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Health and Safety Policies for Electronics Workers

Ted Smith and Chad Raphael

One of the sharpest ironies of the information age is that it is easier for electronics to trace people than for people to trace the materials and labor that make their electronics. A fragmented global supply chain conceals who makes what, how they make it, and with what materials. Electronics companies have a strong incentive to conceal this supply chain from their employees, customers, and even from top management: it is filled with hazards for workers and their communities that tarnish the image of a clean industry of the future. Even the major brand owners – Apple, Dell, and the like – do not know all of the materials and chemicals that end up in these companies' own products.

Given the far-flung and interconnected nature of the industry, reforming workplace health and safety requires policies that extend far beyond regulating what happens on the shop floor. In this chapter, we identify policy goals for making the industry safe and healthy for its workers. We argue that effective change depends upon rethinking the entire life-cycle of electronics, from design and production to recycling and disposal, and even how we measure progress.

The Challenges

There is much to improve in electronics workplaces. In mines that supply the metals used in electronics, tens of millions of workers, around a million of them children, toil in one of the world's most dangerous occupations.[1] The unluckiest miners, in the Democratic Republic of Congo, are enslaved to work in operations controlled by military and paramilitary soldiers, who use the trade in these "conflict minerals" to fund civil warfare.[2]

In electronics production and assembly plants, many workers suffer from grueling work schedules, a regime of physical and verbal abuse from supervisors, and second-class status as

underpaid "student apprentice" workers or as migrant laborers who are denied citizenship rights (see the chapters in this volume by Chan, Pun, and Seldmen; Ferus-Comelo; Grossman; Hong and Wang; Overeem; and Reyes). These workers have been exposed to heavy metals and toxic chemicals, such as lead (in circuit boards and monitors), cadmium (in batteries and circuit boards), mercury (in switches), polychlorinated biphenyls (PCBs) (in older capacitors and transformers), many toxic solvents (used to clean parts), and polyvinyl chloride (PVC) and brominated flame retardants (in cables and plastic casings).[3] Studies have found that production workers suffer higher rates of miscarriages, birth defects, and cancers.[4] Many recycling and disposal workers in the developing world and in U.S. prisons have been exposed to the same health and safety hazards when smashing and burning discarded electronics without protective gear, and report similar diseases.[5]

Few workers in mining, production, or recycling are represented by independent labor unions, which have played a crucial role in advancing occupational health and safety in other sectors. Many electronics workers are difficult to organize because they toil in the informal sector, in small-scale mines, homes, and workshops that are beyond the reach of unions, NGOs, and occupational health and safety regulators.[6] In some countries, electronics workers have little choice but to affiliate with unions controlled by employers, or by states that collaborate with companies to suppress workers' demands for better pay and conditions.[7] In manufacturing and assembly, employers' preferences for young and migrant workers, widespread use of short-term contract hiring, rapid turnover of employees, and harassment of union organizers frustrates many attempts to bargain collectively.

A Policy Roadmap for More Sustainable Electronics Work

In 2011, several United Nations (UN) agencies and treaty organizations invited more than 100 representatives of governments, NGOs, and companies to Vienna, Austria to envision a sustainable electronics industry of the future. Reflecting the growth of global concern, government representatives came from 32 countries, including electronics manufacturing centers (in Europe and Asia) and countries where most of the world's electronic waste is handled (in Asia, Africa, and Latin America). For the first time, a UN body adopted recommendations to improve working and environmental conditions throughout the life cycle of electronics.[8] Based on forty years of organizing and research, these recommendations are the most comprehensive current statement of goals for improving the industry. The UN statement has also influenced subsequent governmental and civil society initiatives. [9]

We will focus on five of the UN goals that especially affect the health and conditions of workers: redefining progress to include workers' human rights, increasing transparency of supply chains, reducing harm throughout the product life-cycle, establishing producers' responsibility for recycling their electronics, and sharing the benefits and burdens of the electronics industry more equitably.

Rethinking Progress as Human Rights

The most fundamental goal is a new and broader definition of the kind of progress we should expect from electronics, one that includes the industry's millions of workers. The Vienna recommendations state that each new generation of technical improvements in electronics should also "require making parallel and proportional improvements in environmental, health and safety, and social justice attributes" of these products. [10] Activists adopted this aim over a decade earlier to draw attention to the importance of anticipating the effects of each new

generation of electronics, rather than continually trying to fix the problems created by how the prior round of products were designed and made.[11]

This goal expanded on Moore's Law, the famous prediction that the processing power and memory capacity of computer chips will continue to double every 18 months to two years. While Moore's Law describes progress in narrow technical terms of the speed and power of chips, the activists focus our attention on a much broader range of benefits to humanity. In their view, each generation of electronics should have more humane effects on the people involved in producing our phones, computers, game consoles, and other gadgets. The spirit of innovation devoted to advancing computing power should also be applied to alleviate the health risks and economic exploitation faced by electronics workers. The "design features" of a better mobile phone, for example, would include better compensation and working conditions, and a healthier workplace and community, for the miners and metal smelters who supply that phone's raw materials, the factory workers who produce its components, the manufacturing employees who assemble it, and the workers who recycle it.

Ensuring that workers can exercise their basic human rights would be a great step forward. The Universal Declaration of Human Rights, adopted in 1948 by the United Nations, and the International Labor Organization Convention 98, adopted in 1949, established workers' rights to free association, to organize their own unions, and to bargain collectively with employers. [12] The Vienna agreement states that governments must guarantee these rights for workers involved in all stages of the electronics life cycle, including the rights:

- [to] form democratic and independent unions and to organize for self-protection;
- to form health and safety committees;
- to receive training to develop the capacity to monitor and enforce effective health and

safety protections in the workplace;

• to refuse unsafe or unhealthy work; and the right to be protected from retaliation for exercising those rights (right-to-act and "whistle-blower" protection).[13]

Delivering on the promise of these basic rights, which are enshrined in international law but violated more often than they are respected in the electronics sector, would be transformational.

A second mark of progress would be the integration of all electronics work into the formal economy. Governments and companies need to acknowledge publicly that a great deal of this work, especially in mining and recycling, is occurring in the shadows. Legislation and regulation are needed to bring this work into regulated workplaces and economic relationships. This would make it easier to educate workers to protect themselves from toxic exposures, improve safety and health standards, enforce regulations on fair wages and overtime, and protect workers' rights to organize.

The Vienna statement calls on governments and companies to facilitate this transition carefully to maintain employment.[14] Immediate enforcement of bans against the informal sector would deprive millions of the most vulnerable workers of their livelihoods without providing better alternatives. A variety of approaches will be needed in different sectors. In recycling, for example, initial efforts have focused mostly on regulating and improving conditions in electronics processing centers, while leaving the job of collecting old computers and phones from homes and workplaces to workers in the informal economy. However, because far more money is made in processing than collection, the wage structure will need to be redesigned to compensate collectors more fairly. A few pilot programs are currently underway in Asia and Africa to develop viable models that will fairly compensate e-waste collectors, while protecting their health by preventing the harmful exposures in primitive e-waste processing.

Creating Transparency

As Fahmi Panimbang writes, "Global value chains in the electronics industry are more geographically extensive and dynamic than in any other manufacturing sector."[15] A typical computer contains components that are sourced, manufactured and assembled all over the world. The metals used in components might be mined in central Africa, Asia, Australia, North America, or Latin America. The semiconductor chips might be made in Texas or Taiwan, in Korea, Malaysia or New Mexico. The disk drive might come from Singapore or Thailand. The monitor is likely produced in Taiwan, China or Japan. These components might be assembled in India or Indonesia, or in Mexico, Malaysia, Costa Rica, Vietnam, or the Philippines. Even the household name brands that exert greatest command over this whole process – Apple, Dell, Hewlett-Packard, and the like – have found it surprisingly difficult to trace their own supply chains.

Until recently, most brand owners have made little attempt to trace their suppliers all the way back to the sources of raw materials. This allowed the companies that put their names on the final product to plead ignorance about whether they were using conflict minerals or buying components from contract manufacturers that mistreated workers. Of course, many of the subcontractors had no interest in revealing their violations of human rights and labor laws. Nor did the brand manufacturers know exactly what chemicals were used to make their products because those decisions were made by subcontractors, often buried many tiers down in the supply chain. Some companies have argued that the materials they use are trade secrets. However, in most cases, companies use similar chemicals and their competitors know they do. While sometimes the exact formula of certain compounds used to manufacture components might provide a competitive advantage and therefore be entitled to trade secret protection, there

is no legitimate reason to hide the identity of each of the potentially toxic materials in such compounds. This leaves workers and community members around these facilities in the dark, unable to protect themselves.

For several reasons, the global brand manufacturers are starting to track their suppliers and some of the materials used in their products. In the U.S., the Dodd-Frank Wall Street Reform and Consumer Protection Act, which re-regulated the financial industry in 2010, also contained an obscure provision requiring manufacturers to trace and disclose conflict minerals used in their products. This pushed many brands to trace their metals supply chains for the first time. Studies conducted by NGOs in China traced water contamination to contract manufacturing plants and the major brands that are their customers, raising awareness of the global pollution emerging from electronics supply chains. These NGOs have insisted that the brands use their greater supply chain power to require compliance from their subcontractors. [16]The raft of NGO reports and media exposés of poor working conditions at Foxconn's China factories, which assemble iPhones, forced Apple to face public scrutiny of how its suppliers drive workers to produce the companies' products, and to acknowledge some responsibility for improving conditions.

Tracing their supply chains has proved surprisingly difficult for the big brands. While a few companies have decided to obtain and manage in their own databases the full inventory of materials used by suppliers, one prominent brand has estimated that it will take years to develop a process for tracking the materials used in its products (and this does not even include the chemicals that are used in their supply chain). Most companies do not appear even to have made this commitment, and no company has agreed to disclose these data. To its credit, Apple has published its supplier responsibility standards, and disclosed the names and locations of factories that supply its products – information that no other brand had released as of early 2014.[17] These

are tangible signs of progress, but the movement toward greater self-scrutiny and transparency about labor and health conditions across the industry is still nascent and uneven.

As the Vienna agreement notes, full transparency also would require every producer and manufacturer to make an inventory of all materials and chemicals used throughout the life cycle, and to disclose this information to the public and workers across the supply chain. Governments would enforce the provision of this kind of detailed health and safety information in the workplace and to surrounding communities, which can help workers and neighbors to hold companies accountable for handling materials safely. The industry needs to cooperate with public agencies, NGOs, unions, and health care providers to train workers and communities to spot dangers, reduce exposure to hazards, and protect health and safety. In the U.S., adopting laws establishing a "right to know" about toxic materials used in workplaces and communities was the first step toward strengthening permitting regulations for handling hazardous materials and establishing buffer zones between industrial facilities and residential areas.

These laws do not exist, or are not enforced, in much of the developing world. For example, in Taiwan, the second most densely populated country on earth, people who live only a few feet away from the high tech plants in the Hsinchu industrial park suffer from intense air, water, and noise pollution.[18] In Japan, regulators publish lists of the chemicals that industry releases into the environment, but withholds the locations and names of the companies responsible for these emissions, leaving workers and neighbors to guess what materials they are being exposed to regularly. China is beginning to require public reporting, and a new initiative that went into effect in January 2014 now requires the 15,000 largest factories to publicly report their air emissions and wastewater discharges continuously.[19] Clearly, a global right to know movement is needed. [20]

Addressing Harm throughout the Life-Cycle

As far back as 1992, Dr. Myron Harrison, a former physician for IBM, recognized that semiconductor "[e]ngineers are not evaluated nor rewarded on their ability to ... understand new or unusual health hazards. This task is the responsibility of health and safety professionals. Unfortunately, the opportunities for the professionals to be involved before these new processes arrive at the manufacturing floor are being diminished by the quickening pace of technologic change…"[21] Today, the electronics industry leaders need to acknowledge that they neglected to protect their workers from exposures to toxic chemicals, compensate the employees who have been made sick, and invest far more in preventing future harm than was spent in the past, up and down the supply chain.

One important step would be to establish legal responsibility for the illnesses already suffered by many electronics workers, and provide them with compensation and treatment. Even in many countries of the global North where workers' compensation laws are well-developed, the kinds of workplace illnesses that are found in electronics production are not compensated effectively. While there are actuarial schedules that establish standard payments for loss of limbs in workplace accidents, these kinds of tables do not exist for illnesses such as leukemia. It is notoriously difficult to determine whether workplace exposure, even to materials known to be toxic, is the main cause of an employee's cancer or miscarriage. Moreover, many of the thousands of chemicals used in electronics production have not been tested or regulated. The rapid churn of young employees through electronics factories and frequent changes in process chemicals make it difficult to trace long-term illnesses to workplace exposures. Courts and regulators have typically put the burden of proof that occupational exposure accounts for an employee's illness on the worker rather than the employer. As a result, corporations often claim

that workers have no proof that toxic chemicals are harmful, while the same companies refuse to conduct ongoing health monitoring or to participate in health studies that could provide the answers.

In a better world, the industry would bear the burden of proof that its workplaces are safe. Workers who develop diseases that are known to be associated with exposure to toxic materials found in in electronics workplaces would be eligible for compensation unless employers could demonstrate that these diseases were contracted by other means. The Vienna statement calls on governments to adopt laws that establish liability and compensation for victims of toxic exposures. This agreement recognizes that the rapid turnover of employees and chemicals characteristic of electronics production requires "systems funded by the employers that are designed to address these inherent challenges to fair compensation by developing mechanisms that assure that workers harmed by such exposure qualify for adequate and timely compensation, as well as treatment and rehabilitation."[22] In two important legal cases in Korea, appellate courts have ordered compensation for young Samsung workers who died from Leukemia, finding that there was sufficient evidence to prove the cases.[23]

Looking forward, it will be important to *prevent* hazardous substances from harming workers throughout the product life-cycle. The most powerful solutions will be implemented "upstream," in design, processing and production, because they will improve health and safety for "downstream" workers as well. Greening the design of electronics, especially by phasing out hazardous materials, replacing them with safer ones, and making electronics easier to disassemble and recycle, will reduce exposure to toxics. Industry should begin by eliminating the most dangerous substances, including those that are persistent and bioaccumulative, known carcinogens and mutagens, as well as substances that threaten reproductive and developmental

health, and the human immune system. Governments need to set and enforce exposure limits for workers based on rigorous testing of chemicals and materials. Testing should be paid for, but not controlled by, electronics producers and chemical companies because they have profited most from introducing poorly understood risks into the production process. Health-based exposure levels must give workers the same protection as community residents. Current laws allow exposures to workers that are often thousands of times less protective than comparable environmental laws designed to protect community residents. Table 1 illustrates these disparities in protection in the United States as of 2006 for several chemicals commonly used in electronics production; since then improvements in environmental standards have made the gaps even greater. Standards with which we are most familiar in Europe and Asia permit similar inequalities. As worker health and safety advocate Amanda Hawes says, "Workplace exposure limits are not even adequate to protect the average 'healthy adult male' worker and should instead be low enough to protect the most vulnerable people, including pregnant workers, their fetuses, and workers with compromised immune systems – the goal of every truly protective standard. This is especially true in electronics manufacturing, where workers are exposed to low levels of multiple toxins simultaneously."[24]

Not only is providing workers equal protection against toxics the only fair approach, it would also create a powerful incentive for employers to switch to safer chemicals. The cost of lowering exposure levels in the workplace to community levels can be a significant investment, and substituting non-toxic alternatives removes the need for such expenditures. Chemical substitution has always been at the top of the hierarchy of industrial hygiene methods but incentives to look for substitutes are too often not readily reflected in a company's bottom line.

Finally, when we do not have enough information to set exposure limits confidently, we should use the precautionary principle, eliminating or reducing exposures as low as possible.[25]

Protecting workers' health also requires a systematic approach, rather than targeting one chemical at a time. Despite using over a thousand chemicals, electronics manufacturers have phased out or reduced their use of only a handful of specific toxics. The industry has done so in response to external pressures. The European Union's Restriction of Hazardous Substances (RoHS) directive forced companies to phase out lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ether (PBDE).[26] The Montreal Protocol, a global treaty enforced since 1989, prompted the elimination of certain chlorofluorocarbons used as solvents in electronics, which deplete the earth's ozone layer.[27] While some manufacturers have stopped using a few additional chemicals (such as certain halogenated flame retardants and PVC) in response to public pressure and NGO campaigns, these efforts have not always resulted in safer substitutions for the chemicals being phased out. Increasingly, companies are becoming aware of this "unfortunate substitution trap" and are searching for ways out of this dilemma.

Creating a systematic road map for a safer future will depend on creating inventories of the chemicals the industry uses, identifying and replacing the hazardous ones with safer substitutes, developing better alternatives where none currently exist, and using best practices to protect workers and communities in the meantime. Electronics companies, their workers, and regulators need to monitor workplace exposure to all hazardous materials aggressively and make the data public to ensure that independent studies of worker health can be conducted. Manufacturers and chemical suppliers should also be required to fund independent research to develop safer chemicals, materials, and production processes.[28] The high technology industry

has thrived by making smart investments in research and development (R&D) to create the next new product. The industry needs to make a similar commitment to collaborative R&D aimed at protecting the health of its workers.

Establishing Extended Producer Responsibility

Extended Producer Responsibility (EPR) policies require electronics brands to collect and recycle their products at the end of their useful lives, or to pay contractors to do so. EPR aims to hold each manufacturer accountable for the full costs of its products at every stage in their life-cycle, thereby internalizing the price of responsible recycling in the manufacturer's bottom line. When companies know that they will bear the costs of collecting and dealing with their waste, they are more likely to redesign their products for easier and safer handling at each step in the life-cycle. In the early 2000s, the European Union, enacted laws that require electronics companies to take back their products from consumers. Since then, twenty-three U.S. states, and several other countries have followed suit. The Vienna agreement calls on all governments to enact policies that internalize the costs of electronics "throughout the life cycle . . . including extraction, materials processing, production, assembly, recycling and disposal."[29]

EPR policies hold several benefits for electronics workers. First, the best EPR policies require *responsible* recycling by including verifiable environmental and labor standards, such as banning e-waste from landfills (where chemicals can leach into water and soils), enforcing strong occupational health and safety regulations, and ending the use of prison labor (the most extreme example of workers who cannot protect themselves against exploitive wages and unsafe conditions) . EPR policies not only give producers an economic incentive to redesign electronics for safe and easy recycling, but also create an impetus to develop markets for reused materials that create safe jobs at living wages. Second, electronics recycling work that is currently

performed in the informal sector is more likely to be brought into regulated workplaces as brand manufacturers become more involved in setting up recycling facilities, and governments become more involved in monitoring the recycling infrastructure. Moving electronics recycling from back yard workshops to centralized facilities will make it easier for workers to organize themselves to protect their safety and demand fair wages, and for governments to check for compliance with labor laws.[30] The E-Stewards certification program (discussed below) has developed greater protections for e-waste workers.

Embracing Equity

The life-cycle of electronics imposes much heavier health and safety burdens on some local populations, especially workers in the developing world who are involved in mining, production, recycling, and disposal. These workers – few of whom enjoy the benefits of owning the latest televisions, computers, and phones – bear the most serious health risks posed by information age gadgetry. The Vienna statement recognizes "the urgent need to reverse the disproportionate burdening faced by developing countries during the more damaging phases of the life-cycle."[31]

The Chinese village of Guiyu, a major destination for much of the world's e-waste, offers one notable example of the unequal burdens of the global electronics trade. In less than a decade, the influx of electronics exports transformed what was a rice-growing and fishing village into a hotbed of computer scrapping. In 2002, NGOs began to draw the world's attention to Guiyu. After a visit to the village, the Basel Action Network collaborated with the Silicon Valley Toxics Coalition to publish a report that documented workers without protective gear being exposed to toxic lead as they smashed open computer monitors with hammers. Workers burned PVC-wrapped wires to get at the metals inside, breathing in smoke laden with dioxin, a

potent carcinogen. Much of this activity was carried out in family dwellings for an average wage of around $1.50 per day in U.S. dollars. Local waterways were choked with discarded circuit boards. Rivers and groundwater had become too contaminated with heavy metals to drink or fish in safely. Many villagers complained of respiratory problems and pneumonia.[32] Later epidemiological studies confirmed that residents suffered from unsafe levels of lead and other toxins in their blood, elevated risk of birth defects, and higher rates of death from male genital diseases.[33]

To the extent that EPR can reduce risks at each stage of the product's life, this can help to address some glaring inequalities. In the past, stricter first world laws aimed at reducing pollution at the point of production have spurred the transfer of hazardous manufacturing to countries with lax enforcement of inadequate health and labor standards. Stronger protections for developing world workers and communities against unsafe recycling and disposal have pushed these activities to the margins of the world economy as well. Rather than shifting risks to workers in developing nations, the goal of EPR is to spread health and safety benefits globally. These benefits – reduced use of toxics in production, responsible local waste collection systems, easier and safer materials separation in recycling and disposal – will be felt by workers at each step in the product life-cycle, wherever it occurs.

Inequities should also be addressed by dispersing safer recycling technologies around the globe rather than dumping e-waste on the developing world. The Vienna agreement demands that wealthier countries make good on their promises to stop exporting hazardous electronic waste to poorer countries. Most developed countries, with the notable exception of the U.S., have ratified the Basel Convention, an international treaty that restricts hazardous waste exports from developed nations to developing countries. Unfortunately, the trade in e-waste continues through

the black market and through legal shipments of "donated" computers, televisions, and phones, which are often a cover for exporting outdated equipment that is nearly useless and will end up being recycled or dumped abroad. New green jobs in recycling can be created in developed countries, but only if these countries take full responsibility for handling their own e-waste, controlling the flow of near-end-of-life equipment, and protecting recycling workers from the hazards. Industry, governments, and NGOs also need to work together to establish and disseminate best practices in manufacturing and recycling, transfer the safest production and disposal technologies around the world, and remediate sites that have been contaminated, as in Guiyu.

Achieving fair compensation and safer working conditions for production workers depends upon governments in the developing world adopting more sensible economic policies. In their lust for Silicon Valley style development, many governments have been too eager to join a bidding war to "win" electronics production facilities by giving away more corporate welfare than other countries. Urged on by the largest global electronics companies who continue to foment bidding wars, these governments have wooed some of the most profitable corporations in the world by creating Special Economic Zones (SEZs), which offer incentives to set up plants for assembling goods aimed at foreign markets. [34] Electronics companies and their suppliers have been some of the main beneficiaries of the huge tax breaks, free provision of infrastructure, and disregard for enforcing safety, health, and labor standards found in many SEZs. Many local governments have been indifferent or hostile to those who bring these issues into the public arena because of officials' blind commitment to export-led development at any cost and their fear that public visibility of the collateral damage will tarnish the image of their countries' "economic miracles." [35] Workers and consumers who care about their effects on the world

deserve something more: economic development with environmental justice, which includes the fair distribution of health burdens and benefits among all who participate in the electronics sector and ongoing improvement of workplace safety.

Conclusion

Achieving occupational health and safety in electronics is not simply a matter of perfecting workplace regulations. While important, these regulations will only be as effective as their implementation, which depends on advancing workers' human rights to organize and participate in workplace health monitoring, greater transparency of global supply chains to outside scrutiny, taking steps to promote safety at each step of a product's life-cycle, requiring producers to take responsibility for recycling their electronics in ways the incentivize safer design, and sharing the benefits and burdens of the electronics industry more equitably.

While achieving these policy goals may appear daunting, there are promising strategies already available (see Raphael and Smith in this volume). We will know that we have arrived at a sustainable electronics industry when authentic workers' organizations, and independent public health experts and non-governmental organizations, tell us so. Electronics workers, their communities, and consumers deserve no less.

Table 1. Disparities in U.S. Occupational and Environmental Health Standards (2006)

Toxic Agent	Most Protective Occupational Exposure Limit in Air (8 hour time weighted average)	Most Protective Environmental Exposure Limit in Air (Converted to 8 hour time weighted average)	Disparity in Exposure Limit
Benzene	1 ppm	1 ppb	1,000 to 1
Trichloroethylene	25 ppm	7 ppb	3,571 to 1
Perchloroethylene	25 ppm	.3 ppb	8,333 to 1
Methylene Chloride	25 ppm	1 ppb	25,000 to 1

Note: ppm = parts per million; ppb = parts per billion.

Source: Amanda Hawes of Worksafe (and founder of Santa Clara Center for Occupational Safety and Health).

[1] In 2010, the International Labor Organization estimated that 3.64 million people work in the formal mining sector, while around 25 million toil in informal artisanal and small-scale mining (ASM) operations. Erick J. Zeballos and Stefanie Garry, *Jobs Recovery: A Global Overview of Employment Trends and Working Conditions by Economic Activity* (Geneva: Sectoral Activities Department, International Labour Organization, 2010). On child labor in mining, see Richard Maxwell and Toby Miller, *Greening the Media* (Oxford: Oxford University Press, 2012), 93-4.

[2] Safiatou Ba-N'Daw et al., *Report of the Panel of Experts on the Illegal Exploitation of Natural Resources and Other Forms of Wealth of the Democratic Republic of Congo*, report to the United Nations Security Council, 12 April 2001, accessed February 26, 2014, http://www.unhchr.ch/huridocda/huridoca.nsf/554221922d46153bc1256991004a440b/5e423385c10ae294c1256b1100505218/$FILE/N0132354.DOC; Global e-Sustainability Initiative, *Social and Environmental Responsibility in Metals Supply to the Electronic Industry* (Brussels: Global e-Sustainability Initiative, 2008).

[3] See Thomas Gassert, *The Global Electronics Industry - Worker and Community Health* (Groveland, MA: New England College of Occupational and Environmental Medicine, 2005), accessed April 4, 2014, http://necoem.org/documents/0512GassertB.pps, especially pp. 16 – 27. The European Union's Restriction of Hazardous Substances (RoHS) directive has required companies to phase out their use of a handful of these chemicals. Yet past exposures can continue to affect workers, there are thousands of toxics used in electronics production, there are still many exemptions that permit the use of dangerous substances, and the European Union has recently failed to update the RoHS directive to address these hazards.

[4] For summaries of the research, see Joseph LaDou, "Occupational Health in the Semiconductor Industry," in *Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry*, eds. Ted Smith, David A. Sonnenfeld, and David Naguib Pellow (Philadelphia: Temple University Press, 2006), 31-42; Joseph Ladou and John C. Bailar, "Cancer and Reproductive Risks in the Semiconductor Industry," *International Journal of Occupational and Environmental Health* 13 (2007): 376-85; Myoung-Hee Kim, Hyunjoo Kim, and Domyung Paek, "The Health Impacts of Semiconductor Production: An Epidemiologic Review," *International Journal of Occupational and Environmental Health* 20 (2014): 95-114.

[5] Basel Action Network and Silicon Valley Toxics Coalition, *Exporting Harm: The High-Tech Trashing of Asia* (Seattle and San Jose, CA: The Basel Action Network and Silicon Valley Toxics Coalition, 2002); Silicon Valley Toxics Coalition and Computer Takeback Campaign, *Corporate Strategies for Electronics Recycling: A Tale of Two Systems* (San Jose, CA: Silicon Valley Toxics Coalition and Computer Takeback Campaign, 2003); Diana Ceballos, Wei Gong, and Elena Page, *Potential Occupational Exposures at Electronic Waste (e-waste) Recycling Facilities* (Washington, DC: National Institute for Occupational Safety and Health), accessed April 5, 2014, http://www.resource-recycling.com/ESC2013/Ceballos.pdf; Richard W. Clapp, "US Computer Manufacturing Workers Studies" (paper presented at the annual meeting for the American Public Health Association, San Francisco, CA, October 27-31, 2002); Myoung-Hee Kim, Hyun-Joo Kim, and Domyung Paek, "Epidemiologic review on the health impacts of semiconductor production," (paper presented at the annual meeting for the American Public Health Association, San Francisco, CA, October 27-31, 2002); Xia Huo et al., "Elevated Blood Lead Levels of Children in Guiyu, An Electronic Waste Recycling Town in China," *Environmental Health Perspectives* 115 (2007): 1113-17; Xia Huo et al., "ALAD Genotypes and

Blood Lead Levels of Neonates and Children from E-Waste Exposure in Guiyu, China," *Environmental Science and Pollution Research* 21 (2014): 1-7.

[6] For overviews of labor conditions in electronics, see Anibel Ferus-Comelo, "Mission Impossible? Raising Labor Standards in the ICT Sector," *Labor Studies Journal* 33 (2008): 141-62; Marisol Sandoval and Kristina Areskog Bjurling, "Challenging Labor: Working Conditions in the Electronics Industry," in *Lessons for Social Change in the Global Economy: Voices from the Field*, eds. Shae Garwood, Sky Croeser, Cristalla Yakinthou (Lanham, MD: Lexington Books, 2014), 99-124; Kathleen Kearney, Sanjiv Pandita, and Fahmi Panimbang, eds., *Labour Rights in High Tech Electronics: Case Studies of Workers' Struggles in Samsung Electronics and its Asian Suppliers* (Kowloon, Hong Kong: Asia Monitor Resource Centre, 2013); Judy Branfman, "Where There Are Few Unions: Health and Safety Education for Organizing in Export Zones," *Research and Policy Brief no. 16* (Los Angeles: UCLA Institute for Research on Labor and Employment, 2013), accessed November 18, 2014, http://www.irle.ucla.edu/publications/documents/ResearchBrief16.pdf; Jenny Holdcroft, Creating Conditions for Collective Labour Relations to Improve Labour Rights in the Electronics Industry (Geneva: International Metalworkers Federation, 2009), accessed March 31, 2014, http://www.ilera-directory.org/15thworldcongress/files/papers/Track_2/Poster/CS1W_45_HOLDCROFT.pdf; Sophie Stracke, Nina Lendal, and Frederik Johannisson, *IT Workers Still Pay the Price for Cheap Computers: Case Study of Labour Conditions at 4 Dell Suppliers in China* (Copenhagen: DanWatch, 2013), accessed March 31, 2014, https://www.danwatch.dk/sites/default/files/documents/dw_kina_181013_0_0.pdf.

[7] Kearney et al., eds., *Labour Rights in High Tech Electronics*; Branfman, "Where There Are Few Unions"; Holdcroft, "Creating Conditions for Collective Labour Relations"; Stracke et al., *IT Workers Still Pay the Price*.

[8] Strategic Approach to International Chemicals Management (SAICM), *Report of the International Workshop on Hazardous Substances within the Life-Cycle of Electrical and Electronic Products, Held in Vienna, from 29 to 31 March 2011* (Geneva: SAICM, 2011), accessed December 19, 2013, http://www.saicm.org/images/saicm_documents/iccm/ICCM3/Meeting%20documents/INF%20Documents/ICCM3_INF24_Report%20e-waste%20workshop.pdf.

[9] Other initiatives that have adopted some or all of the goals in the Vienna agreement include The Sustainable Electronics Forum held on October 15-18, 2012, co-sponsored by the U.S. Environmental Protection Agency, the Green Electronics Council, and The Johnson Foundation; the American Public Health Association's policy statement on improving workplace health in the electronics industry; and the vision for a sustainable electronics industry developed by the Electronics TakeBack Coalition, which is leading efforts for extended producer responsibility laws in the U.S. See White House Council on Environmental Quality, Environmental Protection Agency, and General Services Administration, *National Strategy for Electronics Stewardship* (Washington, DC: Interagency Task Force on Electronics Stewardship, 2011), accessed March 31, 2014, http://www.epa.gov/wastes/conserve/materials/ecycling/taskforce/docs/strategy.pdf; American Public Health Association, *Improving Occupational and Environmental Health in the Global Electronics Industry* (Washington, DC: APHA, 2012), accessed March 31, 2014, http://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2014/07/21/08/43/improving-occupational-and-environmental-health-in-the-global-

electronics-industry#Anchor%201; Electronics TakeBack Coalition, *The Vision for Sustainable Electronics Project* (San Jose, CA: Electronics TakeBack Coalition, 2012), accessed March 31, 2014, http://icrt.co/images/pdf_files/ngo%20sustainable%20electronics%20vision%20project%20narrative%20v8.pdf.

[10] SAICM, *Report of the International Workshop on Hazardous Substances*, 31.

[11] Ted Smith, "Why We Are 'Challenging The Chip' – The Challenges of Sustainability in Electronics," *International Review of Information Ethics* 11 (2009): 12.

[12] United Nations, *Universal Declaration of Human Rights*, Articles 20 and 23 (New York: United Nations, 1948), accessed March 31, 2014, http://www.un.org/en/documents/udhr/index.shtml; International Labour Office, *The International Labour Organization's Fundamental Conventions* (Geneva: ILO Publications, 2002), 18.

[13] SAICM, *Report of the International Workshop on Hazardous Substances*, 23. These rights, governments' obligations to enforce them, and businesses' duty to observe them, are elaborated in United Nations Human Rights Office of the High Commissioner, *Guiding Principles on Business and Human Rights: Implementing the United Nations "Protect, Respect and Remedy" Framework* (New York and Geneva: United Nations, 2011), accessed April 11, 2014, http://www.ohchr.org/Documents/Publications/GuidingPrinciplesBusinessHR_EN.pdf.

[14] SAICM, *Report of the International Workshop on Hazardous Substances*, 28.

[15] Fahmi Panimbang, "Breaking the Chains: Workers' Struggles in Electronics Supply Chains." in Kearney, Pandita, and Panimbang, *Labour Rights*, 13.

[16] See Friends of Nature et al., *The Other Side of Apple II -- Pollution Spreads Through Apple's Supply Chain* (Vienna: Friends of Nature, 2011), accessed March 31, 2014, http://www.ipe.org.cn/Upload/Report-IT-V-Apple-II-EN.pdf; Friends of Nature, Institute of Public and Environmental Affairs, and Green Beagle, *Green Choice Consumers Urge the I.T. Brands to Break their Silence* (Vienna: Friends of Nature, 2011), accessed March 31, 2014, http://www.ipe.org.cn/Upload/Report-IT-Phase-Three-EN.pdf.

[17] Apple, *Supplier Responsibility 2014 Progress Report* (Cupertino, CA: Apple, 2014), accessed March 31, 2014, http://images.apple.com/supplier-responsibility/pdf/Apple_SR_2014_Progress_Report.pdf.

[18]Leslie Byster and Ted Smith, *From Silicon Valley to Green Silicon Island: Taiwan's Pollution and Promise in the Era of High-Tech Globalization* (San Jose, CA: International Campaign for Responsible Technology, 2001), accessed April 7, 2014, http://icrt.co/index.php?option=com_content&view=article&id=166:2001-silicon-valley-to-silicon-island&catid=73:history&Itemid=532.

[19] Linda Greer, "China Fights Back against Airpocalypse: A new air pollution initiative that just might work!" *Switchboard: Natural Resources Defense Council Staff Blog*, January 12, 2014, accessed April 4, 2014, http://switchboard.nrdc.org/blogs/lgreer/china_fights_back_against_airpocalypse_embarking_on_a_new_air_pollution_initiative_that_just_might_work.html.

[20] To this end, countries should ratify and enforce the United Nations Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, known as the Aarhus Convention, and its Protocol on Pollutant Release and Transfer Registers (PRTR) (Geneva: United Nations Economic Commission for Europe, 1998), accessed

March 31, 2014, http://www.unece.org/env/pp/welcome.html. The PRTR became international law binding its signatories on October 8, 2009. As of January 7, 2014, the Protocol has been ratified by 32 countries and the European Union.

[21] Myron Harrison, "Semiconductor manufacturing hazards," in *Hazardous Materials Toxicology: Clinical Principles of Environmental Health*, eds. John B. Sullivan and Gary Krieger (Baltimore: Williams and Wilkins, 1992), 472–504.

[22] SAICM, *Report of the International Workshop on Hazardous Substances*, 24.

[23] Youkyung Lee, "Studies understated Samsung health hazards," *IOL SciTech*, October 25, 2013, accessed April 5, 2014, http://www.iol.co.za/scitech/technology/news/studies-understated-samsung-health-hazards-1.1597427#.Uz8ArvldUrW.

[24] Amanda Hawes, e-mail message to authors, April 11, 2014.

[25] SAICM, *Report of the International Workshop on Hazardous Substances*, 22, 31-2. The precautionary principle states:

> When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof. The process of applying the Precautionary Principle must be open, informed and democratic and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action.

"Wingspread Statement on the Precautionary Principle," accessed March 31, 2014, http://www.sehn.org/state.html#w.

[26] European Commission, *Restriction of the use of certain hazardous substances (RoHS)* (Brussels: European Commission, 2011), accessed November 18, 2014, http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/restriction-of-hazardous-substances/index_en.htm.

[27] United Nations Environment Programme, *Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer, 9th edition* (Nairobi: UNEP, 2012), accessed November 18, 2014, http://ozone.unep.org/new_site/en/montreal_protocol.phpp.

[28] SAICM, *Report of the International Workshop on Hazardous Substances*, 20, 22.

[29] Ibid., 24.

[30] Chad Raphael and Ted Smith, "Importing Extended Producer Responsibility for Electronic Equipment into the United States," in *Challenging the Chip*, 247-59; Chad Raphael, "E-waste and the Greening of the Information Age," *STS Nexus* 3, no. 2 (2003): 23-28.

[31] SAICM, *Report of the International Workshop on Hazardous Substances*, 31.

[32] Basel Action Network and Silicon Valley Toxics Coalition, *Exporting Harm*, 15-16.

[33] Xijin Xu et al., "Birth Outcomes Related to Informal E-Waste Recycling in Guiyu, China," *Reproductive Toxicology* 33 (2012): 94-98; Xijin Xu et al., "Increase Male Genital Diseases Morbidity Linked to Informal Electronic Waste Recycling in Guiyu, China," *Environmental Science and Pollution Research* 21 (2014): 3540-5.

[34] There are a multitude of SEZs, offering somewhat different packages of incentives for investment in manufacturing and assembly for global markets, including Economic Trade and Development Zones, Export Processing Zones, High Tech Industrial Development Zones, and Free Trade Zones. See Sandoval and Bjurling, "Challenging Labor," 104.

[35] Ted Smith, Preface to *Challenging the Chip*, Chinese translation (Taipei: Socio Publishing Co., Ltd., 2014); Branfman, "Where There Are Few Unions."