Recycling e-Waste: The Sky Is the Limit

Jan Krikke

What happens to end-of-life electronics? Because of public pressure, e-waste recycling is becoming one of the fastest-growing industries in the world—and it's profitable.

The world generates about 40 million tons of PCs, cathode-ray tube (CRT) screens, fax machines, game consoles, mobile phones, and other e-waste every year. Barely 20 percent of this highly toxic waste is properly disposed of and recycled. Some e-waste is stripped of precious metal and unusable components are dumped in landfills, poisoning the soil and precious water resources. Unregulated e-waste trade affects a growing section of the population. China, one of the largest processors of e-waste, has exported jewelry containing toxic lead from e-waste. But public pressure to recycle e-waste is having a major impact, and e-waste recycling is now one of the fastest-growing industries in the world.

China is the recipient of about 70 percent of the world's end-of-life electronics (see http://www.sciencedaily.com/releases/2007/10/071022094520.htm). The country has developed a huge e-waste recycling cottage industry—and the result has been dramatic. The city of Guiyu near Hong Kong, known as the world's e-waste capital, is an ecological disaster zone. Workers burn printed circuit boards over charcoal to recover usable computer chips, soak the boards in acid to extract gold, and dump the waste in the Lianjiang River. They open CRTs with hammers to harvest the copper yokes.

These crude recovery methods release massive quantities of mercury, cadmium, and other toxins into the environment. Around 80 percent of the children in Guiyu suffer from lead poisoning.

According to the Guangzhou (Canton) Institute of Geochemistry, Guiyu has the highest concentration of dioxins ever measured (see http://ewasteguide.info/node/3618). India and Africa, and other destinations for end-of-life electronics, have similar ecological disaster zones.

Several international treaties regulate the trade in toxic waste, but corruption, broad interpretation of the rules, and fraud are fueling the trade. According to the Seattle-based Basel Action Network (BAN), recycling a PC in the US or the EU costs about US$30. In China and other developing countries the cost is about $2.

Unscrupulous recycling companies charge up to $20 for each PC collected for disposal and ship them to China, India, or Africa, often labeled as charity donations or scrap metal. Chinese recyclers pay their workers about $2 per day to recover precious metals and reusable components (see Figure 1). Unusable parts like plastic casings and ink cartridges are dumped or burned in the open air.

The most comprehensive attempt to deal with the problem is the European Waste Electrical and Electronic Equipment (WEEE) Directive, a law setting targets for collection, recycling, and recovery of electrical products. The directive covers IT and telecommunications equipment (PCs, laptops, monitors, keyboards, printers, and cordless phones), consumer electronics (radios, TVs, DVD players, and

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video recorders), household appliances, and electrical tools. WEEE puts the responsibility for the disposal of e-waste with the producers, importers, and retailers of EEE goods. These companies are compelled to take back end-of-life products and dispose of them in an ecologically responsible manner or refurbish them.

Implemented in 2004, the results of the directive have been mixed. According to Norbert Zonneveld, executive secretary of the European Electronics Recyclers Association (EERA), the EU's recycling rate is still below 30 percent. WEEE places the responsibility for recycling on the producers, regardless of where the product is made. Companies must register with waste disposal programs and track their products to pay for their disposal.

The weak link, according to Zonneveld, is enforcement in the WEEE policy chain. The cost for implementing WEEE throughout the EU is unknown, but according to the British Department for Trade and Industry, implementing the directive in the UK will cost about $220 million per year. Despite the cost, industry analysts believe WEEE will be a model for legislation in the rest of the world. China has also adopted WEEE, and India is likely to follow suit.

1 Woman in Guiyu, China smashing a cathode-ray tube from a computer monitor to remove the copper-laden yoke at the end of the funnel.

Voluntary Programs

The US has yet to implement a nationwide e-waste recovery and recycling plan. The National Computer Recycling Act, introduced by Mike Thompson (D.-Calif.) in 2005, is stalled in Congress. Current regulations vary by state and often by county and city. California prohibits the disposal of end-of-life e-waste in its landfills. End-users of new cathode-ray tubes pay recycling fees ($6 for a 4- to 15-inch screen and $8 for a 15- to 35-inch screen). New legislation also mandates the proper disposal of cell phones.

In 2007, five states (Oregon, Minnesota, Texas, Connecticut, and North Carolina) passed e-waste laws mandating that electronics manufacturers pay for e-waste recycling in those states. Under growing pressure of consumer groups, and urged by the Environmental Protection Agency (EPA), manufacturers are responding with voluntary programs. Last year, Sony agreed to take back old products and promised to make sure that its recyclers meet a strict set of recycling standards—and that it won't export toxic waste to developing countries. Sony is the first electronics company to offer unlimited free take back and recycling for all its products not contingent on a new purchase.

The Electronics TakeBack Coalition has called on other electronics producers to follow Sony's lead. Companies are urged to sign the "Manufacturers' Commitment to Responsible E-Waste Recycling," which consists of three key principles widely ignored by many recyclers in the US:

- No dumping toxic e-waste in developing countries.
- No use of prison labor in electronics recycling.
- No disposal of e-waste in landfills or incinerators, including waste-to-energy incinerators.

Last year, office-supply chain Staples introduced a take-back program for any brand of used

desktop and notebook computers, monitors, printers, fax machines and all-in-one devices for a fixed fee of $10. Keyboards, mice, webcams, and other small items can be dropped off without charge. The fee covers the cost of collecting the e-waste from retail outlets and transporting it to e-waste recycling plants. Staples worked with the Product Stewardship Institute (PSI) and EPA's eCycling program to test the process. The EPA's eCycling project is an alliance of consumer electronics manufacturers, retailers, and service providers to offer opportunities to donate or recycle used electronic products.

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Crisis Equals Opportunity

The growth of the global electronics industry—and the ever shorter lifespan of electronics products—makes recycling an environmental necessity. It has also become highly profitable. In Europe in 2007, turnover passed the $1 billion mark, according to the European Electronics Recyclers Association (EERA). The industry currently employs about 10,000 people with a wide range of skills: process engineers, chemists, brokers, sorters, dispatchers, and sales representatives. EERA estimates that full implementation of WEEE would push employment to 25,000 people.

This new industry is creating a slew of multinational corporations as well. The Australia-based Sims Group, the largest e-waste processor in the world, didn't exist six years ago. Sims currently operates 20 sites around the globe, processing approximately 270,000 tons of e-waste annually. In 2007, it recycled 25 million computers and TV sets. Now that it's acquired United Recycling Industries, Sims has revenues of more than $4 billion, employs roughly 4,000 people, and grows 30 to 40 percent annually.

The North American market is well-placed to deal with e-waste. In fact, it's dealing with excess capacity. According to Jerry Powell, publisher of Resource Recycling, there are 1,200 for-profit e-scrap reclaimers in the US and Canada and 500 nonprofit groups with their own facilities. None of them operate 24/7, according to Powell. "Our polling shows most reclaimers work at half to 70 percent of capacity at 40 hours per week. In North America, the issue is lack of volume, not lack of processors." Estimates on revenues in the North American market vary. Powell puts it between $1 billion to at most $3 billion.

Overcapacity isn't preventing Canadian-based recycler Global Electric Electronic Processing (GEEP) from investing millions in new equipment. GEEP, part of Barrie Metals Group in Ontario, operates a state-of-the-art 370,000 square foot facility in Durham, North Carolina. The company processes discarded telecom equipment for corporate clients and recently opened a $4 million chain shredder and hammer mill-based processing line. Material from the chain shredder is sorted and sent to the hammer mill, where it's sized into fine gravel and mechanically separated into ferrous, nonferrous, and plastic material. The harvested material (steel, copper, aluminum, and glass) is sold as raw feedstock to manufacturers. The company is also building a facility to convert recycled mixed plastic into diesel fuel.

Certified Recyclers

Reputable e-waste recyclers are usually ISO 14001 Environmental Certified. ISO 14001 is part of the ISO 14000 family of environmental management standards to help organizations minimize how their operations adversely affect air, water, or land. ISO 14000 is similar to ISO 9000 quality management: it pertains to how a product is produced rather than to the product itself.

ISO 14001 is generic and can be applied to any organization producing, manufacturing, or processing any product or providing any service anywhere in the world. It also covers specific environmental aspects, including labeling, performance evaluation, lifecycle analysis, communication, and auditing. Improper disposal of certain e-waste can result in heavy fines, such as $25,000 for dumping CRTs in land fills.

US e-waste recycler ARC developed an elaborate infrastructure, including its own software, to deal with the evolving regulatory landscape. The company offers expertise in compliance with electronic recycling, with services ranging from reverse logistics and customized asset recovery to destruction services and e-waste recovery. Among its 8,000 customers are OEM manufacturers of electronics

and government agencies. In 2007, ARC diverted more than 50 million pounds of e-waste from landfills. The company, which employs 200 people in nine plants, claims a recycling rate of 98 percent.

ARC takes complete responsibility for its customer's legal exposure to the disposition of their e-waste. Clients have access to a Web-based real-time tracking system that covers everything from requested pick-up time to warehouse arrival, product photos of items picked up and received, and printable destruction certificates. At the end of the process, customers receive reports documenting key information such as product model number, serial number, action performed, material breakdown categories, weight, value, and final disposition. The report enables customers to finalize their accounting functions for end-of-life assets and the report can be used for audits.

Clean Machines

Companies and research firms around the world are improving e-waste recycling and recovery technology. The ultimate aim of recycling (with zero landfill and 100 percent recovery of the material) is a major challenge given that much e-waste is composed of a complex set of materials. A typical PC consists of 23 percent plastic, 32 percent ferrous metals, 18 percent nonferrous metals, and 12 percent electronic boards (gold, palladium, silver, and platinum).

Recycling plants operate heavy-duty shredders to reduce e-waste into uniform rough pieces. Sorting the resulting shred is increasingly profitable. A few years ago, the rare metal indium used in LCD screen mobile phones sold for less than $100/kg. Between 2005 and 2007, the price fluctuated between $700/kg and $1,000/kg (see http://minerals.usgs.gov/minerals/pubs/commodity/indium/indiumcs07.pdf). Analysts expect the demand for indium to increase as companies ramp up large-scale manufacturing of thin-film solar technology.

Image courtesy of Wendt Corp.

2 Titech's X-Tract Separator uses atomic density analysis to identify e-waste shred for optimal recovery and recycling of material.

The most widely used machines for sorting e-waste shred are the so-called eddy current separators (ECSs). The machines use magnets to extract ferrous metals and eddy currents (alternating electrical current) to attract nonferrous metals like copper, aluminum, and stainless steel. The remaining inert materials (such as glass or plastic) are sent to a second separator. But ECS, in use since the early 1990s, miss significant amounts of copper windings and other valuable metals. Given the considerable opportunities of e-waste recycling, some companies have invested in new technology that sorts additional materials.

One of the most advanced recovery systems currently on the market is the Titech X-Tract Separator and Finder. Wendt Corporation, the US distributor, says the X-Tract and Finder pick up where the ECS leaves off. The Finder recovers most of the stainless steel missed by the ECS and the X-Tract separates 99 percent of the aluminum from heavier metals. The X-Tract (see Figure 2) sends x-rays through unsorted nonferrous metal shred, using receivers to turn the x-rays into high-resolution x-ray images, and the machine sorts the material by comparing the relative brightness of the images. The higher the atomic density of the material, the darker the image.

The X-Tract, equipped with a fiber optics high-speed computer control system, has a hefty price tag (about $700,000, depending on the configuration), but recovers up to 2,000 lbs (1,000 kg) of valuable metals per truckload of ECS waste. Prices of scrap metal have soared in recent years, in part because of demand from China. The US exports more than $1 billion of scrap to China annually.

Plastic recycling technology is also showing progress, in large part due to the WEEE Directive. Sims Group developed new technology to identify and separate the various plastics found in electronics devices. The company is reticent about discussing its technology, but told the BBC in 2007 that it involves "density separation" to get the required degree of separations. Granulated plastic passes through

different liquids, causing some plastics to float and others to sink. Unlike metals, plastics are classified as "low-grade" material. The WEEE Directive mandates plastics processing, but the resale value of the recovered material is unlikely to cover the processing costs without major technological breakthroughs. Flame retardants and other additives make plastics heat-resistant and durable, but also difficult to recycle and bad for the environment.

Several Japanese electronics makers have pinned their hopes on plastics substitutes. Japanese electronics maker NEC is experimenting with bioplastic that degrades in approximately seven years. The material, made with the hemp-like fibers of a kenaf plant, is used for insertion into empty laptop wireless-card ports or cell phone casings. In 2005, Fujitsu made the world's first personal computer cases from bioplastics (their FMV-BIBLO NB80K line). NEC believes 10 percent of its products will contain bioplastic by 2010. However, some experts believe the mass market for bioplastic will be limited to packaging material. They point out that the production of bioplastic requires more energy than conventional plastic and that broad application of the material requires a technological breakthrough.

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Asian Growth

In Asia, industrial-scale e-waste processing is exploding. Chinese cities used to built so-called technology parks to attract companies; now they build recycling parks. The Taizhou Metal Recycling & Processing Zone in the Eastern Zhejiang Province, the largest such park in China, has attracted 22 recycling technology companies. Chiho-Tiande Metals, a leading Chinese recycling firm, has 1,500 employees and an annual capacity of 200,000 tons. The company makes part of its profits from aluminum harvested from e-waste. The Taiding (Tianjin) Sci-tech Environment Protection Company in northern China processes chips, motherboards, cables, and other components, and harvests gold, silver, and other valuable metals. After demetalization, chips and motherboards are used in, among other things, cement production. Only 90 percent of e-waste material is recovered, but it's a significant improvement over the backyard recycling operations in Guiyu.

Tiny Singapore has no fewer than nine e-waste processors. The largest one, TES-AMM, is expanding to both China and India, attracted by the opportunities offered by the massive amounts of e-waste dumped by western countries and the growing amount generated by the region's increasingly affluent population. Chinese consumers now discard more than 5 million PCs and tens of millions of mobile phones annually, according to studies by the environmental service division of International Enterprise Singapore. TES-AMM's e-waste processing facility near Shanghai is considered a model plant. A global forum on e-waste recycling in Shanghai last year included a visit to it. Among TES-AMM's clients in China are HP, Dell, Nokia, and Motorola and several Japanese multinationals. Formed only three years ago, TES-AMM now operates in 17 locations.

The growth of the e-waste processing industry is fueled in large part by pressure from nongovernmental organizations like Greenpeace, the Basel Action Network, and Toxic Link. Multinationals now demand a standard of professionalism in e-waste recycling, (including certified destruction of storage media containing sensitive corporate data). Greenpeace persuaded Dell, Apple, Sony Ericsson, and a dozen other companies to eliminate brominated fire retardants and polyvinyl chloride from their products and is now targeting game console makers Microsoft and Nintendo. Greenpeace publishes a quarterly green ranking of electronics makers based on criteria ranging from take-back programs to toxic content in products they sell. In the latest edition (see www.greenpeace.org/international/campaigns/toxics/electronics/how-the-companies-line-up), Sony-Ericsson, Samsung and Dell rank at the top, and Nintendo, Microsoft, and Philips rank at the bottom. Companies appear to react quickly to a low rating; only Apple was ranked at the bottom twice in a row.

Notably, the volume of e-waste pouring into China, India

and, more recently, Africa, is still growing. According to the Basel Action Network, several countries and organizations are actively undermining the Basel Convention. Among them is the Liberty Institute, a Delhi, India-based policy institute aimed at "promoting awareness and appreciation of a free society." It opposes any kind of trade restrictions by state agencies: "The West can impose its own restrictions or standards," says Barun Mitra, director of the institute. "But the West claiming to know what is best for poor countries or poor people smacks of neocolonialism." Mitra adds, "Private parties should freely decide if they want to buy or sell anything to each other. One man's waste is another man's treasure. The informal recycling industry in India alone employs more than 30,000 people."

Mitra and his Liberty Institute have powerful allies, among them the US government, the United Nations Center for Trade and Development (UNCTAD), the International Chamber of Commerce (ICC), and the International Council on Metals and Mining (ICMM). But in the battle between free traders and green traders, the ultimate winners will no doubt be global recycling giants like Sims, GEEP, and ARC. With their ability to industrialize the process, and to squeeze every last piece of precious metal out of e-waste, they will ultimately put the backyard recyclers out of business.

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