepin County's 18 percent). This is not surprising given the proliferation of computers in recent years and the maturation of television saturation. It also bodes well for recycling plastics from used consumer electronics because computers tend to have higher-value engineering plastics than televisions.
- **Different resin mix.** Within product categories, the resin distribution varied compared to the Hennepin County sample. For example, in television plastics, there was considerably more HIPS in the current sample, and less ABS and PPE. With computer plastics, there was considerably more HIPS in the current sample, considerably less ABS and PPE, and more resins represented in general. With miscellaneous plastics, there was much less HIPS and PPE and much more ABS, PVC and PC/ABS.
- **Resin types.** The resin composition of the total current sample was both similar to and different from the Hennepin County sample. For example, in both samples, HIPS was the predominant resin, followed by ABS and PPE. Interestingly, HIPS increased as a portion of the total current sample, ABS comprised the same portion of each sample, and PPE declined as a portion of the current sample. In addition, in the current sample there was slightly more PVC, PC/ABS and PC, and slightly less "other."
- **Better separation techniques.** When trying to produce a pure stream of flame-retardant HIPS, the yield was much better in the current effort (48 percent of television plastics compared to 15 percent in the previous study conducted with material collected by the Materials for the Future Foundation (MFF), described in *Report 2000*). This is attributable to MBA's growing familiarity with the resin and better separation equipment and techniques.
- **Specification analysis makes sense.** While a specification sheet was not developed for HIPS from the previous sample, the question was asked: In what markets might plastics from recovered electronics be used? The tests that were performed in this project show that HIPS could potentially be used in similar applications as virgin resins.

Conclusions about plastics

Clearly, the analysis conducted by MBA Polymers for the demonstration project is an important step forward in understanding plastics from end-of-life electronics. Building on prior American Plastics Council initiatives, the work with engineered plastics broke new ground by reporting previously unpublished information on the potential for post-consumer engineering plastics to meet specification standards for new product.[xiv]

Not only do we know, with more precision, what resins are present in what quantities, we also know the properties of the dominant resin—FR-HIPS from televisions. This information is critical to understanding the end markets in which plastics from recovered electronics might be used. The plastics analysis determined that FR HIPS can meet critical specification standards and can be reused in new products. In other words, based on the properties tested, it is possible to segregate post-consumer engineering plastics and meet stringent quality requirements.

Part Five
Conclusions and Recommendations

This report on Minnesota's demonstration project to recycle used electronic products describes work conducted in a specific geographic area over a defined period. The partners fully expect that readers will apply the information and data presented to markets and communities outside of Minnesota, as well as within. Therefore, readers will benefit from paying close attention to similarities and differences between their circumstances and the ones described. It is especially worth noting that it is the nature of markets to fluctuate. Demand for secondary commodities and prices for those commodities are subject to frequent change. The market prices available to us in Minnesota in 2000 will likely be different here and elsewhere in the future.

Finally, the experience of this project is merely a benchmark. The partners view this effort as part of a process in creating a viable recycling industry for used electronic products from households as well as businesses. We hope this report benefits those working in the field and invites further research.

Conclusions

The following conclusions describe some of what the principal partners learned from their collaboration on the demonstration project.

General

Strategic voluntary partnerships can work. The demonstration project proved worthwhile for bringing public and private interests together to work toward common goals and for revealing costs and burdens to everyone for returning used electronics to the recycling supply chain. The project established the value of future collaboration among government, recyclers and manufacturers to find solutions for removing used electronic products from municipal waste.

Working model of shared product responsibility. The demonstration project proved the advantages of public/private collaboration to prevent the disposal of used electronic products in municipal waste. It provided direct ties to the marketplace at critical stages of work, as well as direct communication to regulatory authorities.

General conclusions about costs

Pilot costs are higher than the costs of a mature program. The costs to implement this one-time demonstration project are higher than would be expected under routine operating conditions. Many of the reported costs are one-time capital and operating expenses—costs that would otherwise not be incurred, or could be reduced substantially if collections were conducted as regularly held seasonal events or as permanent programs. Capital and operating costs for new programs are often higher. As programs mature, capital costs are reduced or eliminated and operations are made more efficient.

Costs for collection were higher than expected. Packaging supplies, transportation, equipment to move used products from the point of collection to the processing facility and handling cost more than anticipated, despite efforts to adequately plan for this phase of the project in advance. Mature programs to recycle used electronic products may be less expensive as they develop and adopt more efficient system methods.

The most costly activities for event collections were publicity (39 percent) and staffing events (33 percent). While it is unlikely that changing staffing patterns could significantly reduce the cost to staff future events, including electronics collections in on-going publicity and education campaigns may reduce costs significantly for future collection efforts.

Other cost savings must be evaluated on a case-by-case basis. In the project-sponsored events, planning and administration costs were high because this was a new effort for most site administrators. These costs can be expected to fall as event hosts become more familiar with the routine of collecting used electronics. On the other hand, storage and equipment costs may remain constant or rise.

Minimize handling of used products. There is a high cost associated with handling used products. Reducing the number of times products must be handled from the point of collection to the point of sale as secondary material will reduce overall operating expenses.

The cost to collect and transport used electronic products and related secondary commodities are key to developing a reuse and recycling infrastructure. Data from this demonstration project suggests that collection and transportation may account for up to 80 percent of all costs to collect, process and return secondary materials to the supply chain. While a limited and evolving infrastructure to collect and process used electronic products exists, methods to reduce these costs are critical for developing an economically sound reuse and recovery infrastructure.

Factors that motivate collection hosts

Adequate funding will motivate local government participation. Well-attended public collection events proved more costly to host and required more time to prepare and staff than anticipated. Adequate funding for future events may affect decisions by local government to host or sponsor such events. The cost to collect and transport used electronic products and related secondary commodities are key to developing a reuse and recycling infrastructure.

In addition, many Minnesota counties outside the metropolitan Twin Cities do not currently have full time staff to administer existing waste-related programs for household hazardous waste, recycling, business generators of hazardous wastes, illegal dumping and other solid waste issues. Any program to address waste electronics that anticipates participation from government must provide adequate funding to accomplish its goals.

Retailers will participate if they see a positive response from customers. Retail sponsors of collection events will want to host such events to increase customer base, present an environmental image to potential customers, or at the very least, not have a negative impact on sales. Each retailer that explores the potential to provide recycling options for used electronic products must evaluate these considerations independently.

Retail stores can provide a significant link. Retail stores can provide a desirable and significant link in the process of moving used electronic products from consumers back to the recycling supply chain. The pilot showed that retail stores can add significantly to public participation to collections. Computer World in Duluth and Circuit City in Burnsville and Maplewood made a significant contribution to the number of people who participated in the demonstration and the total volume of products collected.

Factors that influence consumer participation

Based on the experience of this demonstration project, the following factors will affect participation at collection events for used electronics.

Publicity. The amount and types of publicity used to inform the public about an event will dramatically affect turnout. In large metropolitan areas where planners want to draw upon a specific population, targeted publicity in neighborhood newspapers and bill inserts are effective for getting broad participation without overwhelming event planners and site staff.

Length and location of collection events. Duration of an event, in hours as well as days, will affect who has an opportunity to participate. The more varied the collection hours and the more days the site is open, the greater the potential participation. Events held far from population clusters or sites of interest are likely to have fewer participants.

Consistent messages minimize confusion. The fact sheets and advertising developed for the project carried a consistent message to residents throughout the state. This message, about events as well as about what to do with old products, contributed to the success of regional collection strategies and minimized confusion among the public.

Factors influencing collection of used electronics

Used electronics from businesses and institutions can spur development of a reuse and recycling infrastructure. Used electronic products generated by businesses and institutions tend to have higher value and are more uniform and therefore less time-consuming to process. Better efforts to capture unwanted electronic products from these generators for reuse and recycling may result in lower overall costs to manage electronic scrap and have the potential to further develop the recycling infrastructure for all used electronics.

Reuse of electronics. In order for recyclers to include reuse in their efforts to recover used electronic products, care must be taken in the collection process to prevent damaging products with the potential for reuse. This may add cost to a collection effort.

Minnesota regulations have allowed CRTs and circuit boards to be managed under a Special Waste Pilot Program since 1995, a precursor to the federal universal waste rules for hazardous wastes. This regulatory structure made it easier to manage electronic products in all phases of the demonstration. For example, electronics from collection sites were shipped to the processor under a bill of lading rather than a full manifest.

Transportation. Roll-offs were expedient to use at busy collection sites, but created problems at the processing facilities. The ease of use at the collection site compromised efficiency, value and safety at the processing site. It is difficult to segregate materials when loading roll-offs and can be difficult to unload them. Use of roll-offs may result in more breakage, limiting potential resale of products and presents additional safety issues for the recycler.

Processing efficiencies

Hazardous materials in products will increase the cost to recycle. Based on the vintage analysis of televisions collected during the project, roughly half were manufactured in the 1960s and 1970s and may contain PCB capacitors. Polychlorinated biphenyls (PCBs) are known carcinogens and were phased out of consumer products in the late 1970s. These materials found in older products increase the cost to properly manage products at end-of-life.

Product reuse has the potential to increase revenues to recyclers. Reuse was not a primary objective of this demonstration project. Nonetheless, reuse was employed in the project and has potential to increase revenues to recyclers and significantly improve the economics of recycling used electronics.

Engineering plastics can meet manufacturers' specification standards. Post-consumer streams of engineering plastics can meet manufacturers' specification standards for use in manufacturing new products. Characterization and analysis of the plastics collected in the demonstration project indicated that significant opportunities for recycling exist using modern plastic-plastic separation technology.

Secondary commodities

The cost to manage CRT glass can be reduced. Post-consumer CRT glass utilized by the CRT glass manufacturing sector in the production of new CRTs will have a significant net positive impact on the cost of managing CRT glass by electronics recyclers.

Engineering plastics may add significant value to recycling efforts. Engineering plastics may present the single greatest opportunity for adding revenue to the electronics

recycling process. Three main factors will influence the value of these plastics in future commodity markets: the ability to sort engineering plastics by resin and grade, the ability to meet new product specification standards with post-consumer streams of these plastics, and the ability to aggregate sufficient quantities to meet production schedules set by manufacturers.

Product stewardship and Design for the Environment (DfE) initiatives can have a positive influence on reuse and recycling. Product design improvements may result in more simplified commodity segregation and higher value in secondary materials markets. For example, reducing the use of metallic coatings and paint on plastic parts will make plastics easier to process and should result in greater market demand for the material.

Conducting more DfE will benefit manufacturers as well as recyclers. Other product design improvements with the potential to result in a more sustainable system of use and recovery include:

- Television chassis design has progressed over the years from heavy wooden cabinets to single plastic housings without cross-material contamination.
- Circuit boards have been significantly reduced in size.
- Whole products have been made easier to disassemble through better design for assembly (and subsequent disassembly). This reduces labor costs to refurbish and repair products, reuse parts, and recycle materials.

Commercially viable export markets exist for many secondary commodities. Presently there is strong competition in the market place for EoL electronics and recovered materials, including engineering plastics.

Developing an infrastructure for reuse and recycling for used electronic products

Takeback programs. The collaborative work and results from this demonstration project were the largest factors influencing Sony Electronics to explore and ultimately introduce a program for recycling used consumer electronics. Based on the results of this project Sony is confident that, over time, it will be possible to process and recycle used televisions and other consumer electronics at no net cost.

Televisions. Panasonic and Sony, as the manufacturing partners on the project, and other electronics manufacturers consulted on the project results, were generally surprised by the relatively low cost to process used televisions (see Appendix D). This has been useful for refining the discussion on how to manage used electronic products when consumers no longer want them.

Orphan products. The vintage analysis of televisions indicated that 17 brand names accounted for more than 85 percent of all televisions collected. Of the other 15 percent (other manufacturers), many of the manufacturers no longer exist. These orphan products pose a serious disposal challenge. If future plans for recycling televisions include working with the manufacturer, the problem of these "orphan products" must be addressed.

Recommendations for future action

The following recommendations describe some of what the principal partners agreed on based on what they learned from their collaboration on the demonstration project. These recommendations can be used by public and private entities as they design opportunities to recover electronic products at end of life.

Encourage product stewardship initiatives

Industry efforts to foster voluntary and private sector recycling opportunities for used electronic products will contribute to the development of end-of-life management strategies that are environmentally and economically sustainable. These efforts must include initiatives from the

design stages of products through end-of-life management strategies. Such initiatives may offer alternatives to the government mandates emerging in Europe and elsewhere.

Refine collection procedures

Collecting used electronic products is the most costly step toward reuse and recycling of these products. The best collection strategies will distribute this cost equitably among those who benefit from the manufacture, sale and use of these products. The best collection strategies will meet local needs or will meet the needs of specific types of consumers.

Event sponsors. Fully define roles and responsibilities for all event sponsors prior to commencing with work.

Reuse options. At events where large volumes of used product are collected, providing options for reuse will increase EoL revenues, extend the useful value of products and benefit consumers that may otherwise not have access to products or technology.

Retail collection sites. Six steps will help retail stores interested in collecting used electronic products from consumers for the purpose of reuse and recycling:

1. Define a business purpose and communicate with employees about the effort and why the store is involved.
2. Clearly communicate to customers and participants the purpose of the program and how one can participate.
3. Describe what will be done with the used products that are collected.
4. Display appropriate and visible signage at the store before and during the collection events.
5. Plan for good promotion of collection event.
6. Staff adequately for the collection event, enlisting store personnel, local government staff, recyclers and/or volunteers from local service organizations.

Rural collections. More efficient means of collecting used electronic products will be required in less-populated areas to achieve cost-effective programs. The types of activities that might help include storing material locally to achieve significant volumes before shipment to a processing facility, promoting reuse locally, conducting collection efforts in conjunction with other activities, utilizing volunteers and operating in cooperation with nonprofit or community-based programs.

Reduce transportation costs

Transportation is a critical budget element for any recycling enterprise. In the demonstration project, transportation, packaging supplies and equipment to move used products from the point of collection to the processing facility cost more than anticipated, despite efforts to adequately plan for this phase of the project.

Packaging

Pallets, gaylord boxes and shrink-wrap are expensive to use and offer limited opportunities for reuse. Nonetheless, some sort of packaging is necessary to reduce handling, to maximize hauling capacity and to minimize worker health and safety concerns.

- Future efforts to recycle used electronics must better identify packaging needs in advance.
- Improved packaging supplies and materials can reduce the cost to handle and transport used electronic products through the recycling chain. There is an opportunity to develop a new reusable container type to transport used electronics from the point of collection to processing sites.

Storage

- Barriers that prohibit maximum loads should be addressed at the earliest stages of a temporary or permanent system. Barriers may include inadequate planning, regulation, and inadequate storage capacity near the point of collection.

- Identify storage opportunities at collection sites for product to reduce unnecessary transportation expenses.
- Large trucks employed to move product long distances should not travel with less than 60 percent of full load capacity. (The average truck during the demonstration project moved from collection sites to the processing facility at 28 percent capacity, increasing transportation costs by as much as 60 percent).

Spur recycling market development

Manufacturers and others in the manufacturing supply chain can spur recycling market development for CRT glass and engineering plastics by procuring more of these secondary materials for new product manufacturing.

Reclaimed materials. Manufacturers can contribute to recycling market development efforts by experimenting with reclaimed raw materials from EoL electronics in new product.

Buy recycled, including secondary materials for production and new product with recycled content.

Procurement of recycled materials. Increasing procurement of recycled materials to manufacture new products will require attention to specification standards and greater communication along the supply chain as well as within corporate structures. The flow of information must include designers, manufacturing operations, utilities and maintenance personnel and others

Export markets. Commercially viable export markets exist for many secondary commodities and presently offer strong competition in the marketplace for EoL electronics and recovered materials including engineering plastics. Regulators, recyclers and manufacturers should consider the potential environmental and economic consequences of shipping used electronics overseas, including any long-term environmental and legal significance. Good public policy will require better information about export markets and international environmental concerns.

Improve processing technologies

Evaluation of collection and processing. The collection and processing efficiencies for recycling used electronics, and the resulting costs or revenues, should be evaluated against the efficiencies for other recyclable materials and waste management systems.

Improve recycling technologies. Significant progress has occurred in recent years in mechanical recycling technologies for engineering plastics and CRT glass from EoL electronics. Nonetheless, further development of recycling technologies is necessary to recover higher value from many electronic materials and components.

Commodity specifications. Adopt clear, consistent commodity specifications to assist recovery of secondary materials, especially for post-consumer CRT glass and recovered streams of engineering plastics. Commodity specifications communicate clearly to recyclers about how to process material and can signal manufacturers that quality assurance will be met.

Examine regulatory barriers

Simple, common sense regulations for recycling used electronic products will be welcomed by local government, recyclers and manufacturers alike. They are an important part of developing a viable recycling infrastructure for used electronic products. Such regulations can address governments' environmental protection concerns, while simplifying regulatory operations for legitimate recyclers of used electronic products.

Educate the public

Proper disposal. Efforts to educate the public about the hazards associated with improper disposal of used electronics must also provide clear information about what people can do with used products they no longer want.

Reuse options. The opportunity to reuse older electronic products is time-sensitive, and the longer products are kept or stored, the less likely that they will be reused. Therefore, education about electronic product reuse must encourage consumers to pass products on to new users or intermediaries as soon as the consumer no longer wants or uses the product.

Appendix A
Project Partners

The Minnesota Office of Environmental Assistance (OEA) teamed up with local communities across Minnesota and several industry partners — Sony Electronics, Inc., Waste Management-Asset Recovery Group (WM-ARG), the American Plastics Council (APC), and Panasonic Electric—to collect and evaluate recycling options for used household electronic products. Minnesota is trying to develop sound practices for safely recycling or disposing of old TVs, computers and other used electronic and electrical products and their components. This partnership developed a shared approach for keeping used electronic products out of municipal waste. Through this demonstration project, the OEA is taking a progressive approach, working with major electronics manufacturers and others to get electronic products collected and recycled without relying solely on tax dollars to fund the effort.

Office of Environmental Assistance

Minnesota is in the forefront of addressing the issue of how to safely manage old TVs, computers and other used electronic and electrical products through its product stewardship initiatives with electronics manufacturers. The Minnesota Office of Environmental Assistance (OEA) seeks to help make Minnesota environmentally healthy and economically strong through efficiency in resource use, responsible management of waste, pollution prevention and sustainable practices. The OEA does not regulate or enforce environmental laws, but instead is a service organization that helps businesses, local governments, schools, community organizations and individual citizens solve environmental problems. OEA's information, financial assistance and technical services are available to all Minnesotans to help prevent waste and pollution and conserve resources.

Minnesota Office of Environmental Assistance

The OEA:

- Creates partnerships with local government, businesses, community organizations and individual citizens to advance innovative environmental programs and concepts.
- Works with government, business, and community organizations to develop consensus approaches to achieving our environmental goals and objectives.
- Provides financial incentives with grants and loans to advance implementation of environmentally beneficial processes and prototypes.
- Educates, informs and promotes pollution prevention through print and electronic media, such as the Internet, TV and video.
- Works with trade groups, environmental organizations and educational facilities to identify improvements in the nature and delivery of environmental education.

Throughout Minnesota, the OEA is working to assist local environmental initiatives that bring government, business, residents and other organizations together to further the state's economic and social priorities in an environmentally sensitive manner. For more information about OEA's activities, visit their Web site at www.moea.state.mn.us.

Sony Electronics, Inc.

Sony Electronics, Inc. is headquartered in Park Ridge, New Jersey, and has more than 26,000 employees in the United States and Mexico. Sales in the United States exceeded $12 billion for fiscal year 1999. Sony is the co-developer of CD and DVD technologies, and is noted for such recent developments as the MiniDisc digital audio system, flat-screen FD Trinitron® televisions and computer displays, and a new organic electroluminescent (OEL) display that the company hopes will rival other technologies in retiring the bulk cathode ray tube.

"Taking back and recycling products helps Sony design future devices that cost less to manufacture and help save our precious natural resources. It's a win-win situation."

Sony recognizes that as a manufacturer of consumer electronic products it shares an important role in the overall protection of the environment. Sony's involvement in the Minnesota "Plug Into Recycling" campaign is an example of Sony's commitment to preserve and enhance the quality of life of its employees, customers and neighbors. Sony encourages and promotes environmentally sound recycling of all electronic waste. The company designs, manufactures, labels and packages in a manner that facilitates the recycling of the products once their useful lives are over. For each of the products and components designed, manufactured or sold by Sony, the most environmentally sound end-of-life recycling process and method of disposal is always taken into account.

In October 2000, Sony announced its "We Make It, We Take It," campaign to recycle old Sony products from consumers. The program is designed to leverage government support for collection activities and enlist other manufacturers to join. The five-year vision is to develop a self-sustaining recycling infrastructure where no added costs will be passed only to consumers through higher taxes, fees or sales price. Sony has made a five-year commitment to the program in Minnesota.

Sony's sustainable vision revolves around better-designed products that are made from renewable resources. The use-once model will not work. By developing alternative raw materials streams from post-consumer goods, some of this demand will be offset and eventually profitable for all manufacturers involved. "As we continue to create digital products of the future, we must also realize there is a shared responsibility for the products of the past," said Fujio Nishida, Sony Electronics' president and chief operating officer. For more information, visit Sony's Web site at www.sony.com/environment.

Waste Management-Asset Recovery Group

Waste Management Inc. is the leading provider of comprehensive waste management services. Based in Houston, the company serves municipal, commercial, industrial and residential customers throughout North America.

Waste Management, through its wholly owned subsidiary, Recycle America, operates more than 160 material recovery facilities across the United States. In addition, Waste Management's Container Recycling Alliance operates 12 glass processing facilities. Through its extensive network, Waste Management markets more than five million tons of recycled materials each year and is uniquely qualified to manage recovery and recycling on a national scale.

"By sharing our knowledge of existing and potential consumer markets for these materials we hope to contribute to the development of a mature recycling infrastructure for used residential electronics."

Web site: www.wm.com

Waste Management is the first national solid waste and recycling company to focus on the recovery of electronic scrap. In the past four years, Waste Management, through its Asset Recovery Group (ARG), has opened a network of "e-scrap" facilities across the country that sort and recycle more than 60 million pounds of electronic scrap per year.

Waste Management-Asset Recovery Group's role in this demonstration project included transportation, packaging and processing collected materials.

Panasonic

Environmental preservation is one of the guiding principles of Matsushita Electric Corporation of America (Panasonic). Panasonic and its parent in Japan, Matsushita Electric Industrial Co. Ltd., are engaged in a wide range of initiatives aimed at protecting the environment. These include participation in electronic and battery recycling programs in the United States, Japan, Europe and elsewhere, striving to eliminate potentially harmful materials from the manufacturing process, and producing a variety of energy-saving products and components.

"Panasonic believes that a key component of developing a sustainable end-of-life recycling system for electronic products is the creation of collection infrastructure and markets for materials contained in the products."

Focusing on the need for comprehensive solutions to the challenges of collecting and recycling used electronics products, Panasonic is an enthusiastic sponsor of the Minnesota Office of Environmental Assistance's recycling demonstration project—a groundbreaking attempt to reclaim and return back to commerce materials from discarded electronics products. With its $25,000 sponsorship contribution, Panasonic helped finance public environmental education efforts, while also supporting the processing of collected materials.

A global leader in the design and manufacture of electronic products and components, Matsushita Electric is active in a number of Design for Environment activities, many of which are aimed at making electronic products easier to disassemble and recycle.

The demonstration project was designed to test different collection strategies, as well as foster the development of recycling markets. The demonstration project represented an opportunity to further these two worthwhile and essential goals through cooperation with state and local government, other manufacturers, the recycling industry and raw material suppliers.

Based in Secaucus, New Jersey, Panasonic was established in 1959 and is the principal North American subsidiary of Matsushita Electric. Along with its affiliates, Panasonic recorded sales in North America of $9.2 billion during the fiscal year ended March 2000. The company has more than 6,500 employees. Other affiliated operations employ another 21,500 for a total of 28,000 people employed in the Americas. Additional information is available at www.panasonic.com.

American Plastics Council

The American Plastics Council (APC) is a national trade association representing the plastics industry, particularly plastic resin producers and distributors. Since its inception, APC has worked to demonstrate the benefits and integrity of plastics and to ensure that plastics are a contributor to a safer and cleaner environment.

"APC is pleased to be part of this voluntary partnership looking for the overall best market-based solutions for the life-cycle management of these products. We see this groundbreaking project exploring the limits of today's mechanical recycling technology and seeking information about existing end-markets for these materials." — Mike Fisher, Director of Technology

APC has been particularly active in recent years in developing, implementing and deploying technology for the recovery of plastics from end-of-life (EoL) durable products. APC funded the creation of the first commercial-scale pilot facility for evaluating dry and wet processing technologies to mechanically separate plastics from EoL electronics and automobiles. This facility evolved into a second-generation pilot plant operated by MBA Polymers, Inc. in Richmond, California. As a result of MBA's studies on advanced hydrocyclone technology and high-speed identification methods, there now exist a variety of identification technologies that can detect more than 20 kinds of plastics commonly found in EoL products. APC continues to work with MBA to better understand the recycling challenges associated with plastics from EoL durables and to facilitate the development of viable recycling technologies.

Much of APC's work is in concert with partners from the public and private sectors. From the project, APC hoped to learn more about (1) viable methods for collecting EoL electronics from the residential sector, (2) costs associated with collecting and

demanufacturing EoL electronics, (3) the materials—including plastics—that are present in EoL consumer electronics, and (4) the viability of separating plastics and other materials for sale into recycled products. APC believes that as we learn more about these facets of recycling EoL electronics, the public and private sectors can work together to develop economically and environmentally sustainable recovery programs. APC's Web site is www.plasticsresource.com.

Appendix B
Description of Collection Sites

Northeast Minnesota (Arrowhead Region)

Residential events varying in length from one to nine days were held in August and September throughout the Arrowhead region. Collection sites included recycling drop-off events, HHW sites, transfer stations, landfills and retail parking lots.

Aitkin County. Six-day event, September 20 to 25, 8 a.m. to 4 p.m. at county's permanent recycling center. Advertised in the local newspaper, flyers distributed and posters displayed in public buildings.

Carlton County. Six-day event, September 20 to 25, 8:30 a.m. to 4 p.m. at the county's multi-purpose transfer station, which includes waste transfer and permanent HHW and recycling centers. Advertised in three local newspapers, one of which also ran an article on the project. Posters displayed in public buildings.

Cook County. Six-day event, August 9 to 14, afternoons Monday through Friday and Saturday 9 a.m. to 2 p.m. at county's permanent recycling center. Advertised in local paper and flyers distributed in public buildings and stores.

Itasca County. Three collection events, August 30, September 1 and 3, 9 a.m. to 4 p.m. at county transfer station and permanent HHW facility. Advertised in area newspaper and flyers distributed widely in public buildings and local stores. Transfer station is not centrally located and organizers felt participation was low as a result.

Lake County. An eight-day event, August 6 to 13, 8 a.m. to 3 p.m. held at Two Harbors Recycling Center and at Silver Bay Municipal Garage. Ads placed in three local newspapers, posters and fliers distributed in public buildings and stores, and notices distributed in local utility bills.

Koochiching County. A six-day event, September 13 to 18, with 2-hour events in six locations with varying times. The transfer station in International Falls accepted used products each of the six days, 8 a.m. to 4 p.m. Ads were placed in three area newspapers and on the radio. Staff drove 280 miles to consolidate material for pick-up to be shipped to the processing site in the Twin Cities.

St. Louis County. A six-day event, August 23 to 28, 8 a.m. to 4:30 p.m. at two solid waste disposal locations, the Hibbing transfer station and the regional landfill near Virginia. Posters were placed in public buildings and local stores, ads ran in several local newspapers and two newspapers ran articles. Public service announcements (PSAs) were run in a newspaper, on radio and on public access television. Despite the fact that the program was offered free for the public, sponsors still got several responses from concerned residents who wanted assurances that the material would not be landfilled.

Western Lake Superior Sanitary District (WLSSD). A nine-day event, August 13 to 21, held in the parking lot of Computer World in downtown Duluth during regular business hours for the store. This was the single largest event during the project and accounted for 21 percent of total volume collected. There was extensive advertising locally in newspapers, on radio and on TV, and news coverage included newspaper articles, radio and television news broadcasts and talk show appearances. The enormous success of the program made it difficult to collect surveys. At very crowded events, it is critical that pre-publicity is very clear about who can participate, what they can bring and what will happen to material.

Circuit City Stores

Two retail locations in Twin Cities suburbs (Maplewood and Burnsville) held collections for residential electronics during regular business hours in October. Drop off at retail site, either at service counter in store or at trailer in parking lot on weekends. Circuit City described the collection events as extremely inconvenient and disruptive to its business, and aside from a few customer compliments, not necessarily worthwhile. The store was pleased with the service it got from Waste Management, which picked up loads whenever it was called. The chain was disappointed by the lack of staffing support it received from government and the amount of space it took up in its back room.

Dakota County helped advertise the event at the Burnsville store with flyer inserts in neighborhood newspapers, a press release, distribution of flyers at HHW collection events, other waste-related events and to customers at Circuit City, and by placing other locally run ads in area newspapers. The county volunteered 75 hours on weekends at collection events. The OEA also volunteered 50 hours at the Burnsville site during the month of October.

Hennepin County

Two one-day collection events for county businesses, August 2 and October 4. Businesses were charged $5 fee per computer (defined as monitor, CPU and peripherals). The county ran two ads in local and neighborhood newspapers, including a newsletter distributed by the county to its businesses and a county newsletter sent to all licensed waste haulers in the county. It also sent a postcard to hazardous waste generators in the county notifying them of the events. Businesses participating in the two collection events expressed interest in regularly scheduled collection opportunities for used electronic products. The county also received numerous complaints that the fee was too high, although no one refused to pay.

Houston County

Drop-off events at five staffed county sites for drop-off of recycling and residential garbage. Saturdays and Mondays in August and September. Houston County waste is hauled to neighboring LaCrosse, Wisconsin and incinerated in a waste-to-energy facility there. For that reason, Houston County has been collecting used electronics separately at its various recycling and waste drop-off locations throughout the county for several years. Because county residents are familiar with this program, the county did no additional publicity during the project to test volumes against other collection sites in the state. Houston's collection rate per population was significantly lower than that of other sites that participated in the project.

Neighborhood Energy Consortium

One-day Saturday clean-up events in ten St. Paul city neighborhoods, August 21 to October 16. These collections were held in conjunction with annual neighborhood fall clean-up events where residents can bring all varieties of wastes and problem materials for disposal. Some sites had collected used electronic appliances for a fee in the past, and three sites charged a $5 fee at these events. Quarter-page ads ran in neighborhood newspapers, announcing that old televisions, computers and other used electronics would be accepted at the events.

Northwest Counties

Events in seven counties from August 16 through September. Drop-off events at transfer stations and canister sites. Target generators were residents, small businesses or institutions that are not small quantity generators (SQGs) or large quantity generators (LQGs). In general, each of these sites received strong, positive responses from participants in the collection events.

Beltrami County. Seven afternoon events, every Wednesday, from mid-August to late September, held at the county's privately operated recycling center in Bemidji. Ads ran weekly in the local newspaper.

Cass County. Hosted ongoing collection event at recycling center from August 16 to September 30, and one single-day event in conjunction with a HHW collection event. Extensive advertising in seven area newspapers. Five newspapers published articles about the project and three radio talk shows highlighted the county's participation.

Clearwater County. Ongoing collection event in August and September at demolition waste landfill and transfer station. Products were stored onsite in a roll-off container and transferred to a central site by sentence-to-serve crew. Ads in two area newspapers. Publicity intentionally limited to minimize out-of-county participation.

Crow Wing County. Two weeklong collection events in August and again in September, held at permanent HHW collection site. County delivered collected products to Cass County site for consolidation and transport to processor. Ads in area newspaper and some flyers distributed.

Hubbard County. Ongoing event from mid-August to end of September at area transfer station. Residents found it convenient to bring old products to same location where other waste was disposed of. Bulkiness of product posed a problem and would need to be addressed for any permanent program.

Lake of the Woods County. Ongoing event from mid-August to October 1 at permanent HHW collection site. Strong cooperation from area haulers and public. Articles in two area newspapers and through personal communication with area haulers.

Polk County. Ongoing event from mid-August to September 30 at area recycling center, transfer station and landfill. Ads placed in six area newspapers ran length of project and 30 spots ran on two area radio stations. County delivered collected products to Magnuson Trucking in Bemidji to help consolidate material to ship to processing site.

Southwest Region

Variety of residential collection events held in ten counties from mid-August through September, including single-day to month-long events held in association with existing HHW or recycling collection events and activities. Products from each of the sites were shipped and consolidated at one of two sites in the region prior to transport to processing site near the Twin Cities.

Jackson County. Five one-day collection events in August and September open to businesses as well as residents. Ads and coverage in two newspapers and area radio and television.

Lac Qui Parle County. One-day event, August 18 at city of Madison Fairgrounds. Products were consolidated in a roll-off container and delivered to central location for transport to processing site.

Lyon County. Five one-day events in first half of September as part of mobile HHW collection events. Ads placed in three area newspapers, one of which also ran a story. Fliers distributed at county fair in August announcing events.

Murray County. Ongoing collection event at recycling center during late August. Ads placed in two area newspapers and public service announcement on local radio aired 100 times.

Nobles County. Three-day event in late September at two county highway department locations. Ads placed in three area newspapers and public service announcements placed on three area radio stations, each airing 25 times. Two newspaper articles also ran. Event included help from sentence-to-serve individuals.

Pipestone County. One-day event in city parking lot, August 18. Ads ran in four area newspapers and on local radio. Very positive response from participants.

Redwood County. Up to four-hour collection events in August in each of 15 cities in the county, with drop-off at City Hall and curbside pick-up for elderly. Four newspaper articles described the events, ads ran in seven newspapers and extensive radio coverage included PSAs, ads, talk shows and a news summary of the effort. The effort to help the elderly with special service was well-received and got additional attention for the events.

Renville County. One-week collection in late August at county landfill. Ads placed in four area newspapers.

Rock County. Three one-day collection events at city garages. Local newspaper ran an article in addition to an ad placed, and local radio publicity included ads and PSAs. Fliers were distributed at government buildings.

Yellow Medicine County. Two one-day collection events in September in conjunction with mobile HHW collection event. Ads in two area newspapers and PSA on area radio.

Tri-County Solid Waste Management Commission

Residential events held on Thursdays in September at sites in Benton, Sherburne and Stearns Counties. One-day collection events only for used electronic products at highway garage and transfer stations. This effort accounted for 15 percent of all products, by weight, collected during the demonstration project. Extensive publicity included ads in ten newspapers, two articles and one editorial in the St. Cloud Times, news stories and PSAs on a dozen radio stations, and television coverage on area public access channel. Additional publicity included notices placed in St. Cloud utility bills and various area newsletters.

Washington County

Four one-day drop-off events at HHW mobile collection events in July, August and September. Publicity included display ads in local newspapers and distribution of fliers in public places. Press releases were issued for each event.

Appendix C
Materials Supplied to Collection Sites

Each local collection site host received a packet of materials and information for the collection events, including safety recommendations, a list of accepted materials, a cost and tracking form, and participant surveys.

Safety Guidelines

MINNESOTA ELECTRONICS RECYCLING PROJECT

July – October 1999

Please note: These safety recommendations are compiled from documents from several organizations that currently collect or process electronics with CRTs. They are intended to provide guidance and suggestions only. Please check with your local or county safety procedures or requirements to ensure you are using the appropriate safety measures and lifting guidelines for your jurisdiction.

Handling Electronics

- NO TV or computer monitors with broken glass should be accepted. (If this happens on site, the product CAN be shipped to WM-ARG).
- If TV or computer monitor is dropped and glass from the unit is broken, you should treat the unit as hazardous and call local hazardous waste staff.
- Do not throw CRTs or broken glass as very sharp broken glass shards can ricochet several feet.
- Do not lift heavily damaged or cracked monitors, as they can fall apart and lead to a CRT breaking.
- Personal hygiene is an important safe work practice. If CRTs break, wash hands and face after handling broken CRTs, CRT glass and being exposed to particulates generated from broken CRTs prior to drinking, eating, using tobacco products, applying cosmetics or using the restroom.
- Do not store, use or consume foods, beverages, tobacco products or cosmetics in areas where there is potential exposure to particulates from broken CRTs.
- Always lift properly:

- Get a firm footing
- Bend knees
- Tighten stomach muscles
- Lift with legs, not back
- Keep load close to body

- Use mechanical/vacuum assisted lifting devices or two-person lifts when lifting electronics with CRTs that exceed that which can be safely lifted by one person.

Collection and Storage of Units on Site:

- If generators bring air conditioners or microwaves (they are not supposed to, but they may anyway), do not place with the consumer electronics. Keep them separate and load so that Waste Management-Asset Recovery Group can easily remove and handle these products separately.
- Use common sense in loading pallets or gaylords with equipment—avoid breakage.

- Bulky units should be placed so that they will not fall off, become damaged or cause the load to be unstable.
- Place heavy units on the bottom, if possible.
- Place computer monitors face down.
- Place console TVs upside down on load.
- Shrink-wrap load when full to keep it stable.

Participant Survey Collection Site_____ Date _____

Electronics Collection and Recycling Survey

1. How did you hear about this collection?
   - ☐ Newspaper article ☐ Radio ☐ Flyer
   - ☐ Newspaper ad ☐ Friend/word of mout ☐ Other _____

2. Are your electronics from a ☐ Business or ☐ Residence?

3. What is your Zip Code? _____ Do you live in a house ☐ apartment/condominium/townhouse ☐

4. TV's, computers, and some electronics contain parts that can harm the environment if they are improperly disposed. Who do you think should pay for making sure these products are safely recycled or disposed? *(Choose one)*
   - ☐ Customer/ User
   - ☐ Retail Store
   - ☐ Manufacturer
   - ☐ Government
   - ☐ Other (please list other) _____

5. Why did you stop here today? (*Choose up to two)*
   - ☐ I like the idea of recycling this product
   - ☐ I want to protect the environment
   - ☐ I had no other place to take this product
   - ☐ It was an easy way to get rid of my old electronics
   - ☐ Other _____

6. How can we make it easier for you to recycle your electronics? *(Choose up to two*)
   - ☐ Closer collection site
   - ☐ Longer collection hours
   - ☐ Let me drop off my old product where I buy electronics
   - ☐ Offer regular collection events; every ☐ 1 month? ☐ 6 months? ☐ year?
   - ☐ Provide curbside pick-up of electronics for a fee
   - ☐ No need for improvements
   - ☐ Other _____

7. What items did you bring in today?

Item	How many
TV	
VCR	
Stereo Equipment	
Phone	
Vacuum Cleaner	
Small home appliances (irons, toasters etc.)	

Item	How Many?
Computer central processing unit or hard drive	
Monitor	
Computer Keyboard	
Computer Printer	
Fax Machine	
Other_____	
Other _____	

8. How many more computers and TVs do you have (total- at your home or business)? _____

9. Is this your first time shopping at Circuit City? Yes / No *(Put on Circuit City surveys only)*

Cost and Tracking Form

1999 Minnesota Electronics Recovery Project (ERP)
Site Costs and Program Tracking

County Name _____

Person filling out form _____ Phone: _____

Fax: _____ Email: _____

Collection Description

1. What type of collection did you run?

☐ One day collection(s).
- How many collections did you run? _____
- Dates of collections _____
- Hours of operations _____

☐ Ongoing collection
- Dates of collection_____
- Hours of operation _____

☐ Other (Please describe):

2. Where did you hold your collection(s)? Please check all that apply.

☐ Household Hazardous Waste permanent collection site
☐ Mobile Household Hazardous Waste Unit
☐ Recycling Center
☐ Retail Location
☐ School or other public building
☐ Other (please list) _____

3. Some programs had to bring material to a central site from the actual collection location. Were you responsible for getting materials to a central site? _____

4. If you answered yes to question 3, please describe how the materials were stored and delivered to the final transport truck.

Publicity

5. Please indicate the advertising and publicity that was done for the event, include newspaper articles, newspaper ads, any radio coverage and how you used flyers or other publicity. Check all that apply. Please attach copies if it is appropriate.

a. Newspapers			
Name of Newspaper	Type of Coverage (ad, article, etc.)	Dates of coverage	Size of ad (column inches)

b. Radio Coverage		
Type of Coverage (PSA, ads, talk show discussion, etc.)	Dates of Coverage	Number of times aired

C. TV Coverage		
Type of Coverage (PSA, ads, talk show discuss, news, etc.)	Dates of Coverage	Number of times aired

d. Other Publicity			
Type of Coverage (brochures, fliers, bill stuffers, etc.)	How/ Where Distributed	Dates of Distribution	Total Number Distributed

e. Please describe any other publicity not listed above.

Budget

6. What was your total budget for the ERP collection and related activities?
   - Include the money provided by OEA and other partners.
   - Do not include spending for RFP application and pre-collection kickoff meetings.

Expense Category:	**Cash**	**In kind**	**Total Spent**	**Staff Hours**
a. Publicity				
b. Planning				
c. Collection Equipment (Gaylords, forklift, gloves etc.)				
d. Hauling				
e. Storage				
f. Site and building				
g. Administration/oversight				
h. Collection event staff costs				
i. Other (Please describe)				

TOTAL FOR PROJECT				

7. How much of your budget did you receive from other partners (OEA, etc.) Please list each source and the respective amount:

Partners:	**$ Amount:**
OEA	
other_____	
other_____	
other_____	

8. Were the staff (choices go onto the next page):

- ☐ a. County or city staff? Number of hours?_____
- ☐ b. Private employees (if retailer used own employees at a collection site, for ex.) Number of hours?_____ Hourly rate? _____
- ☐ c. Sentenced to serve? Number of hours? _____ Hourly rate? _____
- ☐ d. Volunteers? Number of hours _____
- ☐ e. Other (Please describe and list hours for each)

9. If you collected a fee for drop off:

a. What was the amount of the fee? _____

b. How much money did you collect from the fee? _____

Your Comments

Please let us know what you thought about and learned from the ERP project:

10. What worked best?

11. What didn't work?

12. What was the feedback from generators/customers?

13. Based on your experience, what recommendations do you have for structuring a program to collect and recycle electronics products in the state? (Feel free to attach more pages).

Questions? Call Tony Hainault at the Office of Environmental Assistance AT 651-296-3417 or toll free 1-800-657-3843

Please return the form to: Office of Environmental Assistance
520 Lafayette Road, North, St. Paul, MN 55155
Fax: 651-215-0246

List of Materials Accepted during Collection Events

Minnesota Electronics Recycling Project (ERP)

July – October 1999

Products Accepted at Collections

- TV
- VCR
- Stereo equipment
- Phones
- Vacuum cleaners
- Small appliances (blenders, toasters, answering machines, etc.)
- Computer monitor
- Computer central processing unit or hard drive
- Computer keyboard
- Computer printer
- Fax machine
- Scanners

Products NOT Accepted at Collections

- Copiers—Not accepted at all

White Goods and Similar Products

- Air Conditioners
- Microwave Ovens

Air conditioners and microwaves should not be advertised for or encouraged, BUT: They can be accepted if someone arrives at your collection site with them. Keep these products separated from all other items collected and place them in trucks or roll-offs so they will be the first item(s) unloaded. WM-ARG will have to pull these products from your load and ship them to a different facility to be managed.

Some sites are working with their local white goods recyclers to be on site to collect items traditionally considered white goods, including microwaves and air conditioners. If this is the case at your collection, please give AC and microwaves to them as well.

You can encourage manufacturer and retailer involvement for rejected products: If generators ask what they can do with their products if you won't take them, suggest that they call the manufacturer or the store where they bought it and ask them what they are going to do to help take care of the product when their customers are ready to dispose of it.

Appendix D
Designing a Recovery System for the Future

The following discussion was prepared by David Thompson, General Manager Corporate Environmental Department of Panasonic Electric Corporation of America. It was delivered at the first joint presentation on the demonstration project by the principal partners, May 10, 2000, to attendees at the International Symposium on Electronics and the Environment (ISEE), sponsored by the Institute of Electrical and Electronics Engineers (IEEE).

The demonstration project results regarding TV recycling show that common Design for the Environment (DfE) principles, improved demanufacturing economics and better end markets for materials will likely combine as we move forward in time to render TV recycling more economically sustainable.

The demonstration project collected 8649 TVs, totaling 776,312 pounds. The cost of demanufacturing these TVs was $22.681 ($2.62 per set), not including WM-ARG overhead and profit. The average weight of each TV set collected was approximately 90 pounds.

These net costs represent the labor, packaging supplies and transportation costs less the value of the materials reclaimed in the recycling markets. Costs incurred, to a large extent, are a function of the older vintage TVs that were collected.

There were two major negative cost components, both of which will improve over time.

- Approximately 179,461 pounds of waste wood cabinetry and wood grained laminated plastics were sent for landfill at a disposal cost of $0.03 per pound.
- 199,350 pounds of CRT glass was sent for lead recovery at a smelter at net cost of $0.045 per pound, versus glass-to-glass recovery at a net cost of approximately $0.02 per pound.

As we move forward in time and collect newer sets for recycling, it seems safe to make the following assumptions:

- A reduction in the waste wood and plastic laminated cabinetry that is sent to landfill (or energy recovery) at a cost and a concomitant increase in black HIPS cabinetry and component parts that are sold into the recycling market at a positive net return to the recycler. In fact the HIPS from the newer sets collected during the demonstration project was sold at net return of $0.06 per pound.
- Increasing market values for the HIPS as the cost of raw materials increase and recycled resin markets grow in scale and efficiency.
- An increase in the amount of CRT glass that is sent for CRT glass-to-glass recycling as the CRT glass recycling industry increases in both cost efficiency and capacity.
- A decrease in demanufacturing time and labor costs.

Improving recycling economics

Here are a few specific examples of how these assumptions may translate into improved recycling economics for used TVs. (All scenarios exclude overhead and profit.)

- **Scenario Number One**
  Assuming a 50,000 pound increase in HIPS associated with the collection of newer TVs and an equivalent decrease in waste cabinetry sent to landfill and a 75,000 pound increase in CRT glass sent for glass recycling would result in the cost of recycling televisions dropping from the $2.62 per set found in this study to $1.92 per set.

- **Scenario Number Two**

Assume an increase of 100,000 pounds in HIPS, an increase of 100,000 pounds in glass-to-glass recycling and a reduction in labor costs of $5,000, based on the fact that newer sets are less time-consuming to demanufacture. These assumptions result in net cost per set of $0.78.

- **Scenario Number Three**

  Assume an additional increase in HIPS recycling of 50,000 pounds, an additional increase in CRT glass-to-glass recycling of 50,000 pounds, an additional decrease in labor costs of $5,000 and finally an increase of $0.04 per pound of recycled HIPS. These assumptions translate into a positive value of $1.38 per set.

While it is difficult at this juncture to say when these assumptions will prove realistic, they do not seem implausible given that the newer sets collected in the project do indeed have HIPS cabinets and are less time-consuming to disassemble. Couple this trend with manufacturers' Design for Environment initiatives, and the above assumptions seem all the more plausible.

Appendix E
List of Acronyms

APC	American Plastics Council
ARG	Asset Recovery Group
CRT	cathode ray tube
CSI	Common Sense Initiative
CPU	central processing unit
EoL	end-of-life
HHW	household hazardous waste
ISEE	International Symposium on Electronics and the Environment
MPCA	Minnesota Pollution Control Agency
OEA	Office of Environmental Assistance
PCB	polychlorinated biphenyl
RFP	Request for Participation
SWMCB	Solid Waste Management Coordinating Board
US EPA	United States Environmental Protection Agency
WM-ARG	Waste Management-Asset Recovery Group

Appendix F
References

Analysis of Five Community Consumer/Residential Collections for End-of-Life Electronic and Electrical Equipment, U.S. Environmental Protection Agency, Region 1, Common Sense Initiative Computer and Electronic Sector, EPA-901-R-98-003, April 1999,

Characterization and Processing of Plastics from Minnesota's Demonstration Project for the Recovery of End-of-Life Electronics, Fisher, Biddle, Hainault, Smith, Cauchi, and Thompson, SPE ARC2000, November 2000.

Minnesota Electronics Recycling Project, a paper presented by the above-mentioned project partners at the International Symposium on Electronics and the Environment, IEEE, San Francisco, May 2000.

Minnesota's Multi-Stakeholder Approach to Managing Electronic Products at End-of-Life, Minnesota Office of Environmental Assistance, Sony Electronics, Waste Management Asset Recovery Group, Panasonic, and the American Plastics Council, 2000.

Plastics from Residential Electronics Recycling: Report 2000, American Plastics Council, 2000.

Recovery of Plastics from Municipally Collected Electrical and Electronics Goods, a summary report of research sponsored by the American Plastics Council and the Materials for the Future Foundation, American Plastics Council, 1999.

---

ii *Management of Waste Electronic Appliances,* Minnesota Office of Environmental Assistance, August 1995; http://www.moea.state.mn.us/plugin/wastelec.pdf.
iii *Analysis of Five Community Consumer/Residential Collections: End-Of-Life Electronic and Electrical Equipment,* United States Environmental Protection Agency, Region 1. Common Sense Initiative Computer and Electronic Sector. EPA-901-R-98-003. April 1999.
iv *Residential Collection of Household End-of-Life Electrical and Electronic Equipment, Pilot Collection Project,* United States Environmental Protection Agency, Region 1, Common Sense Initiative—Computer and Electronics Sector. EPA-901-R-98-002, nd.
v CRT Demonstration Project Report, 1998, Solid Waste Management Coordinating Board, http://www.swmcb.org
vi *Plastics from Residential Recycling: Report 2000,* American Plastics Council, April 2000
vii San Jose, California retail demo
viii CSI, EPA-901-R-98-003, Pg. 4, 73.
ix *Analysis of Five Community Consumer/Residential Collections for End-of-Life Electronic and Electrical Equipment,* U.S. Environmental Protection Agency, Region 1, Common Sense Initiative Computer and Electronic Sector, EPA-901-R-98-003, April 1999, p. 44.
x Hennepin County collected 706 tons in 1998 and 851 tons in 1999. Data for 2000 were not available at the time of this publication. In November 1997, the City of Minneapolis began collecting televisions and computer monitors with its curbside collection service for residents. Prior to that, the county program was only available to residents as a drop-off program at two permanent HHW collection facilities and at one-day event collections held in communities.
xi Joseph Carpenter, Michael Winka. Proceedings of the Air and Waste Management Association 93rd Annual Conference and Exhibition, June 2000.
xii Conversation with Brooke Nash, Massachusetts Executive Office of Environmental Affairs.
xiii It is important to note that we did not have a method to track undercounted participation. Also one could equate participants to households. Many waste and recycling programs, such as local government HHW programs, track participation by household. For this project, there was interest to identify total population served.
xiv *Characterization and Processing of Plastics from Minnesota's Demonstration Project for the Recovery of End-of-Life Electronics,* Fisher, Biddle, Hainault, Smith, Cauchi and Thompson; proceedings of the Annual Recycling Conference of Plastics Engineers; November 2000, Detroit.