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Hearing on:

Electronic waste – Can the nation manage modern refuse in the digital age?

Testimony of:

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Chairman Gordon and other Members of the Committee, it is my pleasure to be here today to testify on the topic of end-of-life electronics. My name is Eric Williams and I am an Assistant Professor at Arizona State University with a joint appointment between the Department of Civil and Environmental Engineering and the new School of Sustainability.

The fate of end-of-life of electronics, also known as e-waste, has gained a great deal of attention from policymakers and public around the world. The chain of activities from manufacturing to operation to disposal is highly globalized and continues to globalize further. Policy decisions taken here in the U.S., in Europe, in China have global implications for the industries involved in electronics manufacturing and end-of-life. Here in the U.S. some states such as California and Maine have already developed and implemented state-level legislation mandating recycling of end-of-life electronics. Given the importance of the electronics industry both in the U.S. and globally, I believe it important that the U.S. government takes a leadership role in developing responsible policies and practices for managing e-waste. In my testimony I intend to lay out one view of how this nation might work towards sustainable management of end-of-life electronics.

End-of-life electronics: a unique challenge

First I will discuss how management of end-of-life electronics is a unique new challenge compared to previous products. One reason is the rapid evolution of electronics technology. Rapid progress goes hand-in-hand with rapid obsolescence, which has two main implications for environmental management. One is that it stimulates purchases of new devices as consumers aim to take advantage of improved technology. A second is that the characteristics of the waste stream evolve along with the product.

A second reason is that the environmental intensity of manufacturing electronics, in particular information technology goods, is higher than many other consumer products. For example, it takes four times more energy to make a desktop computer than it consumes while plugged in at home. For a refrigerator, in contrast, most energy is used in operation, the energy used in manufacturing is a small share. This high energy intensity in manufacturing combined with rapid product turnover implies a surprisingly high net impact: when the energy used in manufacturing is amortized over the life of the product, annual energy costs for owning a personal computer are higher than for a refrigerator.

How does this high environmental intensity of manufacturing tie in with the e-waste issue? Reduce, reuse, recycle, or the 3Rs, is a mantra of waste management. However, most of the environmental investment in high-technology electronics is in not in the materials but is in its complex manufactured form. Recycling is less effective at recovering this investment than for many other goods (e.g. an aluminum can). While appropriate end-of-life management is needed, the high environmental investment in form versus materials in electronics tilts the 3Rs such that Reduce and Reuse tend to be much more effective than recycling at reducing life cycle environmental impacts. Extending lifespan is thus an important strategy to mitigate environmental impacts. Extending lifespan does not mean that we should make do with slide rules or pocket calculators! Rather, we should work to match the performance specs of hardware with actual needs of users, for example with reuse markets.

A third reason e-waste management poses a unique challenge is the mix of materials used in making electronics. Electronics contain valuable materials for recycling such as copper, silver and gold as well as known toxic substances such as lead, cadmium and mercury. There are also new substances of concern: for instance, brominated flame retardants are added to circuit boards and cases to reduce flammability. Recent scientific studies show that some brominated flame retardants are endocrine disruptors and that their concentrations in human tissues are rapidly increasing. While the human health and environment effects of brominated flame retardants are uncertain, I believe there is enough evidence to justify concern and response.

Much of the environmental discourse surrounding e-waste centers around the concern that lead and other heavy metals could leach from e-waste put into landfills and contaminate ground water. Circuit boards and Cathode Ray Tubes (CRTs) fail the EPA's Toxicity Characteristic Leaching Procedure (TCLP) test, resulting in these items being classified as hazardous waste. The TCLP test involves grinding up the material in question, putting it into an acidic solution and measuring the amount of material (such as lead) that seeps out. My colleagues and I at Arizona State University recently reviewed the literature relevant to the actual risk of heavy metals leaching from e-waste in sanitary landfills in the U.S. Our conclusion was that the risk of environmental harm from landfilled e-waste is negligible, despite the failure of the TLCP test by some electronic components. The main reasons for this are: 1. that the TCLP tests are considerably more aggressive than the leaching that actually occurs in municipal (non-hazardous) waste landfills and 2. modern landfills have control systems to contain any toxics which may leach out.

Is modern recycling of circuit boards and CRTs actually environmentally preferable to putting these parts in sanitary landfills? We argue that that this is not known and that it is conceivable that recycling could emit more toxic heavy metals over the life cycle. Recycling by definition mobilizes materials (e.g. via smelting), and depending on the level of process control can emit lead, mercury, and other hazardous substances. In contrast with landfills however, recycling has the virtue of replacing production of virgin materials with recycled substitutes. If the avoided lead emissions associated with mining and milling are larger than for recycling, recycling would reduce total lead emissions. If not, recycling e-waste has the potential to release more lead to the environment than e-waste in landfills. Currently there are no analyses addressing under what circumstances which option (recycle versus landfill) leads to lower life cycle emissions of heavy metals. I suggest that this issue be resolved before public policy mandates recycling as the default environmentally preferable alternative.

A fourth reason e-waste management present a challenge is that while reuse and recycling of electronics in the developing world runs a net profit in the U.S. recycling often results in a net cost. The main factors contributing to this dichotomy are lower labor costs, higher demand for reused products and parts, and less stringent environmental protections in the developing world. Recycling in the developing world at a net profit versus recycling in the U.S. at a net cost creates a market dynamic for exporting electronics to the developing world. The electronics reuse/recycling industry is a double-edged sword for the developing world. On one hand reuse markets provides access to technology to people who otherwise could not afford it and creates jobs for thousands of people. Many of the electronics goods people own in developing countries were first used in the U.S. The availability of low cost recycled computers and cell phones, in particular, can play an important role in increasing the use of Information Technology (IT) to enhance economic and educational activities in developing countries.

On the other hand, recycling of electronics in developing countries is often implemented by an informal industry. U.S. NGOs such as the Basel Action Network (BAN) and the Silicon Valley Toxics Coalition have reported that informal recycling activities in China, India and Nigeria cause serious environmental harm. For example, in many cases wires are pulled from computers, collected and burned in open piles to remove casings and recover re-saleable copper. This results in creation and emission of dioxins, furan and other environmental pollutants. Circuit boards are treated to extract copper and precious metals using acid, cyanide and/or and mercury often in a manners that leads to uncontrolled discharge of contaminated process liquid, sometimes next to rivers. Scientific evidence is mounting which confirms that the environmental impacts of these activities are indeed severe. In Guiyu, a town in China well known for informal electronics recycling, emissions of dioxins were shown to be thousands of times the U.S. standard and blood lead concentration in children were found to exceed levels of concern. It is my opinion that informal recycling represents by far the most serious environmental issue for end-of-electronics. Yet there is as yet little action being taken to improve health and safety conditions in the industry. I believe that the U.S. should work with developing countries to address informal recycling.

Policy and e-waste

End-of-life electronics management interfaces with environmental, social and economic issues. What are nations and regions around the world doing legislatively to address this management challenge? There are three primary approaches. The first legislative approach is enacting takeback systems which collect end-of-life electronics for recycling. Such systems have been mandated in the European Union, Japan and other nations, and a few U.S. states such as California and Maine. The ostensible goals of this legislation are to keep e-waste out of landfills and increase recycling of materials. However, the net environmental benefit of this legislation is I believe as yet unclear. Recycling may not be environmentally preferable to landfilling and in addition takeback systems could have an adverse affect on reuse of equipment. I do not believe the landfill versus recycle question has been sufficiently resolved to warrant a blanket priority for policy.

The second approach to legislation regulates the use of materials in electronics. The primary example of this type of policy is the Restriction on Hazardous Substances (RoHS) legislation promulgated in the European Union. RoHS restricts six hazardous elements in different applications; lead, mercury, cadmium, hexavalent chromium, and the polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) flame retardants. Any electronics manufacturer wishing to sell their products in Europe must abide by the rules, thus this regional legislation effects global change in the industry. Exposure to brominated flame retardants presumably occurs while the goods are in service, thus removing them has a high potential to reduce consumer risk. However, banning the use of lead in solder has been a particular source of controversy with respect to RoHS, with many in the U.S. arguing that the environmental need for the ban is unclear. For heavy metals like lead, exposure generally is not an issue during use of the product but depends on handling at end-of-life. Furthermore, while lead exposure in informal recycling is a clear risk to workers and local communities, the overall risk to workers from lead exposure is reduced but not clearly managed by banning lead solder, since lead is only removed from solder but not from CRTs, which contain far more lead than solder.

A third approach to legislation regulates trade in end-of-life electronics. This is usually applied at the national level, for instance China bans imports of used electronics and e-waste. However, while officially a ban is in place in China, the imports of e-waste coming in China have continued unofficially more or less as before. At the international level, the central framework for controlling international movements of hazardous substances is the Basel Convention. The Basel Convention requires prior notification between signatories when trading wastes classified as hazardous. Many categories of e-waste are classified as hazardous waste and thus are targeted for prior notification. Products intended for reuse, however, are exempt from control. Furthermore, the Convention does not suggest how to establish the reusability of a given trade flow in practice, a nontrivial challenge.

Do these current policy directions achieve desirable environmental, social and economic objectives for society? On the environmental side, many in the scientific community are of the opinion that the risk associated with landfilling e-waste has been vastly overstated. The most pressing environmental issue is, in all likelihood, the adverse impact of informal recycling in developing countries. Dealing with these and other issues can lead to complex ethical choices. Policies can result in tradeoffs between environmental, economic and social issues. For example a ban on exports of end-of-life electronics might seem an appropriate course of action to mitigate environmental impacts of informal recycling. However, a blanket trade ban would make used IT equipment less available abroad. Also, it would cut off the supply of raw material to a reuse/recycling industry providing thousands of jobs to poor people. Is this appropriate, especially given an absence of prior attempts to redress occupational and safety issues of the industry?

While it may seem off-topic, I think it important to raise the issue of the environmental applications of IT. Informational Technology can be used to reduce a variety of different environmental impacts. For instance, it can reduce the impacts of transportation systems by enabling telecommuting, virtual meetings, and creating virtual networks of car-poolers. Furthermore, a great deal of energy consumption in residential and commercial buildings goes towards energy services not actually needed, such as heating or cooling unoccupied rooms. Substantial energy can be saved via computerized monitoring and control systems. The environmental management of electronics has come to be conceptualized in terms of its potential end-of-life impacts. While end-of-life impacts should certainly be better managed, we should allocate our attention and resources in proportion to potential benefits. The environmental potential of IT is significant yet relatively ignored.

Towards the future: Product, reuse/recycling processes and policy design

It is important to work creatively towards the design of products, reuse and recycling processes, and policies to achieve multiple societal objectives. An important starting point to achieve this goal is characterizing domestic and international flows of end-of-life electronics. Currently flows of e-waste products and materials are poorly understood. One reason for this is that reuse and recycling activities do not have their own industry or commodity codes and are thus invisible to conventional trade statistics systems. Under a grant from the National Science Foundation in the Environmental Sustainability program, my colleagues and I at Arizona State University are working to characterize international e-waste flows and come up with new solutions to capture this information. This is at present the only U.S. project of its ilk I know of. Japan in comparison is investing far more in order to characterize and plan management of international end-of-life flows for a variety of consumer products and recycled materials.

Product design can be viewed through three different lenses: materials, assemblies, and informatics. Material selection is one important strategy for optimizing end-of-use value. The RoHS legislation for example takes the step of banning two brominated flame retardants. The potential snag is that it is not yet clear whether environmentally acceptable alternatives are available. Research and development in green chemistry is needed to develop and test alternatives. We should however be cognizant that material selection faces limits. Even a computer completely free of toxic substances would still be dangerous to recycle informally because of the toxic substances generated and used in recycling. I believe the target should be managing the exposure to toxics by developing environmentally sound recycling processes rather than the complete elimination of all substances of concern.

Assemblies refer to how parts are put together, which also has effects on end-of-life processing. Disassembly is currently carried out by hand and labor costs are an important cost issue. Snap-fits for easier disassembly and making parts of concern such as nickel cadmium batteries easily accessible reduces labor costs of recycling and potentially reduces adverse impacts of informal recycling.

The design of informatics as it relates to the end of life of products is much less discussed than material and assembly choice. Information Technology can be applied to construct information systems to enhance the reusability and recyclability of products. For example, Radio Frequency Identification Devices (RFIDs) could be placed in computers to provide information wirelessly to reuse/recycling systems. One concept is an RFID “blackbox” for each computer, which periodically records the functionality of different subsystems. At the end of life, a computer arriving at a processing center can be wirelessly scanned for functionality and selected for reuse versus recycling.

Another layer of informatics design relates to the ease and security with which consumers can resell their computers. After purchasing a replacement computer, consumers often store their old computer, unused for years, until some decision is made regarding its end-of-life disposition. One reason for this is concern whether data on the old computer has been backed up and if it can be securely erased before selling. There are software applications which could be packaged with computers which create backups and then thoroughly erase all data. Another obstacle to used markets relates to the transfer of the right to use pre-installed software from first user to secondary user. In general software license agreements grant the secondary user the same rights to use software but in practice the current rights labeling system does not enable the secondary user to clearly establish this right from a legal perspective. To protect themselves from litigation from software companies, reuse and refurbishing companies routinely wipe hard drives of the used computers they purchase. This loss of software reduces the value of the used computer. This could be avoided if pre-installed software rights were packaged with the computer in a verifiable way.

Considering end-of-life processes, one important task is to assess the environmental characteristics of recycling, especially those processes such as smelters and acid leaching which mobilize toxics. There are a variety of recycling processes and practices currently in use around the world. Assessment will reveal which are best practices and in what specific areas it may be most appropriate to invest in research and development of environmentally benign recycling processes.

Another layer of design is policy. It is fair to characterize the current status of policy development as one in which nations and states are experimenting with different policy designs to manage end-of-life electronics. There is still much room to develop policy alternatives. One alternative policy direction is to design systems intended to ensure environmentally safe end-of-life management while at the same time establishing a competitive market for reuse and recycling services. One concrete idea to realize this goal is termed e-Market for Returned Deposit. The e-Market system begins with a deposit paid by consumers to sellers at the time of purchase, electronically registered and tracked via a Radio-Frequency Identification Device (RFID) placed on the product. At end-of-life, consumers consult an Internet-enabled market in which firms compete to receive the deposit by offering consumers variable degrees of return on the deposit. After collection of the computer by the selected firm, the cyber-infrastructure utilizes the RFID to transfer the deposit to the winning firm when recycled. If the firm chooses to refurbish or resell the computer in lieu of recycling, the transfer is deferred until true end-of-life processing.

A second policy proposal focuses on redressing the environmental impacts of informal recycling abroad. The basic idea is to pay workers involved in reuse and disassembly not to recycle those components dangerous to handle with informal processing. This could be implemented via a system which establishes collection points at which workers would be paid fixed prices to deliver targeted parts. The price is set to create a financial incentive for informal recyclers to deliver the targeted parts rather than process them on their own. Under this system the collected parts would be transported and processed in appropriate recycling facilities. Since much of the cost associated with recycling is with transport and disassembly, this system would presumably be an inexpensive option to avoid informal recycling while maintaining an active reuse industry.

Conclusion

Are there product, process and policy designs which allow us to mitigate environmental impacts while at the same time realizing the social and economic benefits of recycling and reuse of electronics? Management efforts up to now have focused on heuristic goals such as increasing recycling rates and banning e-waste from landfills. It is not clear to me that this approach will take us where we want to go. We need to think about desired endpoints such as safety from exposure to toxics, net reduced energy use, availability of affordable IT to everyone, and creating jobs and capital. We should work backwards from these endpoints to find the policies, processes, and product designs which deliver the desired outcomes. In addition, we also need to work much harder on using IT as a tool to achieve environmental goals. Here are some suggested starting points:

- Investigate the life cycle environmental pros and cons of landfilling and recycling end-of-life electronics in order to benchmark best practices. This evaluation should allow reconsideration of whether the current TCLP based standard regulating the landfilling e-waste is appropriate.
- Undertake research to develop new materials as appropriate, such as bromine-free flame retardants. New materials need to be thoroughly evaluated before they are adopted.
- Encourage reuse of electronics through improved informatics design, such as bundling of backup/erase applications with new computers. These improvements make it easier for users to resell their computer securely and with software intact.
- Work to ensure that used electronics we export to developing countries is in good working order. Strategies to achieve this include use of RFID blackboxes to enable remote checking of recent functionality and certification schemes for used equipment.
- Work with developing countries to improve occupational, health and safety conditions in informal recycling industries.

I believe the U.S. federal government should take a leadership role in working towards a sustainable management of electronics. The electronics industry is not a domestic affair, and policies outside the U.S. federal context affect the global system. If the federal government does not take action, other nations will, setting the playing field without US input. I hope we can proceed through a combination of thinking creatively, assessing carefully, and acting decisively to create sound policies and practices for end-of-life management of electronics. I and my colleagues at Arizona State University would like to thank you for your attention.