Part I: Tools From Industrial Ecology

Yale University Electronics Recycling
1998

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ABSTRACT
The objective of this report is to track the acquisition, use, and discard of computer hardware in the Yale University system and make recommendations for how the university can optimize computer recycling. Computer recycling provides an important environmental service by reducing waste and promoting industrial ecology and sustainable commerce. The proper disposal of electronic waste can prevent the dissemination of harmful toxins contained in hardware, such as lead, mercury, cadmium, and chlorinated plastics.¹

An estimated 79 million computers worldwide were retired from their primary use by 1996, according to the Gartner Group. This year, in 1998, another 31 million PCs will join them, and by 1999 the number will climb to upwards of 42 million. Organizations within the United States are assessing the feasibility of computer recycling and implementing programs. Academic institutions, such as education and research centers, have taken the lead in recycling computer hardware. Computer recycling is an environmentally friendly and crucially necessary growth industry that can be successfully pursued at Yale University. Results indicate that Yale can double the number of computers going to Yale Recycling within the next academic year.

COMPUTER RECYCLING IN THE UNITED STATES
Computer recycling closes the recycling loop and improves economic efficiency as semiconductors, metals, plastics, and other materials are recovered and reused. As an added bonus, computer recycling could prove a profitable venture within the next 2 to 3 years, and will most definitely prove profitable within 5-7 years. According to Colleen Mizuki, an electronics recycling expert, “Of all consumer electronic products, the greatest recyclable value is found in computers” (Mizuki 1996).

Personal computers are more and more deeply integrated into our lives as they find their niche in homes, offices, and classrooms. On average, computers become obsolete and are replaced every four years, filling up warehouses and recycling trucks at an astonishing rate. Monitors have an operating life of 12 years (Mizuki 1996) and may be prematurely discarded. It is estimated that roughly 14 to 20 million computers are retired each year in the U.S., according to a 1995 Tufts University thesis (Dillon 1998). This same study estimates that

¹ The electronics industry uses virtually every type of plastic, including polymeric vinyl chloride (PVC) – a dioxin source when incinerated –, copolymer acrylonitride-butadiene-styrene (ABS), and polystyrene (PS). Many resins are also used, such as epoxies.
nearly 75% of discarded computers are simply stockpiled ("closet-filled"), taking their place on obscure shelves, under Ping-Pong tables, in unused offices, and in hallways. Only 10 to 15% of them will be reused or recycled and 15% end up in landfills. Another study shows that 65% of corporate computers simply become closetfill, 15% are trashed, scrapped, or recycled, 15% are resold, and the remaining 5% are shipped off to schools, charities, or non-profits.

Businesses are starting to understand the value of refurbishing and recycling scrap. In the last few years, thousands of computer reselling and recycling outfits have started up around the country, according to a recent Rand Corporation report. The New York Times notes that 2.4 million used computers were resold last year (Goldberg 1998). Leasing companies such as Comdisco (www.comdisco.com) have average contracts that last less than three years. As a result, they are already starting to sell off old Pentiums by the thousands. Another company, The Boston Computer Exchange, has sold used machines since 1982. As the first used PC broker in the United States, the Exchange is now one of the nation’s largest, with annual sales of $36 million. Onsale (www.onsale.com), another reseller, handles as much or more in live auctions over the Net (Parks 1997).

COMPUTER RECYCLING AT YALE UNIVERSITY
The purchase, use and disposal of computers is decentralized at Yale. Each department or program acts independently, but they all depend upon Yale’s Information Technology Service (ITS) for hardware and software support.

The Yale community operates an estimated 12,000 computers, used by the students and faculty. The average turnover rate is four years, which means that each year, up to 3,000 computers need to be redistributed. That number is growing as Yale continues to “computerize.” As a result of Project X – Yale’s initiative to upgrade University-wide financial and human resources computer systems – even more computers would be exiting from Yale in the short term as Macintosh computers are replaced with the standard Dos/Windows operating platform. These estimations imply that the Yale computer recycling program could significantly increase the number of computers recycled.

Some of these computers are re-allocated within departments, some are stored in closets (closetfill), and others are discarded. Last year (1997), the Yale Recycling Club, an undergraduate student organization sponsored by Yale Recycling, collected and transported 6.3 tons of defunct computer hardware (~127 computers, see Table 1) to a local computer recycler. In effect, Yale sells its defunct hardware at 5 cents a pound.

2 By computer, we mean a CPU, monitor, and keyboard. Associated peripherals, such as printers, are also recycled.
Table 1  Computer Weights

I. Average Weight of a personal computer (PC) by material content

<table>
<thead>
<tr>
<th>Materials</th>
<th>Weight (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastics</td>
<td>25</td>
</tr>
<tr>
<td>Metals</td>
<td>25</td>
</tr>
<tr>
<td>Ceramics</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
</tr>
</tbody>
</table>

II. Average Composition of a PC (percent by weight)

<table>
<thead>
<tr>
<th>Computer Component</th>
<th>Percent by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printed circuit board</td>
<td>10</td>
</tr>
<tr>
<td>Cathode tubes</td>
<td>29</td>
</tr>
<tr>
<td>Cables</td>
<td>5</td>
</tr>
<tr>
<td>Plastics</td>
<td>23</td>
</tr>
<tr>
<td>Other</td>
<td>33</td>
</tr>
</tbody>
</table>

Source: OECD, Washington: Waste Minimization Workshop

Our research indicates that out of 3,000 computers in need of relocation, 2,000 enter the waste stream each year. The Yale community closetfills roughly 50%, dumps 38.7%, recycles 6.3%, and donates 5% of the waste stream. Yale has an estimated 2,000-3,500 closetfilled computers throughout its campus, taking up valuable storage space.

According to Cyril May, recycling of computers has grown tremendously during the 8 years he has worked as Recycling Coordinator for Yale University. During the early 1990s there was little interest in recycling the hundreds of computers discarded from the University every year. The first solicitation that Mr. May received was from a businessman who would accept “dead and dying” computers for a small charge. Now several computer recyclers are operating in the Connecticut area and Yale Recycling, the undergraduate student organization, is able to sell defunct computers at 5 cents/pound (May 1998).

The scale of these cybermorgues ranges from that of Computer Recycling and Refining of Branford, staffed only by full-time owner Armand LaCroix and some part-time help, to Absolute Recycling of West Haven, an operation that dwarfs the average Home Depot, with a 500,000 square foot warehouse. The care it gives to each machine, however, cannot compare with that given by the smaller operation. Even Yale’s computer outflow may be too small and heterogeneous to work effectively with Absolute Recycling.

Last year Yale Recycling delivered 6.34 tons of computers to Computer Recycling and Refining of Branford. Computer Recycling and Refining, Inc.

Note: The Yale Recycling Club did not perform a count on the number of computers recycled in 1997. The average computer weighs 60-100 pounds. We estimate that Yale recycled 127 computers (6.3 tons divided by the conservative estimate of 100 pounds per computer).
evaluates each machine: working machines are resold or donated, malfunctioning machines are fixed or have useful components removed, and the truly dead machines are ground up for precious metals. Lead-containing Cathode Ray Tube (CRT) monitors are out-sourced for disposal overseas, a potentially problematic practice, as regulations abroad may not protect the workers and environment. Most computer recyclers charge a fee ($3-$10) to recycle CRT monitors in line with adequate environmental standards (Mizuki 1996).

Yale University makes direct donations of functioning computers to local non-profits. Daisy Rodriguez, Assistant Secretary for Community Relations in the Office of New Haven Affairs, finds homes for working Yale computers in non-profit organizations including schools, libraries, and community groups (Rodriguez 1998). Similarly, Bill Sacco, Peabody Museum Photographer and “Mr. Fixit” for the Yale Macintosh Users’ Group (YMUG), donates old Macintosh computers, many of which he has personally repaired, to worthy causes. During the summer when the program has additional student helpers, it is able to funnel working computers directly to area organizations (Sacco 1998). The Yale Recycling Club delivers many of these computers.

As a result of this study, the University has established standards described below for choosing when a computer should be recycled or donated.

Yale Recycling asks the community to firmly attach a sign to computers that are left for pickup to indicate whether they are “dead,” malfunctioning, or in working order. This helps tremendously in the triaging process. The only times when the program is unable to provide collection services are winter recesses – typical student “crunch” periods when student workers are too busy working on their own computers to recycle others – and when the truck goes in for repairs. Most of the computers collected, however, are either defunct or too far gone to warrant repair for donation.

For every pound of computer hardware diverted from the garbage bin, Yale saves on its trash disposal or tipping fees. It gives these savings to the student Yale Recycling Club to offset their labor costs. We estimate that Yale realizes $3.00-$3.50 in avoided cost for each computer that is recycled. Valuable resources, such as the precious metals and other computer components are recovered, rather than lost in the waste stream. Computer recycling benefits the environment, improves material flow efficiency, educates students, and establishes Yale University as a leader in applied industrial and environmental services.

**PROJECT GOALS**

To fulfill our research project objective, we established the following four goals:

- To assess and document the current Yale Computer Recycling Program (YCRP). This includes establishing a stock/flow diagram, developing financial balance sheets, and gathering information from students, faculty, administrators, and staff.
• To assess and document the movement of computers through Yale. Computers flow through Yale in a highly decentralized manner. We investigated this flow using individual inquiries of staff, administrators, and faculty, and an email survey.
• To specify five potential options for the YCRP and analyze their relative merits.
• To offer short-term and long-term recommendations to the University regarding YCRP.

PROJECT METHODOLOGY
We surveyed the literature, on-line and in print, for background information. Many individuals in the Yale community were contacted to acquire information about computers and computer recycling at Yale. Cyril May, the Yale Recycling Coordinator, served as our primary staff contact, providing us with detailed information. We also contacted local area computer recycling business managers (Bruce Cafasso, Armand Lacroix, and others), a representative of the University of Massachusetts computer recycling program (John Pepi), and a representative at Tufts University (Patty Dillon), to ascertain the regional computer recycling market. We visited and submitted a draft Statement of Work (SOW) to a local area business, Absolute Recycling Inc., which potentially could offer Yale a higher rate per pound for computers. We contacted environmental regulators at the Connecticut Department of Environmental Protection (DEP) and EPA. We contacted experts to get an up-to-date idea of the state of computer recycling and computer leasing (a viable option) across the nation; Colleen Mizuki at the Microelectronics and Computer Technology Corporation (MCTC), a trade-sponsored corporation, provided abundant and detailed information.

In order to gauge the stocks and flows of computer hardware, we first garnered estimates of computer stocks at Yale from Philip Long at Yale Information Technology Services (ITS). We obtained permission from Daniel Updegrove, the Director of ITS, to email a survey questionnaire to the Super-Users Group (refer to Appendix I). The Super-Users Group consists of computer coordinators in Yale’s individual departments, many of which act as computer purchasers. ITS maintains a Super-Users email list, with 236 subscribers. They document purchases and disposal of computers.

Forty individuals replied, representing 45 Super-Users or 20% of the list. We extrapolated total figures for Yale by multiplying the survey responses by five. We also contacted ITS, Yale Recycling, and other computer-related departments for information. The Yale Purchasing Department and Microcomputer Support Center (MCSC) was contacted to determine the flow of computers into Yale through personal purchases and departmental procurement.
PROJECT RESULTS
Fifty-five percent of the Computer Recycling Questionnaire respondents did not know that Yale Recycling picked up and recycled computer hardware. Respondents indicated that computers are replaced once every four years, on average. Figure 1 demonstrates the fate of non-recycled computers in the past four years. By extrapolation, the survey accounts for a total of 1,430 computers being closet-filled, retro-fitted, donated, or otherwise discarded. Many computers probably remain in departments as hand-me-downs to employees and graduate students.

According to Long’s estimates, 85-90% of undergraduates own machines, representing roughly 4,600 computers. Another estimated 2,400 computers are owned by graduate students. Graduate and Professional School student ownership is harder to gauge (ownership probably varies considerably by course of study from 100% in Yale School of Management to, say, 40% in the Schools of Art or Drama). Additionally, there are roughly 350 computers in clusters throughout the University. Further computer ownership estimates are: 1,600 computers for management and professionals; 800 operated by clerical and technical employees, 560 operated and an additional 1,500 machines in use by faculty and research staff. Long’s estimate comes out to a total of 12,000 computers. This does not include computer support hardware, such as printers and scanners (Long 1998).

Survey respondents reported that their departments operate 2,838 computers. This suggests that Yale, as a total, operates 14,200 computers. The entire Yale community, including personal computers used by students and faculty,
probably ranges between 12,000 to 14,200. If computers are replaced at a rate of one in four per year, then we estimate that Yale departments will need to recycle, donate, or dispose of between 3,000 to 3,500 computers annually. Most departments re-assign computers internally and personal users tend to keep their own computers, so we have lowered this estimate of computer outflows that Yale will need to handle. We set the value of closet-filled and discarded computers at 2,000 per year in our analysis (an estimated 60-100 tons of CPUs and monitors annually). The handling load increases when considering computer peripherals such as scanners and printers.

Gail Tarantino of the Purchasing Department mentioned that her department purchases 2,500 computers annually (Tarantino 1998). In addition to this, the Microcomputer Support Center, which is the department that provides pre- and post-support services on computers coming into Yale, buys approximately 2000 computers (desktops and laptops) a year.

It is difficult to determine the number of computers coming in through schools and departments. While most schools and departments procure computers through the purchasing department and MCSC, a few bought them through such vendors as Micron, Gateway, Dell, Databyte, and direct ordering. Survey respondents indicated purchasing 363 monitors, 349 CPUs, 59 laptops, 125 printers, and 26 scanners in the past year.

Recycling depends upon the recyclability of the product that is purchased; more modular and recyclable designing on the part of manufactures could improve the profits generated from computer recycling in the long-term. When asked if computer recyclability would be a consideration when purchasing, 60% responded in the affirmative, although many individuals emphasized the primary importance of usability and performance.

The fact that only about half of Yale’s computer coordinators knew about computer recycling reinforces our conclusion that Yale can double the amount of computer hardware recycled in the next three years. We include in our recommendations ways in which computer recycling can be publicized.

The compiled stock/flow diagram, (Figure 2) compiles the flow of computers through Yale. This is the first step in any effective computer recycling/hardware management program.
COMPUTER RECYCLING MARKET IN CONNECTICUT AND NEW ENGLAND

As part of our research, various recyclers in the New England area shared with us their perspectives and recent experiences related to the computer recycling business. The market is nascent and volatile. In general, most companies charge a management fee for overseeing a computer/electronics recycling program. Establishing a formal recycling program with some of these companies could involve fees for services, such as inventory, monitor dismantling, miscellaneous equipment, and transportation.

There are plenty of smaller players at this point in the food chain: scrappers and recyclers who disassemble dead computers and separate them into circuit boards, plastic, and steel. Sometimes they grind up whole machines and separate them into ferrous and non-ferrous material. The steel cases go to a metal recycler. Cables go through a refining process that removes the insulation and recovers the copper. The plastic is often landfilled or incinerated as fuel.

PROPOSED OPTIONS

There are five general options that Yale University can adopt when considering its computer recycling program. Some are more feasible and environmentally effective than others.
Option 1: Stop Recycling

Aside from being environmentally negligent and a potential public-relations fiasco, ceasing to recycle computers would place Yale at a disadvantage as the computer recycling market develops and/or if CRT monitors become regulated for their lead content. Yale would pay an extra $476.55 in waste disposal fees that it avoids by recycling.

Option 2: Continue Program with Computer Recycling and Refining Inc.

Yale University receives 5 cents per pound for computer hardware it recycles through Computer Recycling and Refining Inc. and saves money in avoided waste tipping fees. Last year, Yale Recycling recycled 6.34 tons, grossing $1,108.55. The Yale Computer Recycling Program (YCRP) pays student wages at $6.95 an hour, and $120 for the trailer space it uses to store computers before they go to Branford, costing $3,830. In the academic year 1996-1997, Yale paid $2,721.45 to recycle its computers. Table 2 compares the current operating balance sheet for the YCRP with a balance sheet if the number of recycled computers were doubled. We assumed a 1:1 linear relationship between number of computers and work hours. Doubling the number of computers recycled is a realistic goal of this study.

The largest cost ($3,590) for 1996-1997 went to paying student wages for 528 hours of work. A portion of these hours went to recycling non-mandated plastics, another project of the Yale Recycling Club. While our group is investigating the feasibility of higher rates for Yale’s computer hardware through another company (Absolute Recycling), 5 cents an hour is the putative industry standard in the near future (see Table 2). In order for YCRP to break even with current costs, it would have to sell its defunct hardware at $0.25 per pound, a five-fold increase over the current rate. In the short term, for YCRP to be profitable, it should cut costs.

The most effective way for YCRP to cut costs is to reduce the number of student hours it takes to pick-up and deliver computer hardware. With a projected doubling of computers, YCRP would have to reduce the number of work hours from 1,000 to 302 to break even, at the current wage of $6.80 per hour. Student workers report that they could not effectively handle and transport the hardware load in 1/3 the time. However, when we proposed instituting a definite pickup schedule for different areas of Yale University for improved efficiency, Cyril May indicated that this could reduce the number of work hours.

Computer recycling is unlikely to be profitable within the next 4 years; however, as computers are designed for end-of-life recycling and as the computer recycling market develops, the price per pound of computer hardware should increase.
Another way for YCRP to reduce operating costs due is to pay students through the Work Study program. Computer recycling is a valid community service, because the same service transports computers for donation to the community. Computer recycling also shows environmental and social responsibility. Students would actually receive a higher wage, $8.15 per hour, with Yale Recycling paying for 1/2 or $4.07 per hour. In order for YCRP to break even, the number of work hours would have to be reduced to 516 (from an estimated 1,000) or the rate per pound of computer hardware would have to increase to 13 cents per pound (a 2.6 fold increase). These are more realistic goals. If Yale were to receive 8 cents per pound and YCRP work-study student employees worked 713 hours, YCRP would break even, assuming a doubling of the number of computers recycled.

Recycling of computers positions Yale very well for the future. Computer recycling is unlikely to be profitable within the next 4 years; however, as

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### Table 2: Computer Recycling Budget (actual vs. projected)

<table>
<thead>
<tr>
<th></th>
<th>Current Recycling Program A</th>
<th>Option 2 with Doubling of Computers B</th>
<th>Option 2 with New Wage and Doubling of Computers C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wage</strong></td>
<td>$6.80</td>
<td>$6.80</td>
<td>$4.07</td>
</tr>
<tr>
<td><strong>Hours/week</strong></td>
<td>10</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>Hours/year</strong></td>
<td>528</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td><strong>Total personnel/year</strong></td>
<td>$3,590.00</td>
<td>$6,800.00</td>
<td>$4,070.00</td>
</tr>
<tr>
<td><strong>Rental of trailer/year</strong></td>
<td>$85.00</td>
<td>$85.00</td>
<td>$85.00</td>
</tr>
<tr>
<td><strong>Rental of parking/year</strong></td>
<td>$35.00</td>
<td>$35.00</td>
<td>$35.00</td>
</tr>
<tr>
<td><strong>Total storage/year</strong></td>
<td>$120.00</td>
<td>$120.00</td>
<td>$120.00</td>
</tr>
<tr>
<td><strong>Total expenses/year</strong></td>
<td>$3,830.00</td>
<td>$6,920.00</td>
<td>$4,190.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sale of Scrap</th>
<th>Sale of Scrap</th>
<th>Sale of Scrap</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tons recycled/year</strong></td>
<td>6.34</td>
<td>12.5</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Price paid/ton/year</strong></td>
<td>$100.00</td>
<td>$100.00</td>
<td>$100.00</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td>$634.00</td>
<td>$1,250.00</td>
<td>$1,250.00</td>
</tr>
<tr>
<td><strong>Other Income (avoided fees)</strong></td>
<td>$476.55</td>
<td>$853.10</td>
<td>$853.10</td>
</tr>
<tr>
<td><strong>Total income/year</strong></td>
<td>$1,108.55</td>
<td>$2,103.10</td>
<td>$2,103.10</td>
</tr>
<tr>
<td><strong>Total expenses/year</strong></td>
<td>$3,830.00</td>
<td>$6,920.00</td>
<td>$4,190.00</td>
</tr>
<tr>
<td><strong>Net income/year</strong></td>
<td>($2,721.24)</td>
<td>($4,826.90)</td>
<td>($2,086.90)</td>
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</tbody>
</table>
computers are designed for end-of-life recycling and as the computer recycling market develops, the price per pound of computer hardware should increase. Computer recycling experts, and our research, indicate that computer recycling will be profitable within the next seven years. Yale could realize returns earlier if it continues to progress. Yale also positions itself to avoid future costs, as waste tipping fees are likely to increase. Additionally, should the government start to regulate CRT monitors due to their lead content, Yale would already be in compliance.

Option 3: Switch Service Provider to Absolute Recycling
Seeking an alternate service provider is another option Yale University should consider. After researching recycling service providers in the New England Area, we decided to explore establishing a relationship with a large-scale recycler. Conveniently located in West Haven, Absolute Recycling, Inc. represents an attractive option, given the breadth and scale of recycling services it provides.

As a full service recycler, Absolute Recycling, Inc. offers several advantages over the current small-scale program with Computer Recycling and Refining Inc. First, Absolute’s access to its own fleet of vehicles and trailers would reduce Yale’s administrative and economic costs associated with the rental of trailers. Second, Absolute offers several transportation services, one of which hauls trailers to the client’s facilities. This service would reduce the number of student work hours required. Finally, other electronic and medical equipment could be eventually considered for recycling given the breadth of services Absolute Recycling, Inc. provides.

The Sales Manager, Bruce Cafasso, was our primary contact at Absolute. We were able to visit the company’s 500,000 square foot facility one afternoon. Mr. Cafasso mentioned that the value of recoverable computer components varies depending on the make, model, and volume of computers recycled. Volume determines price given that selling 10,000 of a particular component is easier than finding a buyer for limited quantities. He also mentioned that the more expensive the component during manufacture, the more valuable it is at the end of life (e.g., the processor and the display); furthermore, the more modular a component, the less costly it was to recover, as fewer hours were required for disassembly (Cafasso 1998).

Although Absolute cannot be compared to the typical scrap dealer, it performs similar activities. The CPU’s are first scavenged for usable chips; then, the remaining circuit boards are sent to a smelter for the recovery of precious metals, such as gold and silver. Plastic reclamation presents a more difficult problem since the plastics are often in the form of multi-resin laminates or have bits of metal embedded in them. The plastics market, which is cost driven, places a higher value on plastic that is uncontaminated. One computer manufacturer, IBM, has recently begun to address this problem by using more single-resin polymers. Regarding monitors, Mr. Cafasso noted that many are sent overseas to countries in Africa, Asia, and Latin America, where worker compensation is not considered.
An important distinction between Absolute and our current recycler is the method of payment. Yale’s current recycler offers a price based on tonnage – 5 cents/pound or $100/ton. Absolute, however, offers a price based on a computer number and type. Mr. Cafasso stressed that computer components, as commodities, obtain varying prices on the market. As a result, Mr. Cafasso recommended that we list the type of equipment that Yale would consider recycling. Hence, we drafted a Scope of Work (SOW) (see Appendix II) and sent it to Absolute Recycling to determine whether a higher value could be obtained for recycling obsolete computer equipment. Based on the SOW, Absolute would determine its current value on the market. If Yale were to strongly consider implementing the pilot project in the future, the SOW and other documents listed under the in-house recycling option could be used as a framework to further the process. Prior to initiating a program with a new service provider, Yale should ensure that the company is completely permitted.

Yale’s present computer outflow is relatively small and too heterogeneous to represent a profitable opportunity for Absolute Recycling. Absolute is more accustomed to dealing with large business corporations across the country, such as IBM. Therefore, this option should be examined in the medium term. If our predictions are correct, the Yale Computer Recycling Program should be able to significantly increase the number of computers recycled through the program. A larger flow of computers would represent a more significant commodity for Absolute Recycling. More accurate planning numbers could also be determined if Yale established better tracking systems for recycled computers.

Absolute Recycling also expressed interest in participating in future Request for Proposals involving the recycling of commodities such as paper, cardboard, and wooden skids. By increasing the number of commodities recycled through Absolute, Yale could obtain a higher rate of return on its recycling program.

**Option 4: In-house Electronic Recycling**

This option would involve disassembling computers and other electronics in-house at Yale instead of having to sell at a bulk price as currently done through Computer Recycling and Refining Inc. Computer Recycling and Refining Inc. pays $0.05/pound for recycled computer components and salvages the parts for valuable materials (Computer Recycling and Refining, Inc. 1998). Given that computers and other electronic equipment contain valuable materials and some components can still be put to use, Yale could start an in-house recycling program, whereby pieces of electronic equipment could be triaged and their parts segregated and sold separately for a profit. This involves determining the value of recycled components.

Electronic recycling is a relatively new business and we have yet to understand the economies of scale for this sector. Profitability in recycling electronics is highly dependent on the market value of recycled components. We tried to estimate the market value of different components through interviews with
various recycling companies, particularly in the New England area, but it was difficult to obtain specific market values for these goods. The recycling market seems to be affected by a complex array of demand and supply factors.

What Yale could think of doing under this option could be something similar to what the University of Massachusetts (UMass) is currently undertaking. In 1993 Marc Fournier, Waste Manager of UMass, started a disassembling line for electronic equipment called the Intermediate Processing Facility (IPF) as a way to divert additional materials from the university waste stream. He identified a local company, Electronic Processing Associates Inc. (E.P.A, Inc) in Lowell, Massachusetts, and with its help designed a de-manufacturing unit to determine what materials were marketable. According to John Pepi of the University of Massachusetts Waste Management Office, an intermediate on-campus organization called PC Maintenance salvages the electronics for usable components before they actually get to the IPF. The de-manufactured components from the IPF are eventually sold to local recycling companies by bids (Appendix III). The IPF employs students who collect used computers and other electronics from both on the university campus and off (local municipality, organizations, and individuals). A fee of $5.00 is charged for every monitor, $4.00 for other computer components, and $1.00 for keyboards and other small accessories collected outside the campus (Pepi 1998).

The capital cost for establishing the de-manufacturing unit was only $1,000. The facility uses a 13,000 square foot space owned by the University and uses simple equipment such as air-powered screw drivers and other hand tools. The operating cost of the unit is $58,900, which basically covers student labor ($7.00 per hour). The revenue generated from the operation is $4,000. Fifty-five percent of the finance comes from the University and 45% comes from the sale of electronic components to E.P.A, Inc.

The facility at UMass is the largest publicly-owned electronics recycling and processing facility in the United States. By starting such a program, UMass has been able to create new work study jobs for its students, generate revenues from the sale of computer components, create new markets for materials not recycled previously, divert hazardous materials from landfills, and reduce expenses in waste disposal. UMass estimates that recycling and reusing electronics is approximately $10.00 cheaper per ton than landfill disposal ($55.00 in Massachusetts vs. $70.00 in Connecticut).

However, according to Mr. Pepi, the program at UMass is actually not profitable. He said that the revenue generated from the sale of electronics merely offsets the cost of operating the facility (collection, labor, hauling, electricity, etc). But Mr. Pepi was very optimistic about the program despite the poor rate of return. The authors of this project share Mr. Pepi’s view that although the program is not profitable, it is worth pursuing, especially since UMass is a non-profit organization.

There are major environmental benefits in recycling and reusing electronics. These benefits are difficult to quantify and therefore are left out of the cost.
benefit analysis. There is also the salient issue of liability. Electronic equipment is comprised of various heavy metals (e.g., lead, cadmium, mercury) and chemicals that are highly toxic to humans and the environment, and therefore increase the risk of being a potential health and safety hazard if disposed of improperly. Recycling and reusing electronic equipment reduces the risks of future liability of an organization that is involved in the disposal of such wastes.

Based on the above discussion, we feel that the establishment of an in-house de-manufacturing unit similar to the one at UMass would be a feasible option. The following are some of the pros and cons of this option for Yale University. As Project X continues to publish standards for Yale’s departmental desktops, the number of computers dumped, abandoned, or picked up by the Yale Recycling Program is going to increase as users are forced to upgrade. This means most computers will either go to Computer Recycling and Refining Inc. as it is now, or will be donated or passed down to staff. Eventually, however, all these computers will be trashed or recycled. Hence an in-house recycling program would be a feasible option. Computers are already piling up in basements and hallways and causing fire hazards and obstacles to exits. Yale is losing money by having to 1) rent trailer space to store dead computers, 2) pay students to move the computers from one site to another, and 3) dump the computers for a nominal return. Conversely, Yale would save money by instituting a system whereby the computers were picked up, triaged, and moved out.

It is also possible to donate usable computers and equipment to the community to enhance town-gown relations. Additionally, students have expressed their interest in having a computer recycling program as part of the Green Plan (the University’s environmental plan). Such a program not only provides employment for students but also provides training in computer de-manufacturing.

With the growing recognition of the concept of industrial ecology (and therefore design for environment), the electronic industry will, in the near future, design products such that de-manufacturing is easier and less time consuming. Computer recycling will also reduce pressure on virgin materials and therefore help in conserving natural resources (e.g., energy and reduction in waste generated). Finally and most importantly, by implementing an in-house de-manufacturing unit, hazardous metals and chemicals will be diverted from the normal waste stream, thereby eliminating future liability cost to Yale. Therefore, an in-house recycling program is an option that Yale University could consider in the near future.

There are disadvantages in establishing an in-house recycling unit at Yale, however. Recent changes in technology in the electronics industry have reduced the use of valuable waste materials. Therefore, there is not as much incentive to recycle. However, as resources get scarce, the value of current computer components will increase. Given this future trend, it is likely that recycling will still be a profitable business. Space will be a problem for Yale. Yale
will have to rent a space to store all the dead and unused computers. The location should be accessible to delivery trucks.

Yale may want to explore incubating or inviting the establishment of an electronics recycling company in Science Park as a viable alternative to an on-campus departmental facility.

Currently, there are no federal or state regulations governing the recycling of electronics. In the absence of stringent regulation, there is less incentive to recycle and reuse. In addition, the current computer recycling market is not very well established, and therefore it is difficult to predict the costs and benefits of recycling.

Option 5: Explore Computer Leasing

Leasing is quickly becoming the procurement method of choice for many organizations. According to the IBM Credit Corporation, more than 50% of computer equipment in the United States is acquired through leasing programs. Leasing offers several technological and environmental advantages.

The first advantage offered by leasing is that it hedges against obsolescence. Experts note that due to rapid technological advance, a computer can lose up to 80% of its value within a year of purchase. Thus, in order for Yale to maintain the most current computer technology, it would be more financially efficient to establish a leasing program, which allows the option of system upgrades. When a better system comes out in the middle of the contract, some leasing plans offer the option of allowing upgrades on a timetable that would fit the organization’s needs. Any upgrades would entail additional costs, but those costs would most likely offset the costs of purchasing and disposing of computers every 3-4 years. Leasing also offers the advantage of flexible contract terms.

Environmental advantages are also important to consider. Yale University would not have to worry about the potential hazards associated with the disposal of computers, as they would be returned to the manufacturer or leasing firm at the end of the contract term. Hallway and basement space that is currently occupied by obsolete computers could become available for other purposes and pose less fire hazard risk.

More importantly, leasing promotes the recycling and reuse of computers and their components. As computer leasing becomes popular, a larger number of leased computers of the same models and of similar quality would be returned to computer manufacturers. This characteristic of leasing could reduce the contamination problem of recyclable materials. The manufacturer also could take advantage of the economy of scale. By incorporating design for environment (DfE), computer manufacturers could design computers so that they are more easily dismantled and recycled, or upgraded and reused. For example, Dell Computers started a leasing program a couple of years ago. As computers come off of lease, they are resold (often with some upgrade) or de-manufactured and recycled for material recovery. As increasing numbers of

*Experts note that due to rapid technological advance, a computer can lose up to 80% of its value within a year of purchase. Thus, in order for Yale to maintain the most current computer technology, it would be more financially efficient to establish a leasing program, which allows the option of system upgrades.*
leasing contracts come to term, computer manufacturers will need to place greater emphasis on end-of-life considerations. Rapidly changing technology is a challenge faced by the computer manufacturing industry.

Yale University could take advantage of its purchasing power to obtain better leasing rates if the program were administered through a single channel. Preferably, the leasing program would be administered by a central organization on campus, like the Micro Computer Support Center. The MCSC has examined leasing options in the past, but was unable to pursue them due to legal issues surrounding Yale’s non-profit status. However, the MCSC noted it would be willing to reconsider leasing, if presented with new options.

Ownership mentality is one obstacle to a leasing program that needs to be overcome. Since most people tend to place higher value on owning personal goods, such as computers, it might be more difficult to persuade departments and individuals to give up ownership rights and switch to leasing. However, a flexible leasing program might overcome this ownership tendency as the reward of upgraded technology outweighs the non-ownership costs.

RECOMMENDATIONS

The computer recycling program at Yale University has successfully evolved in the past three years to fill a much needed niche. With this report, we hope to guide Yale towards making computer recycling profitable and more effective, in terms of the number of computers recycled, recycling efficiency, and environmental performance. The demand for computer recycling is growing and it is currently met by an unstable supply, mostly because computers are not designed with disassembly in mind. Manufacturers have not traditionally thought about the end-of-life of their products, or the potential value of re-using or breaking down defunct hardware – a recurrent theme in the modern-day effort to integrate ecological principles of materials flow and sustainability into the human system. Computer recycling is a growth industry.

The best option in the short-term is Option 2 above, to continue the current computer recycling program, with some improvements. The three key components in the short-term (1 year) are (a) awareness and publicity (b) reduction of student labor hours per computer recycled and (c) better tracking of computer hardware through the Yale system.

According to our survey, less than half the respondents knew that Yale recycles computers. This observation points toward the feasibility of significantly increasing the number of computers recycled, especially if a portion of the large number of closet-filled computers (an estimated 2,000-3,000) are recycled.

The responses of individuals to our survey demonstrated considerable confusion about the nature of computer recycling. A few respondents thought that computer recycling meant re-use by another user, not the disassembly and sale of the component parts. The fact that people closetfill computers demonstrates an understanding of the wastefulness of throwing computers away. In other words, reflex sentiments support computer recycling, especially
if it benefits Yale financially. Publicity is a crucial early step to strengthen computer recycling at Yale.

Faculty, staff, administrators, and students need to know who to call to recycle their broken or defunct equipment. Yale Recycling already publicizes and handles a heavy workload. However, we recommend that Yale Recycling (a) advertise computer recycling at the Staff Orientation Day fair, (b) put signs up at MCSC and the Repair Unit, (c) pursue a computer hardware drop-off day, and (d) investigate other publicity channels. The ITS Super-Users group could receive two standard emails per semester from Yale Recycling, one at the beginning of the semester to establish contact information, and one at the end to inform users of the progress of hardware recycling. Undergraduate Computer Assistants, university-paid troubleshooters, could also receive computer recycling contact information as a part of their yearly training.

We recommend obtaining a copy of the baseline report on electronic product recovery and recycling in the United States produced by the EPR2 Project (Electronic Product Recovery and Recycling). The baseline report addresses the volume and nature of equipment currently being recovered and recycled; the nature, size, and distribution of recycling and de-manufacturing facilities in the United States today; projections for equipment turnover in the coming decade; and the market for key materials.

The evaluation of Option 2 (continue the current recycling program) pinpoints labor costs as the primary reason that the YCRP operates with a yearly fiscal net loss. The section above discusses this in greater detail, but it is important to reiterate that the Yale Recycling Club could take steps right now to approach profitability. However, we feel strongly that profitability cannot be the sole criterion when evaluating the merit of computer recycling, especially given the immature nature of computer recycling in general. Computer recycling clears space used up by closetfill. It also positions Yale well for future regulations and/or markets.

We recommend that the Yale Recycling Club maintain a log-book for the computer hardware that is recycled. Finer resolution of the hardware that is going to recycling could be used to leverage better financial arrangements with recyclers in the future. The School of Forestry & Environmental Studies, Yale Recycling, or another element of Yale University should continue to refine the computer hardware flow/stock diagram that we have developed.

The best option for the medium-term is Option 3. The three key components in the medium-term (2-3 years) are (a) switching the computer recycling company that handles Yale’s defunct hardware (push for 8 cent/pound rate) (b) conducting further self-assessment and investigation of the external computer recycling market and (c) using Yale’s stature as a premier educational institution as a forum for computer recycling and a method for obtaining advice from experts using Yale’s program as a case example. We believe that in the medium-term, Yale can double the number of computers it donates to the New Haven community. The merit of maintaining the Yale Computer Recy-
cling Program will become more apparent as the market develops and/or CRT regulations begin to accumulate.

The prevalent options in the long-term are Options 4 and 5. There are three key components in the long-term (4+ years) for computer recycling. They are (a) to establish an in-house electronics recycling program (b) to foster an electronics recycling outfit at Science Park and (c) to pursue computer leasing. Computer recycling will probably become more profitable in the long-term as design-for-end-of-life is implemented and new recyclable materials are manufactured.

CONCLUSION
In order for industrial ecology to be feasible, its methodology must be able to encompass complex products. Source materials for computer hardware are highly heterogeneous because computers are the ensemble of literally hundreds of intricately designed and manufactured products. The pace of technological change in the industry further complicates the challenge of incorporating industrial ecology concepts, such as design for the environment and product take-back-design for end-of-life. Computer recycling represents the first step in the transformation of a complicated industry into a more sustainable and environmentally responsible venture. Yale’s Computer Recycling Program is already an unwitting leader in this effort. With the use of industrial ecology, Yale University can achieve far more.

REFERENCES


FURTHER INFORMATION


Amore, Dawn. Senior Program Leader, Environmental Health Center, A Division of the National Safety Council, Washington, D.C. Personal communication.


http://www.compaq.com/resellers/capital/smb/qa.html


Epix Internet Services. http://enviro@epix.net


http://www.computer.financing.com/why.html

MacRae, Katy. Computer Repair Unit, Yale University. New Haven, Connecticut. Personal communication.


Preserving Resources through Integrated Sustainable Management of Waste.

http://www.wrfound.org.uk/wrftbmrft.html#top


The Super User Group (a list of computer personnel at Yale University). Yale University. New Haven, Connecticut. Email survey interview.


http://www.cs.cmu.edu/afs/cs/usr/sdx/www/used-computer-equip.html

APPENDIX I  Questionnaire for the Survey on Computer Recycling at Yale

(Please use additional sheets if necessary).

TO:  Libraries
     Information Directors of Departments in Schools and Colleges

1. Do you know Yale has a Computer Recycling Program that helped recycle 6.3 tons of computer hardware last year?
   □ Yes  □ No
   a. If Yes, how many computers has your department channeled through them? ________
   b. What else do you do with your old computer hardware? (please provide numerical estimates)
      □ Closet-fill ________  □ Retrofit (i.e. email Kiosk) ________
      □ Donate ________  □ Others ________

2. How many computers are currently in use in your department? (give an estimate)

3. Do you expect this number to increase in the future?
   □ Yes  □ No

4. What is the average turn-over for computers/How long are they used?

5. Do you buy your computers through Yale’s Micro-Computer Support Center (MCSC) or directly from a distributor? If not, where do you buy them?

6. How many computers do you buy in a year? (If purchasing is through multiple routes, please indicate source; for instance: 10 monitors – 5 MCSC, 5 non-Yale).
   □ Monitors ________  □ CPUs ________
   □ Laptops ________  □ Printers ________
   □ Scanners ________  □ Other ________

Bonus Question:
Would computer recyclability ever be a purchasing consideration in your department?
APPENDIX II  Yale Computer Recycling Project

DRAFT STATEMENT OF WORK
as of 4/20/1998

1. Task Order Title: Computer Recycling Pilot Project

2. Background: As part of an Industrial Ecology course project at the Yale School of Forestry & Environmental Studies, we are investigating the computer recycling market in the New Haven Area. In particular, we wish to determine whether it is economically feasible to continue and expand the current computer recycling program at Yale. At present, the Yale Computer Recycling Program collects approximately 300 computers (CPU and monitor) per year. Based on a recent computer recycling survey conducted at Yale, we estimate that we may double the number of computers channeled through the program within the next year. This is based on the fact that many respondents were unaware of the existence of a Yale computer recycling program and a significant number of them expressed willingness to participate in the program in the future. Consequently, we plan to achieve a significant increase in computer recycling via increased publicity and more accurate computer outflow record keeping. Therefore, we wish to examine the possibility of establishing a Computer Resale and Recycling Pilot Project with Absolute Recycling and assess the economic value of implementing such a project.

3. Objectives and Length of Pilot Program: We wish to obtain a cost estimate from Absolute Recycling, Inc. regarding recycling and disposal services for computers that enter Yale’s recycling program over a 12-month period. These services could include any of the following activities: refurbishment, resale, recycling, and smelting activities. The cost estimates should include all labor, supervision, equipment, vehicles, premises, license fees, and costs necessary to perform the service.

4. Scope: In order to assess a value on the program, we are providing a list of commodities that would be channeled through the computer recycling pilot project. Given the decentralized process of computer purchase and disposal within Yale University, it is extremely difficult to determine such a number; therefore, the numbers listed below represent our best estimates for a twelve month period.

<table>
<thead>
<tr>
<th>Component</th>
<th>Estimated numbers</th>
</tr>
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<tr>
<td>Monitors</td>
<td>300</td>
</tr>
<tr>
<td>CPU Model</td>
<td></td>
</tr>
<tr>
<td>286</td>
<td>200</td>
</tr>
<tr>
<td>386</td>
<td>100</td>
</tr>
<tr>
<td>486</td>
<td>50</td>
</tr>
<tr>
<td>Keyboards</td>
<td>50</td>
</tr>
</tbody>
</table>

5. Specific Tasks: Below is a list of the tasks associated with establishing the subject project with Absolute Recycling, Inc. This is not a comprehensive list, rather it is a preliminary task list that should be viewed as a tool to help factor all costs associated with implementation of the pilot project.
TASK 1. STORAGE AND TRANSPORTATION:
Absolute Recycling, Inc. will provide trailers for placement of the computer equipment collected by Yale. Yale will contact Absolute each time trailers are nearing capacity. Based on current program figures, these calls will occur on average every three weeks.

TASK 2. COMPUTER COMPONENT VALUATION:
Upon receipt of the commodities, Absolute will inspect all units for the possibility of resale. Units with no value will be sent to the dismantle line, where they will be sorted into the proper material streams for recycling. Units that have possible resale value will be further inspected and tested for resale. Yale understands that upon further inspection, some additional units will be also be sent for dismantling.

TASK 3. TABULATION OF RESULTS AND DISBURSEMENT OF FUNDS:
Absolute will provide a monthly tabulation of results that includes number of monitors, CPUs, keyboards, and their corresponding weight figures. Based upon those figures Absolute will disburse the corresponding funds to Yale University.

6. Other Pertinent Information or Special Considerations:
Permits
Prior to the implementation of the subject project, Yale would require Absolute Recycling, Inc. to secure and maintain all licenses and/or permits as required by federal, state, or city government for the duration of the project. In addition, Absolute Recycling should be able to provide a Certificate of Destruction upon request, as well as proof that all materials are being sold or otherwise transferred by Absolute Recycling to a recycling facility.
## APPENDIX III


<table>
<thead>
<tr>
<th>Recycling Firm</th>
<th>Address</th>
<th>State and Zip</th>
<th>Telephone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Recycling, Inc.</td>
<td>477 Elm Street, P.O. Box 26184, West Haven</td>
<td>CT 06516</td>
<td>203-932-2422</td>
</tr>
<tr>
<td>Absolute Computer Resource</td>
<td>155 Research Drive, Stanford</td>
<td>CT 06497</td>
<td>203-380-4600</td>
</tr>
<tr>
<td>Colt Refining, Inc.</td>
<td>12 Baer Circle, East Haven</td>
<td>CT 06512</td>
<td>203-466-2658</td>
</tr>
<tr>
<td>Computer Recycling and Refining</td>
<td>27 Ciro Road, Branford</td>
<td>CT 06471</td>
<td>203-488-1535</td>
</tr>
<tr>
<td>Handy &amp; Harman</td>
<td>Precious Metal Refining Division, 300 Rye Street, South Windsor</td>
<td>CT 06074</td>
<td>203-289-4327</td>
</tr>
<tr>
<td>Boston Computer Exchange</td>
<td>210 South Street, Boston</td>
<td>MA 02111</td>
<td>617-542-4414 ext. 110</td>
</tr>
<tr>
<td>The Boston Computer Society</td>
<td>101 A First Street, Waltham</td>
<td>MA 02154</td>
<td>617-290-5700</td>
</tr>
<tr>
<td>Duseau Waste Industries</td>
<td>129 Elm Street, Hartford</td>
<td>MA 01038</td>
<td>413-586-4100</td>
</tr>
<tr>
<td>East-West Foundation</td>
<td>23 Dry Dock Avenue, Third Floor, Boston</td>
<td>MA 02110</td>
<td>617-261-6699</td>
</tr>
<tr>
<td>Development Foundation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational Assistance Limited</td>
<td>Boston</td>
<td>MA 00000</td>
<td>617-542-1234</td>
</tr>
<tr>
<td>E.L. Harvey &amp; Sons, Inc.</td>
<td>P.O. Box 1243, Westboro</td>
<td>MA 01581</td>
<td>508-836-3000</td>
</tr>
<tr>
<td>Electronics Processing Association, Inc.</td>
<td>133 Congress Street, Lowell</td>
<td>MA 01852</td>
<td>508-970-2700</td>
</tr>
<tr>
<td>Electric Recyclers</td>
<td>Shewsbury</td>
<td>MA 01852</td>
<td>508-842-3612</td>
</tr>
<tr>
<td>EPA</td>
<td>Foundry Industrial Park, 1A Foundry Street, Lowell</td>
<td>MA 01852</td>
<td>508-970-2700</td>
</tr>
<tr>
<td>Gordon &amp; Co.</td>
<td>P.O. Box 893, Westborough</td>
<td>MA 01581</td>
<td>508-480-9370</td>
</tr>
<tr>
<td>IPL Environmental Products</td>
<td>Worcester</td>
<td>MA 01581</td>
<td>416-931-6061</td>
</tr>
<tr>
<td>Molten Metal Technology</td>
<td>508 South Street, Holyoke</td>
<td>MA 01801</td>
<td>617-487-7634</td>
</tr>
<tr>
<td>Monico Inc.</td>
<td>Lowell</td>
<td>MA 01581</td>
<td>413-522-3710</td>
</tr>
<tr>
<td>Omni CEO, Inc.</td>
<td>Cambridge</td>
<td>MA 00000</td>
<td>508-937-5004</td>
</tr>
<tr>
<td>Polaroid Corporation</td>
<td>Bedford</td>
<td>MA 00000</td>
<td>607-577-4106</td>
</tr>
<tr>
<td>Pre-Owned Electronics</td>
<td>21 First Street, Pittsfield</td>
<td>MA 00000</td>
<td>800-247-5343</td>
</tr>
<tr>
<td>Recompute</td>
<td>337 Summer Street, Boston</td>
<td>MA 01201</td>
<td>413-496-9846</td>
</tr>
<tr>
<td>Rentax, Inc.</td>
<td>1A Foundry Street, Lowell</td>
<td>MA 00000</td>
<td>800-545-2313</td>
</tr>
<tr>
<td>RST Reclaiming Co., Inc.</td>
<td>61 Ward Hill Road, Haverhill</td>
<td>MA 01852</td>
<td>978-453-3425</td>
</tr>
<tr>
<td>SAR</td>
<td>207 Marston Street, Lawrence</td>
<td>MA 01835</td>
<td>508-374-0666</td>
</tr>
<tr>
<td>Tombarello Recycling, Inc.</td>
<td>Medford</td>
<td>MA 01841</td>
<td>508-682-5226</td>
</tr>
<tr>
<td>Tuft University</td>
<td>Office of Waste Management, Box 36710, Amherst</td>
<td>MA 01841</td>
<td>617-627-3113</td>
</tr>
<tr>
<td>University of Massachusetts, Intermediate Processing Facility</td>
<td>15 Medford Street, Lawrence</td>
<td>MA 01003</td>
<td>413-545-4386</td>
</tr>
<tr>
<td>Windfield</td>
<td>1627 Straight Path, Wheatley Heights</td>
<td>MA 01841</td>
<td>508-689-2470</td>
</tr>
<tr>
<td>Alco Refiners</td>
<td>280 Water Street, Suite 5A, Newburgh</td>
<td>NY 11798</td>
<td>609-234-6156</td>
</tr>
<tr>
<td>Electronic Resource Recovery</td>
<td>P.O. Box 550, New Paltz</td>
<td>NY 12550</td>
<td>914-561-1900</td>
</tr>
<tr>
<td>Hudson Valley Material Exchange</td>
<td>29-11 Queens Plaza North, Second Floor, Long Island City</td>
<td>NY 12561</td>
<td>914-255-3749</td>
</tr>
<tr>
<td>INWRAP Materials Exchange Program</td>
<td>118 East 25th Street, Suite 10-A, New York</td>
<td>NY 11101</td>
<td>718-786-5300</td>
</tr>
<tr>
<td>Nacomex (National Computer Exchange)</td>
<td>130 East Merrick Road, Freeport</td>
<td>NY 10010</td>
<td>800-622-2239</td>
</tr>
<tr>
<td>Re-Used Goods</td>
<td>Hallstead</td>
<td>NY 11520</td>
<td>516-223-2522</td>
</tr>
<tr>
<td>Envirocycle, Inc.</td>
<td></td>
<td>PA</td>
<td>800-711-6010</td>
</tr>
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**CAMPBELL ET AL.**

**YALE F&ES BULLETIN**
APPENDIX IV  Items Included in the Computer Scrap and Dismantling Category

1. ITEMS INCLUDED IN THE COMPUTER SCRAP AND DISMANTLING CATEGORY

1. Scrap Whole Computers: Scrap whole computers consist of whole, un-dismantled PC or mainframe computer systems.

2. Scrap CPU Units: Scrap CPU units consist of whole, un-dismantled CPUs (Central Processing Units), free of monitors or keyboards.

3. Populated Circuit Boards: Populated circuit boards consist of whole circuit boards will all components still attached (the term “populated” refers to the components “living on the board” i.e. ICs, Capacitors, etc).

4. Circuit Boards (sheared flush): Circuit boards (sheared flush) consist of unpopulated circuit boards or circuit boards that have had all the components removed either by manual dismantling (de-soldering) or by means of shearing the components off so that the surface of the circuit board is “sheared flush.”

5. Soldered Circuit Board Trimmings: Soldered circuit board trimmings consist of trimmings or rejects from new etched (solder coated) copper clad circuit boards.

6. Finger Trimmings: Finger trimmings consist of gold-plated trimmed “male” cookout board connections trimmed in such a fashion as to remove any excess non-gold content materials, trimmed as close to the gold as possible.

7. Mixed Scrap Integrated Circuits (IC chips): Mixed scrap integrated circuits contain assorted integrated circuit chips, whole or sheared from populated circuit boards, free from other types of components. May include ceramic or balolite covered chips.


9. Scrap Capacitors: Scrap capacitors consist of whole or recovered capacitors. Must be primarily tantalum capacitor materials. May include sorted capacitors from populated circuit board shearing.

10. Mixed Components (sheared or dismantled): Mixed components consist of assorted electronic components recovered from dismantling or shearing populated circuit boards. Must be free of shredded circuit boards or trimmings of circuit boards.

11. Unclipped Internal Wires and Connectors: Unclipped internal wires and connectors consist of wires and connectors attached to wires from the interior of the computer. May include ribbon wire and fine plastic insulated wires (may not include double insulated wires).

12. Clipped Internal Wires: Clipped internal wires consist of wires from the interior of the computer. May include ribbon wire and fine plastic insulated wires (may not include double insulated wires). Must be free of all connectors.

13. Unclipped External Wires and Cables: Unclipped external wires and cables consist of wires and cables with connectors still attached. May include double insulated wires.

14. Clipped External Wires: Clipped external wires include all sorted trimmed computer wires and cables free of connectors and attachments. May include double insulated wires.

15. External Connectors: External connectors consist of sorted connectors, free of wires.

16. Transformers and Transformer Windings: Transformers and transformer windings consist of sorted copper wire coils on cores, free of attachments.
17. Scrap Drives: Scrap drives consist of assorted hard drive units or floppy drive units.
19. Scrap Printers: Scrap printers consist of whole scrap printer units.
20. Scrap Plastic (computer shells): Scrap plastic consists of sorted clean plastic shells or outer cases of computers, video display units, keyboards, or printers. Must be free of metal (including screws) and other foreign materials.
21. Assorted Scrap Computer Plastics: Assorted scrap computer plastics consist of any part of the computer system made of any grade of plastic, sorted and free of metal or other non-plastic materials.
22. Scrap Floppy Disks: Scrap floppy disks consist of assorted used or unuses 3.5' or 5.25' floppy diskettes.
23. Scrap CDs: Scrap CDs consist of assorted used or unused compact disks.
24. Scrap Monitors (VDT): Scrap monitors consist of whole Video Display Terminals which contain a Cathode Ray Tube in a shell or case.
25. Other Computer Scrap: Other computer scrap contains miscellaneous computer scrap materials not included in the listed grades.

II. USED COMPUTER ITEMS CATEGORY:

- Used Home Computer Systems
- Used Commercial Computer Systems
- Used Computer Parts
- Used Printers
- Used Printer Parts
- Used Monitors
- Used Keyboards
- Used Disk Drives
- Used Computer Software
- Used Computer Manuals
- Used Computer Furniture
- Other Used Computer Items

III. ITEMS INCLUDED IN THE CRT (CATHODE RAY TUBE) RECYCLING CATEGORY:

1. Whole VDT/TV Scrap: Whole VDT/TV scrap consists of whole, assembled computer monitors, video display terminals (VDT) and television sets suitable for dismantling (uncrushed/broken); suitable for CRT recovery.
2. CRT Scrap: CRT scrap consists of scrap, whole or broken Cathode Ray Tubes; may contain cores and windings but must be free from metal and plastic frames.
3. 1/8” Recovered CRT Glass (Andela #16): Recovered CRT glass consists of Cathode Ray Tube glass processed and sized to minus 1/8” inch. Must be free of cores, metal windings, and other foreign materials. This is equivalent to Andela #16.
4. 3/8” Recovered CRT Glass (Andela #17): Recovered CRT glass consists of Cathode Ray Tube glass processed and sized to minus 3/8” inch. Must be free of cores, metal windings, and other foreign materials. This is equivalent to Andela #17.
5. CRT Tailings: CRT Tailings consist of CRT processing rejects and may include screens, cores, coils, windings, and residual metal from gun remnants.
6. Other CRT Scrap: Other CRT scrap consists of other CRT scrap not included in the listed grades.