The Environment and the Information Age

The Costs of Coping With Used Computer Monitors

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The "information economy" has brought about a surge in demand for electronic equipment. According to recent estimates, shipments of personal computers in the United States grew from about 10 million units in 1992 to just over 30 million units in 1997. At the same time, the useful life of electronic equipment grows shorter and shorter with each successive generation, due to the rapid pace of advances in computing technology. For example, in 1997, the average life span of a computer was four to six years; by 2005, it is expected to be just two years. As a result, much electronic equipment becomes obsolete each year.

The growing quantity of old equipment poses real challenges for waste management officials. One of the primary concerns is that the equipment often contains hazardous materials, which could be released into the environment during incineration or concentrated and then dispersed in the form of incineration ash. For example, most computer monitors and color televisions use cathode ray tubes (CRTs), which contain lead to shield users from radiation. This lead poses a potential environmental hazard when CRTs are incinerated. Some experts say that, in the United States alone, approximately 1 billion pounds of lead from computers and other electronic equipment will enter the waste stream within the next decade.

Dealing with used electronic equipment also is a challenge for the businesses and households that generate the waste. Under Subtitle C of the Resource Conservation and Recovery Act, domestic commercial and industrial users of large numbers of CRTs must treat the used equipment as hazardous waste, using special carriers licensed to transport hazardous waste and disposing of the equipment at a hazardous waste facility—a procedure that costs much more than conventional landfilling. In recent years, a growing number of large companies are finding it economical to send their used equipment to recycling facilities, but this practice is not widespread.

Current Disposal Practices

With the exception of some jurisdictions that now restrict all landfilling and incineration of CRTs, smaller commercial users and households can dispose of CRTs with the rest of their ordinary trash. In practice, however, surveys repeatedly indicate that both large and small businesses and households appear to be storing their obsolete CRTs and postponing their ultimate disposal.

In light of concerns about the eventual disposal of CRTs, some states and localities have initiated restrictions on disposing of the equipment as ordinary trash and have set up programs specifically to increase recycling. Since April 2000, Massachusetts has banned disposal of CRTs at all municipal solid waste (MSW) landfills and incinerators. This ban is being coupled with the establishment of several CRT drop-off sites throughout the state, as well as other efforts on behalf of the state to promote use of these facilities and other means of CRT recycling. Communities in New York, Minnesota, New Jersey, Virginia, and Illinois have experimented with various types of collection programs, including one-day drop-off opportunities for consumers to bring in old equipment, the siting of permanent depots for disposal of equipment, curbside collection, and point-of-purchase (retail) collection.

Some approaches also seek to assign manufacturers the responsibility for funding the disposal or recycling of machines they have produced. Manufacturers have opposed these approaches, noting that they already participate in and underwrite many pilot projects to reclaim old computers. These manufacturers have instituted programs under which consumers may return used equipment for a fee, either to a local retail electronics store or a local waste management facility, or by shipping directly to a recycler that has a contract with the manufacturer. The manufacturers donate usable equipment to charity and dismantle the rest.

Several countries, including the United Kingdom, Belgium, Sweden, the Netherlands, and Japan, are developing regulations that require manufacturers or distributors of electronic equipment to take the equipment back at the end of its useful life. A prominent related issue is the effect of take-back requirements on overseas companies that manufacture and export electronics.

Some of these policies could prove to be quite costly, while the associated benefits to the environment are largely unknown. We developed a model of consumers' options for discarding computer monitors based on the costs of different options and their associated effects on human health of lead releases from incineration. For the stock of monitors disposed of in the United States in 1998, our preliminary findings suggest that banning some disposal options, such as incineration and landfilling, would increase disposal costs on the order of from $1 per monitor to between $3 and $20 per monitor. Policies to promote a modest amount of recycling of monitor parts, including lead, can be less expensive. In all of the policies we studied, the costs of the policies exceed the value of the avoided health effects of CRT incineration.

Environmental Concerns

A computer monitor display is typically composed of a glass panel, a cathode ray tube, a casing, connecting wiring, and shielding. Lead in the glass of the cathode ray tube itself is the major source of lead in the display. While CRTs and other electronics are not the primary use of lead, they now comprise the largest proportion (by weight) of lead entering the solid waste stream in the United States. This differential may be partially explained by restrictions on disposal of lead-acid batteries in MSW landfills and increased battery recycling.

Our focus was limited to the environmental and health damages associated with lead that may be released into the air during incineration of CRTs in computer monitors. We chose this focus because these incineration-related damages are the largest likely source of health effects according to the epidemiological literature. Incinerated lead either is emitted into the air or remains in the ash. The ash obtained from the incinerator must then be disposed of in a landfill—or a hazardous waste landfill if the lead content is above acceptable levels.

Lead uptake may result in several health problems for different segments of the population. However, it is important to note that environmental releases of lead and other hazardous substances can take place throughout the monitor's life cycle. For example, the extraction and processing of the raw materials used in CRT production—as well as the fabrication of the CRT—may lead to environmental releases of lead and, subsequently, adverse health effects. The mining and manufacture of lead used in CRTs result in emissions of lead: lead mining results in solid by-products released into the environment, while lead smelting and the production of lead oxide (the form of lead used in CRT glass) result in lead emissions into the air as well as solid by-products that contain lead, which are subsequently disposed of and thereby disseminated. Other stages depend critically on a host of parameters outside the scope of our model, such as the effectiveness and cost of enforcing occupational safety and health provisions, or even any environmental effects of the recycling

processes themselves. The extent of many of these effects are regulated by existing environmental, safety, and other laws.

Our Model

In order to analyze the private and social costs of different approaches to CRT waste management, we constructed a simulation model to track what happens to monitors in the United States once they are retired at the end of their useful lives. This model provides a snapshot of how consumers manage their used CRTs during a single year. We assumed that all consumers pick the least costly discard option among the options available to them, but that consumers do not take explicit account of the social cost of the health effects that may arise from incineration of monitors.

The discard options we examined for residential consumers were disposal in the regular trash pickup (in which case the monitors are incinerated or landfilled based on the municipality's MSW practice); and recycling by either dropping off the CRT at a designated recycling center or by placing the CRT at the curb. Nonresidential consumers that generate large quantities of CRTs for disposal must, by U.S. federal law, treat disposal as hazardous waste. Nonresidential consumers generating smaller quantities may use regular trash service. All consumers—residential as well as firms—may choose storage as a short-term discard option.

There are significant differences in the costs of these options. To capture these differences, we divided consumers into six groups. Four of these groups cover different types of residential consumers: those who live in apartments and those who live in houses, and in each case, those who face pricing of their waste collection and those whose waste fees are "buried" in other local taxes and fees (most often, in property taxes). We distinguished apartment and house dwellers because we assumed they face different storage costs. The other two groups are nonresidential consumers classified as hazardous waste generators and nonresidential consumers classified as nonhazardous waste generators.

We included both the private and social costs for each end-of-life option by sector. The private costs of these options include the costs of storing a monitor, which we based on rental rates per square foot for residential apartment dwellers and nonresidential consumers, and which we assumed to be zero for residential consumers living in detached homes. The cost of using other options includes residential household time and travel (transportation) costs; shipping costs if the monitor is shipped to a disposal or recycling facility; and recycling process costs when paid by the consumer. Under some options, some of these costs are paid by general governmental revenues and we defined these as the community costs for managing the waste. In addition to private and community costs, the full social costs of disposal also include the health effects of monitor disposal. We used a U.S. Environmental Protection Agency model that relates the health effects of lead and the economic value of these effects to approximate their monetary cost.

Our Results

We evaluated a variety of approaches that policymakers are taking or have proposed. These included banning disposal in landfills, incinerators, or in both; subsidizing recycling; making it easy for households to recycle their monitors by allowing them to simply place them at the curb; and various combinations of these approaches. It is important to note that, in all cases, someone bears the costs—for example, when using a drop-off center, consumers bear the transportation and travel time costs to take monitors to the center and the community as a whole bears the cost of operating the center. With curbside recycling, the costs to the householder may be much less but the community bears the pickup costs. We sought to compare these costs, both private and community, with the value of the health effects that would be avoided were various policies implemented.

We used the most recently available U.S. data (for 1998) to both estimate how many computer CRTs were retired during the year and then assess how many of those CRTs will be dis-

Table 1. Policy Costs and Recycling Rates

	Policy Intervention	Private and Community Costs ($ millions)	Cost of Recycling Subsidy ($ Millions)	Health Damages ($ Millions)	Recycling Rate (percent)
A	Baseline	13.54	N/A	2.67	0.2
B	Ban All Disposal (Incineration and Landfill)	292.3	N/A	0	23.4
C	Ban All Disposal and Subsidize Recycling by $10 per Monitor	333.7	96.6	0	61.1
D	Curbside Recycling with Ban on All Disposal	300.6	N/A	0	29.7
E	Ban Incineration Only	50.3	N/A	0	3.5
F	Curbside Recycling Offered	28.1	N/A	2.5	5.3
G	Subsidize Recycling to Achieve 10% Recycling Rate	51.9	22.9	2.36	10.3
H	Subsidize Recycling to Achieve 23% Recycling Rate	100.8	65.9	2.03	23.1

carded using different options. (See Table 1 for a summary of our results regarding the nearly 16 million monitors retired that year.) In our "baseline" case—in which consumers may store, dispose of, or recycle their used monitors by taking them to drop-off centers—we found that the private and community disposal and recycling costs are a little less than $1 per monitor. The health damages that would be avoided by recycling are about a nickel per monitor. The total cost of handling monitor waste is about $13.5 million and the associated total health damages are about $2.7 million (see Table 1, row A).

How do various policy interventions compare? We can evaluate them based on their consequences for a variety of possible goals: reducing or eliminating health effects, increasing recycling, or achieving a combination of these objectives.

Two options, banning disposal in both landfills and incinerators—as now practiced in Massachusetts—or coupling such a ban with various financial incentives to recycle at drop-off centers, eliminate health effects associated with disposal and also increase the rate of recycling significantly (Table 1, rows B, C, and D). However, the cost to consumers and the community's waste management budget is quite large—on the order of $300 million compared with avoided health damages ($2.7 million). If the policy objective were to avoid health effects entirely, the most economical approach is to ban incineration only, according to our model; although even in this case, the cost is $50 million to avoid damages of $2.7 million (Table 1, row E).

Another goal for CRT disposal policies is to encourage recycling, in the hope that increased recycling activity will ultimately lead to lower costs of recycling. If the policy goal is strictly to increase recycling, then providing recycling at the household's curb is the least expensive policy intervention (Table 1, row F). It produces a modest amount of recycling (5%), but it does very little to reduce health damages. We also considered subsidies to recycling to attain specific goals of recycling rates as some states and communities have proposed—a modest 10% (Table 1, row G) and a more ambitious 23% (Table 1, row H; we chose this percentage to match the level of recycling predicted in our outright ban on disposal). These approaches are expensive and, moreover, they do not greatly reduce health damages.

Conclusions

Our research offers a basis for evaluating policy alternatives for the case of a growing component of the CRT waste stream, used computer monitors. The significant differences in costs resulting from our policy scenarios indicate that identifying the most cost-effective policy depends on the goal of the policy (for example, eliminating or reducing health effects, encouraging recycling generally, encouraging recycling to meet a specified recycling goal, or some combination of these). Regardless of the type of intervention, the benefits of reducing airborne emissions of lead associated with CRT incineration appear to be small. Other end-of-life benefits or environmental benefits that may be achievable earlier in the CRT lifecycle—for example, during manufacturing—would need to be large to justify the costs associated with policy actions that induce increased storage and recycling.

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