The Economics of E-Waste and the Cost to the Environment

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E-waste or waste electrical and electronic equipment (WEEE) has been generally defined as anything with a cord or battery. *See* Balde, C.P., Wang, F., Kuehr, R., Huisman, J., *The Global E-waste Monitor 2014, Quantities, Flows and Resources*, United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS) (2014) (Balde). Because products with cords and batteries have been around since at least the nineteenth century, managing the waste stream for those products at the end of their useful life is not a new problem. What is relatively new is the perception of WEEE not just as waste, but instead as a valuable resource that can be managed through reuse of the electronic device itself (reuse), recycling of its components (recycling), or disposal of the device or its components (disposal).

Recognition of WEEE as a resource has led to a paradigm shift in WEEE management. Historically, management of WEEE simply involved choices between disposal options. That outlook has given way to a focus on recycling and reuse, with disposal becoming much less prevalent. This change has been attributed to a host of concerns—commercial, societal, and environmental. In the modern view, a successful approach to the management of WEEE seeks to achieve economic efficiency while minimizing impacts to the environment. Regardless of the perspective taken on WEEE, there can be no denying that economics are the leading policy driver. But societal or environmental concerns do not take the back seat. Acceptable WEEE management is seen as requiring harmonizing of commercial, societal, and environmental interests equally.

Recycling and reuse of WEEE has become a common practice around the world due, in large part, to the ubiquity of electronics in our daily lives. The boom in personal electronic devices began when households started purchasing cathode ray tube (CRT) televisions in the mid-twentieth century. It has steadily grown since and now includes devices unimaginable when the first CRT televisions were introduced. Today, in developed countries and many developing countries, life without personal electronic devices is almost inconceivable. Examples engrained in our daily lives include flat-screen televisions, personal computers, and most significantly smartphones; all of which are being constantly improved and replaced with newer, more advanced versions, leaving behind them a trail of WEEE.

As the generation of WEEE has boomed, concern has grown over sustainability, not simply for the negative environmental impacts, but also over the scarcity of rare earth elements (REEs) used in the manufacture of electronics. Both of these considerations have led to global initiatives to institute sustainable practices for management of WEEE. Evidence of mainstream interest in the subject is demonstrated by a recent national news segment on the seventeen REEs and their role in electronic devices in the United States, on the television show *60 Minutes*. *See* www.cbsnews.com/news/rare-earth-elements-china-monopoly-60-minutes-lesley-stahl/.

REEs include fifteen chemical elements in the periodic table referred to as lanthanides. *See Rare Earth Elements: A Review of Production, Processing, Recycling, and Associated Environmental Issues*, U.S. Environmental Protection Agency (Dec. 2012 Revised) (Rare Earth Elements). Two other elements, scandium and yttrium, have similar physiochemistry to the lanthanides and are commonly found in the same mineral assemblages. *Id.* These two additional elements are often also referred to as REEs. Examples of the seventeen REEs used in electronics include yttrium, neodymium, europium, terbium, and dysprosium. REEs are now present in almost all newly manufactured personal electronic devices and serve purposes ranging from enabling your smartphone to vibrate to optimizing the screen resolution on your flat-screen television. *See* www.livescience.com/38094-facts-about-rare-earth-elements-infographic.html (accessed Apr. 24, 2015). Utilization of these elements and others has allowed devices to increase in efficiency and decrease in size.

The benefits of REEs do not come without significant costs. Extraction, production, and processing of REEs involve substantial negative environmental impacts for a relatively small yield. Although REEs are abundant in the earth's crust, they rarely occur in concentrated forms. Mining of ore-containing REEs produces extensive potentially toxic waste. Further impacts occur in the production and processing of REEs (using, e.g., grinding or acid digestion), which create contaminated waste materials. Disposal of mine tailings or process wastewater creates still other environmental issues. Rare Earth Elements at pp. 3–10.

The problem is exacerbated by the fact that the mining of REEs is conducted almost exclusively in developing countries or in parts of developed countries where environmental regulations, if any, may be loosely enforced. For example, the U.S. Environmental Protection Agency estimates that in recent years China has provided more than 95 percent of the REE consumed worldwide, under far looser environmental regulations than those of Western countries. Rare Earth Elements at pp. 2–7.

REEs are increasingly recognized as finite in nature. Given that current production is centered in countries where, for geopolitical or other reasons, stable supply cannot be assured, recycling of WEEE, which contain REEs, becomes clearly

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advantageous not only from environmental but also from economic perspectives.

As mentioned above, WEEE was historically managed almost exclusively by disposal. And while recycling and reuse have recognized environmental advantages over disposal, ultimately, the determination of which management option is preferable will depend on the facts and circumstances presented. For example, in countries where the practice of WEEE management is well developed, recycling may be the most effective and efficient tool. By contrast, in developing countries, where WEEE management is still developing, reuse may be the most effective and efficient option.

Recycling WEEE

Oftentimes, the process of WEEE recycling in developed countries begins with a collection point. Typically, these points are organized by local or national governmental entities, contracted out to private waste management companies, or through retailers of personal electronic devices. At those collection points, members of the community are encouraged to bring all of their WEEE. From there the materials are typically sent to a sorting facility where the WEEE is sorted based on the types of products and materials that make up the WEEE. For example, CRTs can be sorted into one bin and smartphones into another. From that point the materials are broken down into their component parts where the valuable materials present in the WEEE are extracted. This process of breaking down the materials can occur through an automated system in more formal and advanced settings or it can take the form of individuals doing the labor by hand. *See* Hieronymi, K, Kahhat, R., and Williams, E., *E-Waste Management: From Waste to Resource* (2013) (Hieronymi).

In developing countries, informal (or backyard) methods are more prevalent. Individuals are typically responsible for breaking the component parts down by hand and then extracting the materials using rudimentary processes like open burning pits. Hieronymi at pp. 9–11. Such practices can be harmful not only to the environment, but also hazardous to individuals doing the extracting. Recovered materials are then resold on a secondary market and eventually make their way into other electronic devices or similar products.

The WEEE recycling industry is booming. According to a recent study by the United Nations, the world generated approximately 41.8 million metric tons of WEEE in 2014. That number is projected to grow to 50 million metric tons by 2018. Balde at p. 8. The revenue generated from the global WEEE management market is expected to grow from $9.15 billion in 2011 to $20.25 billion in 2016. *See* www.reportsnreports.com/reports/125083-global-e-waste-management-market-2011-2016-.html (accessed Apr. 24, 2015). As the turnover of electronic devices and ubiquity of those devices in developed and developing countries increase, the supply chain volume for WEEE will increase as well. Given that WEEE recycling requires employees with only minimal skills, all indications are that the industry will continue to grow and thrive, producing more revenue and jobs. Hieronymi at p. 16.

Given this trend, it would appear to be in the best interests of all stakeholders that the growth occurs largely in the context of formal WEEE recycling, through an infrastructure assuring operation in a responsible fashion. Formal WEEE recycling is the most efficient economically and likewise serves to limit negative environmental impacts. While both formal and informal strategies are currently employed around the world and likely will be in the future, greater environmental awareness and available recycling infrastructure could tip the scales in favor of more formal WEEE recycling. While aligning stakeholders' incentives on a global scale may seem like an insurmountable hurdle, policy makers have devised approaches that could be implemented on such a scale.

One proposal involves instituting worldwide collection point systems. Under such a system, informal WEEE collectors and dismantlers would continue in business, but a marketplace would be created where the materials collected and extracted could be brought to collection points for sale to institutional recyclers for prices higher than those generated through informal recycling by the collectors and dismantlers themselves. This would remove the informal collectors and dismantlers from the processing of the WEEE, typically the point at which environmental and health risks are the greatest. *See* Williams, J. Yu, J., & Kahhat, R., *Collection Points as Alternative Policy Instrument to Address Informal Recycling of E-Waste*, presented at International Society for Industrial Ecology, Lisbon, Portugal (2009). By limiting the processing of the dismantled WEEE to formal operations, the impacts to individuals and environment could be more closely and carefully managed. The ultimate tool would be the economic disincentivizing of informal recycling altogether. *Id.* Implementation of a worldwide collection point system was initially envisioned to require government subsidy, but current simulations, taking into account the current WEEE marketplace, show that it could be profitable even without subsidy. *Id.*

Another form of recycling proposed involves instituting extended producer responsibility. EPR makes the manufacturer of the product responsible for the entire life-cycle of the product, including its take-back, recycling, and final disposal.

A worldwide collection point system would not require significant upfront costs or additional infrastructure to handle the movement of the WEEE; rather, it would require a form of partnership between informal and formal recyclers whereby the two could work with each other for the benefit of both. Such a system exists, in part, today in developed countries where formal recyclers leave many of the collection efforts to informal recyclers who then resell the bulk WEEE to formal recyclers who are then responsible for the dismantling and extraction processes.

Another form of recycling proposed involves instituting extended producer responsibility (EPR). EPR makes the manufacturer of the product responsible for the entire life-cycle of the product, including its take-back, recycling, and final disposal. The objective of EPR is to ensure that the costs of end-of-use management are born by the producers and consumers, rather than externalized onto society as a whole. The costs are thrust upon producers through regulation or government mandate and those costs are then passed on, in part, to consumers through higher prices for the products they are purchasing. *See* Rossem, C., Tojo, N., and Lindhqvist, T., *Extended Producer Responsibility: An Examination of its Impact on Innovation and Greening Products*, International Institute for Industrial Environmental Economics (2006) (Rossem).

Reuse of electronic devices makes the most efficient use of scarce materials, reduces the amount of transportation required to put a device back on the market, provides jobs and opportunity for individuals, and reduces supply for environmentally degrading informal recycling in developing countries.

In the abstract, EPR sounds simple enough: producers of electronic devices should be responsible for the environmental attributes of their products. However, in practice, implementing EPR has faced significant hurdles in the adoption and implementation of regulations and in the subsequent enforcement of regulations on producers. Rossem at pp. v–vi. Despite these obstacles, EPR has taken hold as the leading policy for ensuring responsible WEEE recycling, having been effectively implemented through legislation and regulation in some of the most populated regions of the world, including the European Union (EU), China, and India. *See* European Commission, EU Waste Legislation Overview, http://ec.europa.eu/environment/waste/legislation/index.htm (accessed Apr. 2, 2015).

Effective implementation of EPR should promote two goals: (i) design improvements in products, and (ii) high reuse of products or product components. *See* Rossem, at p. v. The latter is furthered through (a) effective collection efforts; (b) environmentally sound treatment of collected products; and (c) high use of products and materials through reuse and recycling. *Id.*

A recent report by the United Nations has identified the EU, China, and India as the world leaders in WEEE recycling. Balde at p. 8. This finding regarding India and China may at first glance seem surprising, given the focus on rapid growth in these two countries, but makes sense in the context of China given that government regulation there can be adopted and implemented much more quickly than in democracies like the United States or Canada. From the purely regulatory perspective, WEEE practices in China and India are more progressive those of North America.

Reuse of Electronic Devices

Reuse of electronic devices is less prevalent around the world, but that trend seems to be changing. Hieronymi at pp. 209–235. With electronic devices being replaced at a much more rapid pace than in decades past, reuse no longer involves devices that are completely outdated or obsolete. The latest new smartphone leads to last model of smartphone becoming potential WEEE, even if that last model of smartphone is still functional. Reuse of still-functional devices can meet the needs of communities or individuals who would not otherwise acquire them. Reuse can provide individual and societal benefit not just in developing countries, but in developed countries like the United States. *See, e.g.*, Miller, C., *Fighting Homelessness, One Smartphone at a Time*, N.Y. Times (Apr. 14, 2015).

From a policy perspective, reuse of electronic devices makes the most efficient use of scarce materials, reduces the amount of transportation required to put a device back on the market, provides jobs and opportunity for individuals, and reduces supply for environmentally degrading informal recycling in developing countries. Hieronymi at pp. 209–235. Looking forward, with the prevalence of the Internet and cloud computing, it seems likely that reuse will play an even bigger role in WEEE management as computer systems become less dependent upon electronic hardware and more focused on Internet accessibility and software.

Disposal of WEEE

The leading policy concern for worldwide WEEE disposal is the smuggling and disguised trade of non-reusable/non-recyclable WEEE as metal scraps, plastic scraps, or secondhand electrical and electronic equipment. This trade often results in illegal dumping and informal recycling operations. In an effort to address this issue, international trade regulations have been implemented under the framework of the Basel Convention (Convention).

Adopted by the international community in 1989 and implemented on May 5, 1992, the Convention calls for environmentally sound domestic waste management and minimal transboundary movement of hazardous wastes. *See* www.basel.int/TheConvention/Overview/tabid/1271/Default.aspx (accessed Apr. 24, 2015). On the subject of WEEE, the Convention requires exporters of products containing hazardous wastes to give prior notification to the governments of the importing countries, and to obtain their approval prior to importation. While the Convention serves as a solid foundation for international efforts to regulate the international flow of hazardous wastes, it has a notable shortcoming when it comes to the regulation of the WEEE trade, in that it does not cover international trade of "secondhand" goods. Hieronymi at pp. 167–172. The definitions in the Convention are also problematic because they are stated so vaguely as to be unclear as to whether the Convention actually regulates WEEE. *Id.*

In light of the vague definitions of the Convention, it is difficult to determine whether WEEE can be classified as either hazardous waste or non-hazardous waste. The Convention does not indicate the method to be used to determine the proportion of hazardous substances or the risk assessment measures necessary to make the classification of a particular trade item as hazardous within its terms. Ultimately, the classification depends on whether the trading parties decide to define the trade transaction as either for purposes of reuse, recycling, or disposal.

As one might surmise, defining a trade transaction as for purposes of reuse does not trigger the regulations of the Convention whereas recycling and disposal do. This obvious loophole of allowing trading parties to define their transaction has resulted in those parties exporting WEEE under the pretense that it is secondhand or reusable WEEE, when in fact the intended use of the WEEE is for recycling and disposal.

Despite these shortcomings, the Convention is largely viewed as the leading international regulatory scheme for WEEE. And while there will always be those who seek to take advantage of its loopholes, there are others who will seek to avoid the regulations of the Convention altogether. For example, smugglers can avoid detection by routing container ships through ports where customs enforcement is weak or open to bribery. Recognizing this reality, some nongovernmental organizations (NGOs) are working with those countries seen as weak on enforcement of the Convention and other developing countries to limit the opportunities available to smugglers of WEEE. Hieronymi at p. 167–172.

Domestically, disposal of WEEE in landfills is generally perceived as environmentally unacceptable. Given the current stricter regulation of disposal practices at landfills, however, the WEEE component of the overall waste stream may be less of a landfill issue today than formerly. WEEE accounts for an estimated 2 percent of the annual waste stream currently going to municipal solid waste (MSW) landfills in the United States. *See* U.S. Environmental Protection Agency (USEPA), *Electronics Waste Management in the United States through 2009*, EPA 530-R-11-002 (2011). WEEE makes up this fairly limited percentage of waste at MSW landfills despite the fact that between 2006 and 2009, approximately 75–78 percent of electronic devices that reached their end of life ended up in MSW landfills. *Id.* Even with this fairly limited proportion of waste at MSW landfills, there is a concern among policy makers, regulators, and the public at large that disposal of WEEE through MSW collection poses a significant environmental risk. This concern may be, in part, based on the realization that some MSW is not deposited in landfills but is incinerated. Incineration presents serious air toxics issues, particularly where lead, mercury, chromium, or other hazardous metals are present—all of which are found in varying forms of WEEE.

The risks associated with WEEE are real. WEEE includes many constituents recognized as harmful to humans and the environment. Some of the more toxic ones are the rare earth elements mentioned above. Federal environmental statutes like the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. § 9607 and the Resource Conservation and Recovery Act (RCRA), 42 U.S.C. § 6901 as well as state environmental statutes include toxic elements present in WEEE in their definitions of hazardous waste or substances. Many types of WEEE that are and could be disposed of at a landfill have the potential to produce toxic leachate.

Disposal of WEEE in informal settings, such as open dumping, unlined burning pits, or acid baths presents even more serious environmental threats to groundwater or air quality. Such informal disposal and recycling practices are on the increase worldwide as a result of the steadily increasing market value of the elements present in WEEE. *See* Solving the E-Waste Problem, www.step-initiative.org/index.php (accessed Apr. 24, 2015). They have been characterized as the leading source of adverse environmental impacts worldwide. While such practices have been reported as most prevalent on the continents of Asia, Africa, and South America, they exist everywhere, including in developed countries like the United States and Canada. Basel Action Network (BAN) & Silicon Valley Toxics Coalition (SVTC), *Exporting Harm: the High-Tech Trashing of Asia*, www.ban.org/E-waste/technotrashfinalcomp.pdf (accessed Apr. 24, 2015); Carrol, C., *High-Tech Trash*, National Geographic (Jan. 2008); Toxic Link India, *Scraping the High-Tech Myth*, Computer Waste in India (2003).

The Future of WEEE Management

WEEE management is shifting from disposal to recycling and reuse, a trend not likely to end. Given the current and foreseeable circumstances, it would seem that disposal may become a less and less relevant management approach. Whatever different variations develop for recycling and reuse, some of the major challenges that need to be addressed include: (1) implementation or expansion of WEEE collection systems separate from other waste streams; (2) financial support and infrastructure for WEEE recycling systems; (3) technological improvements to increase the yield of elements extracted from WEEE, including REEs; and (4) the phasing out of hazardous materials and substances in electronics. Addressing these challenges will require effort and cooperation on a global scale.

Beyond the practical issues of WEEE management that exist today, there are policy challenges for the future. Concerns previously seen as fringe issues, are now impacting the electronics industry as environmental concerns move beyond legal compliance, corporate social responsibility, and green branding to questions about longer-term viability of the industry itself. Sustainability is no longer a platitude but reality for an industry more and more reliant on mined materials that are finite and expensive to extract. This reality is bringing together the ordinarily divergent interests of industry and environment into what could be a unified approach to dealing with the issue of managing e-waste.