

Managing Electronic Waste: Issues with Exporting E-Waste

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Summary

Electronic waste (e-waste) is a term that is used loosely to refer to obsolete, broken, or irreparable electronic devices like televisions, computer central processing units (CPUs), computer monitors (flat screen and cathode ray tubes), laptops, printers, scanners, and associated wiring. E-waste has become a concern in the United States due to the high volumes in which it is generated, the hazardous constituents it often contains (such as lead, mercury, and chromium), and the lack of regulations applicable to its disposal or recycling.

Under most circumstances, e-waste can legally be disposed of in a municipal solid waste landfill or recycled with few environmental regulatory requirements. Concerns about e-waste landfill disposal have led federal and state environmental agencies to encourage recycling. To date, 23 states have enacted some form of mandatory e-waste recycling program. These state requirements, mixed with increased consumer awareness regarding potential problems with landfilling e-waste, have led to an increase in recycling. With that increase have come new questions about e-waste management. Instead of questions only about the potential impacts associated with e-waste *disposal*, questions have arisen regarding the potential danger associated with e-waste *recycling*—particularly when recycling involves the export of e-waste to developing countries where there are few requirements to protect workers or the environment.

Answering questions about both e-waste disposal and recycling involves a host of challenges. For example, little information is available to allow a complete assessment of how e-waste is ultimately managed. General estimates have been made about the management of cathode ray tubes (CRTs, the only devices where disposal is federally regulated), but little reliable information is available regarding other categories of e-waste. For example, accurate data regarding how much is generated, how it is managed (through disposal or recycling), and where it is processed (domestically or abroad) are largely unknown. Further, little information is available regarding the total amount of functioning electronics exported to developing countries for legitimate reuse.

What *is* known is that e-waste recycling involves complex processes and it is more costly to recycle e-waste in the United States. It also is known that most consumer electronics manufacturers (who provide the market for material recovery from recycled electronics) have moved overseas. As a result, the majority of e-waste collected for recycling (either for reuse or recycling) appears to be exported for processing.

Although there may be limited data regarding how e-waste is managed, the consequences of export to developing countries that manage it improperly are becoming increasingly evident. In particular, various reports and studies (by the mainstream media, environmental organizations, and university researchers) have found primitive waste management practices in India and various countries in Africa and Asia. Operations in Guiyu in the Shantou region of China have gained particular attention. Observed recycling operations involve burning the plastic coverings of materials to extract metals for scrap, openly burning circuit boards to remove solder or soaking them in acid baths to strip them for gold or other metals. Acid baths are then dumped into surface water. Among other impacts to those areas have been elevated blood lead levels in children and soil and water contaminated with heavy metals.

The impacts associated with e-waste exports have led to concerns from environmental organizations, members of the public, and some Members of Congress.

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Introduction

Electronic waste (e-waste) is a term that is used loosely to refer to obsolete, broken, or irreparable electronic devices like televisions, computer central processing units (CPUs), computer monitors (flat screen and cathode ray tubes), laptops, printers, scanners, and associated wiring. Rapid technology changes have led to increasingly large e-waste surpluses. Electronic devices, particularly older units in use today or in storage, contain a host of hazardous constituents such as lead, mercury, or chromium, as well as plastics treated with brominated flame retardants. The presence of these constituents has led to end-of-life (EOL) management[1] concerns from state and federal environmental agencies, environmental organizations, and some Members of Congress.

E-waste is essentially unregulated at the federal level—meaning it can be disposed of with common household garbage in municipal solid waste landfills (the primary disposal method) or incinerators. The Environmental Protection Agency (EPA) has stated that landfill disposal of e-waste is safe.[2] However, EPA's preferred method of EOL management is reuse or recycling. Further, state and local waste management agencies have expressed concerns regarding the potential cumulative impact to human health and the environment of landfilling millions of pounds of e-waste. As a result, individual states have begun to enact their own e-waste management requirements. To date, 23 states and New York City have enacted some form of e-waste management law. Those laws include provisions such as restrictions on landfill disposal of certain e-wastes and the establishment of mandatory recycling programs, generally paid for by electronics manufacturers. In the coming years, it is likely that more states will enact similar laws.

New state requirements, mixed with increased consumer awareness regarding potential problems with landfilling e-waste, have led to an increase in recycling. With that increase have come new questions about e-waste EOL management. Instead of questions only about the potential impacts associated with e-waste *disposal*, questions have arisen regarding the potential danger associated with e-waste *recycling*.

Because e-waste recycling is largely unregulated, virtually no data are available to track its fate.[3] Accurate data regarding how much is generated, how it is managed, and where it is processed (either domestically or abroad) are largely unavailable. What is known is that e-waste recycling may involve costly, complex processes and that there is an insufficient, though growing, national recycling infrastructure[4] to enable the United States to fully manage its own e-waste. It also is known that markets for e-waste (either for reuse or recycling for scrap) are largely overseas. As a result, the majority of e-waste collected for recycling appears to be exported for processing.

[1] EOL management options include disposal (in a landfill or through incineration) or recycling (which may include reprocessing for parts or refurbishment and reuse). While reuse may be considered a form of recycling, in this report, "recycling" will generally refer to recovering a device for the purposes of dismantling and parts or materials recovery. "Reuse" will include the reuse of a device "as is" or with refurbishment.

[2] For more information, see Robert Tonetti, EPA Office of Solid Waste, presentation materials, "EPA's Regulatory Program for E-Waste," October 2007, available online at http://www.epa.gov/waste/conserve/materials/ecycling/docs/e-wasteregs.pdf.

[3] Most available waste management data attempt to approximate disposal, recycling, or export information about cathode ray tubes (CRTs). Little, if any, data are available regarding the generation, disposal, or recycling of other types of e-waste such as flat panel monitors, CPUs, or laptops.

[4] Although not defined in law or regulation, in this report, "recycling infrastructure" refers to collection, transportation, and processing of e-waste for reuse or recycling.

Although it is difficult to know exactly how much e-waste collected for recycling is exported, it appears that India or developing countries in Asia or Africa are most likely to receive it. Those countries are more likely to have electronics manufacturing plants that can cheaply repair or refurbish e-waste for reuse. Also, developing countries are more likely to value e-waste more highly than developed countries for its potential to recycle for scrap.

While some exports may be sent to facilities that manage e-waste in a way that protects workers and the environment, a significant amount is likely sent to countries that have few if any protections for workers or the environment, or that have regulations that are not enforced. The result is that recycling operations in those countries may pose a significant risk to human health and the environment. Increasingly, environmental organizations, university researchers, and the media have documented contamination to air, soil, and water, and health impacts to the people working and living near these operations—particularly to children (these issues are discussed in more detail in the section "Impacts of E-Waste Exports").

Concerns regarding the potential impact of exporting e-waste for processing in developing countries have led to increased scrutiny from members of the public and environmental organizations, as well as some Members of Congress. On May 21, 2009, Representative Gene Green introduced H.R. 2595, a bill that would amend the Solid Waste Disposal Act (42 U.S.C. 6921) to establish certain e-waste export restrictions. There have also been several congressional hearings on issues associated with e-waste management, one of which specifically addressed issues associated with e-waste exports.[5]

There are various issues of concern with regard to e-waste disposal and recycling. This report looks at issues specifically related to its export for recycling. Particularly, it discusses documented impacts to human health and the environment that have been tied to unsafe recycling practices in developing countries.[6] It provides an overview of various factors necessary to understand why e-waste disposal has become a concern in the United States. Specifically, the report discusses issues that have motivated certain stakeholders to divert e-waste from landfill disposal and, hence, increase recycling. It also discusses waste management requirements in the United States, to illustrate how e-waste disposal and recycling are essentially unregulated; and why processing e-waste in undeveloped countries has, and will likely continue to have, a predominant role in the recycling process.

Impacts of E-Waste Exports

It is difficult to determine how much e-waste is exported from the United States to developing countries. It is further difficult to determine how much of the waste that *is* exported is sent to facilities that will manage it safely as opposed to those that use disassembly and disposal methods that will expose workers to toxic chemicals with little, if any, protection. It is also difficult to determine how much e-waste may be sent to countries that have a limited regulatory framework

[5] House Committee on Foreign Affairs, Subcommittee on Asia, the Pacific and the Global Environment, "Exporting Toxic Trash: Are We Dumping Our Electronic Waste on Poorer Countries?" September 17, 2008. For more information, see http://www.internationalrelations.house.gov/hearing_notice.asp?id=1031.

[6] The primary focus of this report is on issues associated with exports to *developing countries*. It does not look at exports and recycling operations in *developed countries* that may operate in a manner that protects both its workers and the environment.

to protect the local environment—potentially exposing the surrounding communities to resulting contamination.

What is becoming easier to document is the impact that e-waste exports are having on less developed nations. With increased exports have come increased media attention on the improper handling of e-waste in those areas and its resulting impacts.[7] Various reports have graphically documented health and safety threats to workers and environmental contamination from e-waste recovery practices in developing countries. It is difficult to document all e-waste recycling hubs, but popular destinations for e-waste exported from the United States (and other developed countries) are waste processing operations in Guiyu in the Shantou region of China, Delhi and Bangalore in India, and the Agbogbloshie site near Accra, Ghana.

Multiple studies have documented environmental and health effects of uncontrolled waste processing activities. Environmental impacts include contamination of all local environmental media—soil, air, surface water, and ground water. For example, a June 2009 study[8] found that the primary hazardous recycling operations in Guiyu involve

- metal recovery that involves open burning of wires to obtain steel and copper, cathode ray tube (CRT) cracking to obtain copper-laden yokes, desoldering and burning of circuit boards to remove solder and chips, and acid stripping chips for gold;
- plastic recycling through chipping and melting; and
- dumping of materials that cannot be further processed (such as leaded CRT glass and burned circuit boards) and residues from recycling operations (such as ashes from open burn operations, spent acid baths, and sludges).

It was observed that burning circuit board plastics treated with brominated flame retardants emitted harmful heavy metals, dioxins, and aromatic hydrocarbons. Further, heavy metal contamination in surface water and sediments was found that could be attributed to the direct effects of e-waste recycling operations in Guiyu. Copper from surface water was found to be 2.4 to 131 times the reference background concentrations, and sediment samples were 3.2 to 429 times the reference levels. The study also found severe levels of contamination for lead, cadmium, mercury, and arsenic in sediment and surface water as a result of recycling operations.

In addition to environmental contamination, impacts on humans have been observed. In a 2007 study, children from one to six years old in Guiyu were compared to those living in a neighboring

[7] See *FRONTLINE/World*, "Ghana, Digital Dumping Ground," originally broadcast June 23, 2009, available online at http://www.pbs.org/frontlineworld/stories/ghana804/video/video_index.html; *60 Minutes*, "Following the Trail of Toxic E-Waste," broadcast November 9, 2008, and August 27, 2009, available online at http://www.cbsnews.com/stories/2009/08/19/60minutes/main4579229.shtml; *National Geographic*, "High Tech Trash," January 2008, available online at http://ngm.nationalgeographic.com/2008/01/high-tech-trash/carroll-text; Basel Action Network and Silicon Valley Toxics Coalition, "Exporting Harm: The High Tech Trashing of Asia," February 25, 2002, available online at http://www.ban.org/E-waste/technotrashfinalcomp.pdf; *Scientific American*, "Not in My Backyard: Stopping Illegal Export of Junked Televisions and Computers," November 19, 2008, available online at http://www.scientificamerican.com/article.cfm?id=stopping-illegal-e-waste-export-and-mishandling; *BusinessWeek*, "E-Waste: The Dirty Secret of Recycling Electronics," October 15, 2008, available online at http://www.businessweek.com/magazine/content/08_43/b4105000160974.htm.

[8] Yan Guoa, et al., *Journal of Environmental Quality*, "Heavy Metals in the Environment: Heavy Metal Contamination from Electronic Waste Recycling at Guiyu, Southeastern China," July-August, 2009, Vol. 38:1617-1626.

town where no e-waste processing was done. [9] Children in Guiyu were found to have blood lead levels (BLL) that were significantly higher than those in the neighboring village. The study concluded that elevated BLLs in Guiyu children were common as a result of exposure to lead contamination caused by primitive e-waste recycling activities.

Concerns About Domestic E-Waste Disposal

To understand why e-waste is exported, it is helpful to understand why landfill disposal has become a concern to certain stakeholders in the United States. Those concerns center largely around the waste's increasing volume and the hazardous constituents, such as lead and mercury, it likely contains (particularly in older electronic devices). Increased awareness has encouraged state waste management and water resources agencies to consider the potential impacts to human health and the environment associated with e-waste and has led to increased efforts to divert e-waste from landfill disposal.

Waste Volume

The proliferation of and increasingly rapid technological advances in electronics mean that the volume of e-waste generated in the United States is large and growing. Data regarding electronic products sold, stored, recycled, and disposed of are limited. However, in 2008, EPA completed a study that attempted to gather more current data.[10] According to that study, in 2007, of the 2.25 million tons of televisions, cell phones and computer products ready for end-of-life (EOL) management, 18% (414,000 tons) were collected for recycling and 82% (1.84 million tons) were disposed of, primarily in landfills. Further, EPA estimated that approximately 235 million units sold between 1980 and 2007 were obsolete and in storage, awaiting some method of EOL management.

Although EPA estimates that e-waste comprises about 2% of the municipal solid waste stream, it is anticipated that this percentage will grow as consumers continue to replace old and outdated electronic equipment and discard equipment in storage.

Hazardous Constituents

Electronic devices may contain any of a host of hazardous constituents. Cathode ray tubes (CRTs)[11] found in televisions and computer monitors and printed circuit boards (PCBs, also referred to as printed wire boards, or PWBs), often contain significant amounts of lead.[12] CRTs

[9] Xia Huo, et al., *Environmental Health Perspectives*, "Elevated Blood Lead Levels of Children in Guiyu, an Electronic Waste Recycling Town in China," Vol. 115, Number 7, July 2007, 1113-1117.

[10] EPA published the final results of its study on "Electronics Waste Management in the United States" in July 2008. The consumer electronics covered in EPA's analyses are televisions, personal computers (desktops, laptops, and computer monitors), hard copy computer peripherals (including printers, scanners, and fax machines), computer mice, keyboards, and cell phones. EPA used two different approaches to gather its data. Summary information about the study as well as the results of each approach is available on EPA's Web page, "Statistics on the Management of Used and End-of-Life Electronics," at http://www.epa.gov/waste/conserve/materials/ecycling/manage.htm.

[11] CRTs are the large vacuum tubes that provide the video display in older televisions and computer monitors.

[12] Lead is a toxic metal that can cause delayed neurological development in children and other adverse health effects in adults, including increased blood pressure, nephritis, and cerebro-vascular disease. For more information, see EPA's (continued...)

contain an average of four pounds of lead but may contain more, depending on the size, age, and make of the device.

Although high lead levels in CRTs and PWBs often get the most attention from federal and state waste regulators, electronic devices such as personal and laptop computers, keyboards, and computer mice may contain toxic constituents such as arsenic, cadmium, chromium, or mercury.[13] In addition to potentially toxic constituents, plastics used in electronic devices often contain brominated flame retardants (BFRs). BFRs are widely used in plastic cases and cables for fire retardancy.[14] Plastics containing BFRs cannot be recycled as easily as plastics such as those used in plastic bottles or other containers.

While an individual electronic device may not have dangerously high levels of a given toxic material, the cumulative impact of large volumes of e-waste being disposed of in a municipal solid waste landfill has become troubling to many state waste management agencies.

E-Waste Management Requirements

Broadly speaking, discarded e-waste has two potential fates—it may be disposed of (most likely in a landfill) or it may be recycled. Once the device is in the hands of the recycler, it may be resold and reused "as is" or it may undergo some degree of refurbishing. Products that cannot be reused or refurbished are either dismantled or shredded, with the resulting material separated into secondary material streams and at least partially recovered. The resale of electronic devices for reuse or material recovery may occur domestically or abroad.

Regardless of whether an electronic device is disposed of or recycled, there are virtually no federal environmental regulatory requirements applicable to its management. Factors specific to e-waste that affect the lack of regulation are useful in understanding the challenges associated with addressing e-waste management issues.

(...continued)

Final Rule, "Hazardous Waste Management System; Modification of the Hazardous Waste Program; Cathode Ray Tubes," 71 *Fed. Reg.* 42927 July 28, 2006.

[13] See report prepared by Timothy G. Townsend, et al, "RCRA Toxicity Characterization of Computer CPUs and Other Electronic Devices," by Department of Environmental Engineering Sciences the University of Florida, Gainesville, Sponsored by EPA Regions 4 and 5, July 15, 2004.

[14] Polybrominated diphenyl ethers (PBDEs) are the most commonly used brominated flame retardants (BFRs) which became a replacement for polychlorinated biphenyls (PCBs). The extent to which PBDEs pose a threat to human health is unclear (see the Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, ToxFAQs™ for PBDEs, available online at http://www.atsdr.cdc.gov/tfacts68-pbde.html). However, concerns about the potential impacts of the use of BFRs have led some countries to ban their use and some manufacturers to voluntarily phase-out their use. Also, some U.S. states have banned their use. (For more information, see the Organisation for Economic Co-Operation and Development Web page regarding "Brominated Flame Retardants," see particularly the Hazard/Risk Information Sheets, available online at http://www.oecd.org/document/63/0,3343,en_2649_34375_2403647_1_1_1_1,00.html.) However, BFRs are present in many devices still on the market, in use, or in storage.

Relevant Waste Disposal Requirements

Federal standards regarding waste management are specified under provisions of the Resource Conservation and Recovery Act (RCRA, 42 U.S.C. §6901 et seq.).[15] RCRA establishes criteria for managing both "solid" and "hazardous" waste. All regulatory requirements arising from the act stem from the initial determination of whether an item is actually a "waste" and, further, if that waste is "hazardous."

Solid waste is defined under the law as "any garbage, refuse ... or other discarded material." Subtitle D of RCRA establishes state and local governments as the primary planning, regulating, and implementing entities for the management of nonhazardous solid waste, such as household garbage and nonhazardous industrial solid waste. Landfills that collect household garbage are predominately regulated by state and local governments. EPA has, however, established minimum criteria that certain types of landfills must meet in order to stay open.[16] Also under Subtitle D, states are encouraged (but not required by regulation) to develop comprehensive plans to manage nonhazardous industrial solid waste and municipal solid waste.

Under Subtitle C of RCRA, EPA has established regulations on the transport, treatment, storage, and disposal of "hazardous wastes." For a material to meet the regulatory definition of hazardous waste, it must first meet the definition of "solid waste." Further, for waste to be considered hazardous, it must either be listed specifically or exhibit any of four hazardous characteristics: ignitability, corrosivity, reactivity, and toxicity. E-waste would most likely exhibit toxicity characteristics, meaning it would be harmful or fatal when ingested or absorbed (because it contains toxic substances such as mercury or lead). When toxic wastes are disposed of on land, contaminated liquid may drain (leach) from the waste and pollute ground water. A common test method to determine the toxicity level of a waste is the Toxicity Characteristic Leaching Procedure (TCLP). The TCLP test is intended to simulate conditions that would likely occur in a landfill, and measures the potential for toxic constituents to seep or "leach" into groundwater.[17]

EPA has determined that CRTs and printed circuit boards meet the regulatory definition of hazardous waste, but has not determined if other electronic devices and components would consistently fail TCLP (i.e., exceed toxicity limits). Studies have determined that devices such as personal computer central processing units (CPUs), laptop computers, printers, computer mice, and keyboards *have the potential to* exceed toxicity limits, but it has not been determined that entire classes of electronic devices will always be toxic.[18] Toxicity levels would likely vary by manufacturer, make, and model.

[15] The Solid Waste Disposal Act (SWDA), enacted by Congress in 1965, provided federal statutory provisions regarding solid waste disposal practices. RCRA was a 1976 amendment to SWDA. All subsequent amendments to SWDA, including the Hazardous and Solid Waste Amendments (HSWA, P.L. 98-616) of 1984 and the Federal Facilities Compliance Act (FFCA, P.L. 102-386) of 1992, are commonly referred to as RCRA.

[16] For more information about landfill standards, see EPA's "Landfills" website at http://www.epa.gov/osw/nonhaz/municipal/landfill.htm.

[17] TCLP is not the only approved method to determine a waste's toxicity. Other test methods may also be acceptable. For more information, see EPA's website regarding various test methods for evaluating solid waste, at http://www.epa.gov/waste/hazard/testmethods/index.htm.

[18] See footnote 13, Timothy G. Townsend, et al, "RCRA Toxicity Characterization of Computer CPUs and Other Electronic Devices," p. 5-1.

Even if a device meets the definition of hazardous waste, that does not necessarily mean that the device must be disposed of in accordance with RCRA's hazardous waste regulations. EPA regulations have established many exclusions and exemptions to its hazardous waste disposal requirements.[19] Implementing exclusions or exemptions is often used as a mechanism to facilitate recycling. Examples of e-wastes that are excluded or exempt from the definition of hazardous waste are:

- Any electronic devices *discarded by household consumers*.
- Devices that can be *reused*.
- Scrap metal, processed scrap metal, precious metals, whole circuit boards, shredded circuit boards, processed CRT glass, intact CRTs, and partially processed CRTs *sent for recycling*.[20]

RCRA establishes certain minimum waste management standards that states must meet, but states have the option to implement requirements that are more stringent than those specified under RCRA. To date, 23 states and New York City have opted to regulate e-waste more strictly. Although the specific requirements vary somewhat from state to state, all have the same goal—to avoid landfill disposal and incineration of certain types of e-waste. Most state laws have certain broad elements in common, such as specifying the electronic devices covered under the law; how a collection and recycling program will be financed; collection and recycling criteria that must be met to minimize the impact to human health and the environment; and restrictions or requirements that products must meet to be sold in the state.

EPA's stated policy on e-waste management is to encourage equipment reuse, recycling, and then disposal, in that order. Further, EPA has acknowledged that e-waste can be safely disposed of in municipal solid waste landfills. However, that is not its preferred management option.[21]

Recycling and Export Requirements

There are no federal laws that require e-waste recycling by commercial entities or households. Also, as with e-waste disposal, there are few federal environmental regulatory requirements applicable to recycling operations themselves (including the export of e-waste for recycling or reuse).

The term "recycler" broadly refers to a company that may engage in any of a number of activities including collecting, sorting, demanufacturing, or processing of waste. E-waste recycling can be a labor-intensive process (see "Factors Influencing E-Waste Exporting," below). Any federal regulation applicable to recycling operations would likely address human impacts associated with the disassembly process and apply to workplace health and safety operations. Any environmental

[19] An "exclusion" is a situation where a designated material would be deemed a "non-waste" that is, it is excluded from the definition of solid waste and, therefore, could not be defined as a hazardous waste. An "exemption" is a situation where the material is considered a waste, but specifically exempted from the definition of hazardous waste.

[20] For more information see EPA's eCycling "Regulations/Standards" Web page, http://www.epa.gov/waste/conserve/materials/ecycling/rules.htm. Regulatory exclusions specific to CRTs are specified in regulations that have come to be referred to as the "CRT Rule"; see EPA's Final Rule, "Hazardous Waste Management System; Modification of the Hazardous Waste Program; Cathode Ray Tubes," 71 *Fed. Reg.* 42927 July 28, 2006.

[21] Robert Tonetti, EPA Office of Solid Waste, presentation materials "EPA's Regulatory Program for E-Waste," October 2007, available online at http://www.epa.gov/waste/conserve/materials/ecycling/docs/e-wasteregs.pdf.

regulations applicable to a recycling operation would likely apply to the management of residual waste generated during the recycling process.

Exporting e-waste is generally considered a potential element of the recycling process, wherein electronic devices are sent for reuse, refurbishment, or materials recovery. As with disposal and other elements of the recycling process, there are no requirements applicable to e-waste exporting as a whole. However, there are export notification requirements that apply to certain CRTs. Those requirements are stipulated under EPA's 2007 "CRT Rule."[22] Export notification requirements under the CRT Rule are summarized in **Table 1**, below.

Table 1. Summary of the CRT Rule's Export Notification Requirements

Type of CRT Subject to Regulation	Overview of Regulatory Requirements
Used CRTs (Broken and Intact) Exported for Recycling	Used CRTs exported for recycling must comply with requirements specified in 40 CFR 261.39(a)(5), including requirements to notify EPA of an intended shipment 60 days before the shipment. Notification may cover exports extending over a 12-month or shorter period and must include contact information about the exporter and recycler, and an alternate recycler. It must also include a description of the recycling, frequency and rate of export, means of transport, total quantity of CRTs, and information about transit countries. Consent is not required from transit countries, but EPA will notify the exporter of any responses from these countries.
CRT Glass Exported for Recycling	Processed glass (i.e., CRT glass that has been removed from the monitor and sorted from other material) is not subject to export requirements. Unsorted glass would be considered a "broken CRT" and would be subject to export requirements.
Used Intact CRTs Exported for Reuse	Persons who export used, intact CRTs for reuse must submit a one-time notification to the appropriate EPA Region with contact information and a statement that they are exporting the CRTs for reuse.
Unused Intact CRTs Exported for Reuse or Recycling	No regulatory requirements.

Source: Table generated by the Congressional Research Service (CRS) using information from the Environmental Protection Agency's Web page, "Final Rules on Cathode Ray Tubes and Discarded Mercury-Containing Equipment," available online at http://www.epa.gov/osw/hazard/recycling/electron/index.htm.

High demand for used electronic products can facilitate illegal export—at least with respect to CRTs. Export notification requirements do not apply to CRTs exported for reuse. A recycler can export CRTs without notification by claiming such a purpose. In 2008, the Government Accountability Office (GAO) determined that EPA was not sufficiently enforcing the export notification requirements specified under the CRT Rule.[23] Since then, EPA has initiated enforcement actions against several recyclers for not submitting the proper notifications.

[22] See footnote 20.

[23] Government Accountability Office report to the Chairman, Committee on Foreign Affairs, House of Representatives, "Electronic Waste: EPA Needs to Better Control Harmful U.S. Exports through Stronger Enforcement and More Comprehensive Regulation," report GAO 08-1044, August 2008, available online at http://www.gao.gov/new.items/d081044.pdf.

In addition to a lack of regulatory restrictions on recycling activities, there are currently no consistently applied industry standards applicable to e-waste recyclers. This can actually pose a problem to recyclers that limit their exports.

A recycler that removes hazardous constituents from e-waste, sorts and disassembles its e-waste, and exports the waste to a responsible recycler or confirms that devices are in working order before exporting them for reuse, will likely offer its services at a significantly higher rate than a recycler that simply ships unsorted e-waste abroad. The recycler that ships unsorted e-waste can still make the claim that it is operating in a "green" way because it diverts the waste from landfill disposal. A recycler can also claim that it does not export its waste, but that is a claim that would be very hard for the average consumer (or even a state or charitable organization using the recycler) to confirm.

Voluntary Efforts

Various electronics manufacturers have adopted company polices that address issues associated with exports to developing countries. For example, Hewlett-Packard (HP) and Dell have adopted company policies that ban exports of nonworking electronics to developing countries.

Also, since 2008, voluntary recycler certification programs have been developed by environmental organizations, the recycling industry, and EPA. Certification programs implemented by environmental organizations, such as the Basel Action Network's "E-Stewards" program, would prohibit certain e-waste exports.[24] EPA's "Responsible Recycling (R2) Practices" program specifies that a recycler exporting e-waste must obtain "assurances from downstream vendors both domestically and internationally … [that] show that the materials are being handled properly and legally by downstream vendors throughout the recycling chain."[25]

Any impact these voluntary certification programs may have has yet to be seen. At this point, it is difficult to determine how effectively voluntary certification programs may be enforced. It is also difficult to determine if voluntary programs will have an effect on companies willing to make false or misleading claims about the environmental attributes of their recycling services.

Factors Influencing E-Waste Exporting

Since e-waste recycling is largely unregulated, accurate data regarding the end markets, both domestic and abroad, are not publicly available. Therefore, it is difficult to know how much e-waste that is collected for recycling is actually exported for processing. However, in a 2008 report, EPA consulted an industry expert to develop a "best estimate" of the end markets for CRT-containing devices (televisions and computer monitors). According to that estimate, between 77% and 89% of those end markets were outside the United States.[26] EPA acknowledged that

[24] For information about the Basel Action Network's "E-Stewards Certification Program," go to http://www.e-stewards.org/esteward_certification.html.

[25] See EPA's "Responsible Recycling (R2) Practices" available online at http://www.epa.gov/waste/conserve/materials/ecycling/r2practices.htm.

[26] See the EPA's Office of Solid Waste, "Electronic Waste Management in the United States: Approach 1," EPA530-R-08-009, July 2008, p. 29. Available online at http://www.epa.gov/epawaste/conserve/materials/ecycling/manage.htm.

such data are fluid—market conditions change rapidly. Also, since this estimate only applies only to CRTs, it is not possible to apply those estimates to all e-waste. Still, it can be estimated that the majority of e-waste collected for recycling is processed, at least to some extent, abroad.

There are various reasons why recyclers export e-waste instead of recycling it domestically. Most reasons relate to the high costs of processing the waste domestically and the lower costs and higher demand for the material abroad.

Costly and Complex Domestic Recycling Processes

E-waste collected for recycling may be reused or processed for parts or components. Before it can be determined which of those two fates it may meet, the device will require a certain level of sorting, inspection, and testing.

If a product is ultimately processed for parts or components, it would have to go through various processing activities. Unlike recyclable products that contain essentially a single component, like plastic bottles or newspaper, electronic devices contain a host of mixed materials that may not be easily separated or extracted. Before the device can be recycled it may go through any of a number of steps, including some or all of the following:[27]

- **Demanufacturing into subassemblies and components**—involves a worker manually disassembling a device or component to recover value from working and nonworking components (e.g., video cards, circuit boards, cables, wiring, plastic or metal housing).
- **Depollution**—the removal and separation of certain materials to allow them to be handled separately to minimize impacts to human health and the environment (e.g., batteries, fluorescent lamps, CRTs, or plastics embedded with brominated flame retardants).
- **Materials separation**—manually separating and preparing material for further processing. At this stage, materials that have already been disassembled would be sorted into material categories.
- **Mechanical processing of similar materials**—generally involves processing compatible plastic resins, metals, or CRT glass to generate market-grade commodities.
- **Mechanical processing of mixed materials**—generally involves processing whole units, after depollution, followed by a series of separation technologies.
- **Metal refining/smelting**—after being sorted into components or into shredded streams, metals can be sent to refiners or smelters. At this stage, thermal and chemical management processes are used to extract metals of many types.

Many of the processes described above must be done by hand and can be labor intensive. This can be a costly operation. Depending on the value of the commodities being extracted, among

[27] Activities listed here are specified in "Closing the Loop: Electronics Design to Enhance Reuse/Recycling Value," a study conducted by the Green Electronics Council and funded through a cooperative agreement with EPA's Office of Solid Waste and Emergency Response Innovations Pilot Projects, pp. 5-7, January 2009. The report is available online at http://www.greenelectronicscouncil.org/documents/0000/0007/Design_for_End_of_Life_Final_Report_090208.pdf.

other factors, a recycler may find it more profitable simply to send all of the e-waste it collects abroad, where labor is less costly but health and safety practices may not be implemented when extracting hazardous materials or precious metals. If an e-waste collector or recycler offers its services for free, it likely ships whole units abroad.

Limited Domestic Recycling

Limits on domestic recycling apply to both the infrastructure (the network of waste collection, transportation, and sorting activities) and the actual processing of the waste. Compared to paper, glass, and plastic recycling, electronic recycling has a short history. An e-waste recycling infrastructure is still being developed.

E-waste may be collected at state- or locally-sponsored household hazardous waste collection sites or events (meaning, it is not collected on an on-going basis, but may be collected semi-monthly or semi-annually). E-waste may also be collected at manufacturer or retailer sponsored events. Regardless of where it is collected or who is responsible for collecting it—consumers will likely be required to drop off their e-waste.

According to the Government Accountability Office (GAO), cost and inconvenience inhibit consumers from recycling used electronics.[28] Most stakeholders agree that if e-waste is to be recycled, it must be as easy for consumers to recycle electronics as it is to buy them. Many local and state agencies, retailers, and electronics manufacturers have worked with EPA to sponsor pilot programs providing convenient, free recycling services to consumers. [29] Although such events often collect large amounts of e-waste, it is difficult to determine what happens to the waste after collection.

The extent to which e-waste may be processed domestically after collection is also limited. A company that operates as a "recycler" may actually be a waste consolidator that sends the waste to another vendor to sort or process it in some way. Those downstream vendors may separate the units for reuse, ship whole units abroad for processing, or process it domestically to some degree (see the list of potential steps in recycling under "Costly and Complex Domestic Recycling Processes," above).

However, once a unit has been broken down into its component parts, the presence of recycling facilities with the ability and capacity to recycle those components is limited, and varies from region to region. For example, there are few facilities in the United States capable of processing CRT glass. There are also limited opportunities in the United States for copper and precious metal recovery from circuit boards or for processing flame retardant-containing plastic. Further, most consumer electronics manufacturers (who provide the market for materials recovered from recycled electronics) have manufacturing operations overseas. For example, almost all glass manufacturers that may reuse CRT glass are located overseas.

[28] Statement of John B. Stephenson, Director, Government Accountability Office (GAO) Natural Resources and Environment, before the Subcommittee on Superfund and Waste Management, Committee on Environment and Public Works, U.S. Senate, "Electronic Waste: Observations on the Role of the Federal Government in Encouraging Recycling and Reuse," July 25, 2005, pp. 8-10.

[29] EPA lists information about e-waste recycling on its website at http://www.epa.gov/epawaste/conserve/materials/ecycling/donate.htm. Information provided is from not-for-profit organizations, industry associations, electronics manufacturers, and electronics retailers.

High Demand Abroad

Demand abroad is high in both recycling and reuse markets. When U.S. consumers discard electronic products, they are not necessarily broken. In developing countries, there is high demand for electronics that American consumers may deem "waste."

According to EPA estimates, in 2005, 61% of CRTs collected for recycling were refurbished or remanufactured into new televisions abroad.[30] Also, a study specific to exports to Peru found that 85% of used personal computers (PCs) imported by Peru were reused rather than recycled. [31] The study concluded that decisions regarding the end-of-life management of computers were driven by reuse as opposed to recycling.[32]

Further, in 2008, GAO reported that there is significant demand for used electronics in developing countries. In particular, GAO reported:

> In a search of one Internet e-commerce site, we observed brokers from around the world place 2,234 requests to purchase liquid-crystal display (LCD) screens. On the same site, we found 430 requests for central processing units and 665 requests for used computers. In an extensive search of two Internet e-commerce sites over a 3-month period, we observed brokers in developing countries make 230 requests for about 7.5 million used CRTs. Brokers in developing countries represented over 60 percent of all requests we observed.[33]

Developing countries also have a high demand for scrap. Demand for plastics for recycling is almost entirely overseas.

Conclusions

An unintended consequence of avoiding *potential* negative impacts of domestic e-waste disposal has been a contribution to *actual* environmental contamination and human health impacts to some communities in developing countries. If environmentally preferable management of e-waste is the goal, is recycling it preferable to landfill disposal if recycling means exporting the waste to developing countries? Determining how to address this issue—that is, take into consideration concerns regarding domestic e-waste disposal *and* the negative impacts of recycling abroad—involves many factors.

One significant factor is the lack of timely, accurate data needed to help fully understand the scope of the potential problem. It is almost impossible to know exactly how much e-waste is generated, to what extent it is processed domestically (e.g., to what degree it is sorted or disassembled by domestic recyclers), how much is exported, and, of the waste that *is* exported, how much is actually reusable or sent to a facility that will manage it properly. That is not to say

[30] See EPA's "Electronic Waste Management in the United States: Approach 1," pp. 31-32.

[31] Ramzy Kahhat, Eric Williams, "Product or Waste? Importation and End-of-Life Processing of Computers in Peru," *Environmental Science & Technology*, 2009 43 (15), 6010-6016.

[32] Still, the study found that when PCs were eventually disposed of, they may not be processed properly.

[33] See GAO's "Electronic Waste: EPA Needs to Better Control Harmful U.S. Exports through Stronger Enforcement and More Comprehensive Regulation," p. 16.

that all or even the majority of e-waste that is exported is managed improperly. It is simply impossible to know using existing data.

Electronics manufacturers are currently driven by various forces to make their products more easily recyclable and with fewer hazardous constituents.[34] Any *future* changes to electronic devices have no impact, however, on the hundreds of millions of devices currently in use or obsolete devices currently in storage. Eventually those devices will make their way to the disposal or recycling markets.

The high cost of domestic recycling, high demand for exports, and a lack of barriers to export will continue to drive reuse and recycling markets abroad. As stated previously, the current regulatory structure involves no or very limited prohibition on exports and limited options for reuse or recycling (although, those options will likely increase as e-waste collection increases). As long as there are legitimate reuse markets and recycling operations in developing countries, an *outright* prohibition on exports would be problematic, particularly when limited opportunities for recycling exist in the United States. This presents policy-makers with multiple challenges: principal among them are how to address the obstacles that limit domestic recycling, and how one might establish export controls that facilitate reuse and recycling but prohibit delivery of e-waste to operations that do not protect workers or their environment.

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[34] These forces include consumer demand for "greener" products and regulatory restrictions on the use of hazardous substances. Regulatory restrictions are being developed primarily outside the United States. For example, European Union (EU) Directive 2002/95/EC is the restriction on the use of certain hazardous substances (RoHS) in electrical and electronic equipment. The RoHS Directive bans the use of certain heavy metals and brominated flame retardants from certain electronic equipment. Further, EU Directive 2002/96/EC on waste electrical and electronic equipment (WEEE) includes provisions that encourage the design and production of electronic equipment that will facilitate dismantling and recovery, particularly the reuse and recycling of electronic equipment.