ELECTRONIC WASTE: INVESTING IN RESEARCH AND INNOVATION TO REUSE, REDUCE, AND RECYCLE

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COMMITTEE ON SCIENCE AND TECHNOLOGY

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ELECTRONIC WASTE: INVESTING IN RESEARCH AND INNOVATION TO REUSE, REDUCE, AND RECYCLE

WEDNESDAY, FEBRUARY 11, 2009

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Committee met, pursuant to call, at 10:06 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bart Gordon [Chair of the Committee] presiding.

Hearing on

ELECTRONIC WASTE: INVESTING IN RESEARCH AND INNOVATION TO REUSE, REDUCE, AND RECYCLE

Wednesday, February 11, 2009
10:00a.m. – 12:00p.m.
2318 Rayburn House Office Building

Witness List

Dr. Valerie Thomas
Anderson Interface Associate Professor
School of Industrial and Systems Engineering, Georgia Institute of Technology

Dr. Paul Anastas
Teresa and H. John Heinz III Professor in the Practice of Chemistry for the Environment
School of Forestry and Environmental Studies, Yale University

Mr. Philip J. Bond
President
TechAmerica

Mr. Jeff Omelchuck
Executive Director
Green Electronics Council, Electronic Product Environmental Assessment Tool (EPEAT)

Mr. Willie Cade
Founder and Chief Executive Officer
Home of the Computers for Schools Program, PC Rebuilders and Recyclers

HEARING CHARTER

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Electronic Waste: Investing in Research and Innovation to Reuse, Reduce, and Recycle

WEDNESDAY, FEBRUARY 11, 2009
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On February 11, 2009, the Science and Technology Committee will receive testimony on draft legislation entitled "The Electronic Waste Research and Development Act of 2009." Witnesses will provide their comments on, and suggestions to, the bill. They will also discuss ways in which research and development (R&D) can help address the challenge of managing the disposal of electronics products in the United States. Five witnesses, representing perspectives from academia, a non-profit, electronics producers, and electronics recyclers, will offer testimony.

Witnesses

- **Dr. Valerie Thomas,** *Anderson Interface Associate Professor, Georgia Institute of Technology.* Dr. Thomas will discuss her research on innovative methods to manage electronic waste and the challenges facing the recycling and re-use of electronic products.
- **Dr. Paul Anastas,** *Teresa and H. John Heinz III Professor in the Practice of Chemistry for the Environment and Director of the Center for Green Chemistry and Green Engineering, Yale University.* Dr. Anastas will discuss the applicability of research in green chemistry and engineering to the electronics sector.
- **Mr. Philip Bond,** *President, Technology Association of America.* Mr. Bond will discuss ways in which innovation through R&D could help electronics manufacturers address the challenge of electronic waste. He will also give his views on promoting collaboration between industry and non-industry researchers to encourage the transfer of successful research into products.
- **Mr. Jeff Omelchuck,** *Executive Director, Green Electronic Council and Electronic Product Environmental Assessment Tool (EPEAT).* Mr. Omelchuck will discuss the development and utility of EPEAT, challenges to making existing electronics products more environmentally friendly, and ways in which R&D could address these challenges.
- **Mr. Willie Cade,** *Chief Executive Officer, PC Rebuilders and Recyclers.* Mr. Cade will describe the challenges faced by electronics refurbishers and recyclers, and discuss ways to promote collaboration between academic researchers and the recycling and refurbishing businesses.

Issues and Concerns

- Electronic waste, or e-waste, the term used to describe used televisions, computers, cell phones, monitors, etc., that are ready for discard, is a growing problem in the U.S. and worldwide. The Environmental Protection Agency (EPA) estimated that between 1980 and 2004, two billion electronic products were sold in the U.S. Of these they estimated just over half were still in use, while 42 percent had been disposed of and nine percent were in storage. Of the amount disposed of, only 11 percent reached recyclers. The rest went to landfills.[1] Electronics are bulky and contain hazardous materials that pose concerns for disposal in landfills. Due to the involvement of State and local governments, environmental groups, and electronics producers, more of these products are being recycled. However, as described below, there are still many hurdles to cost-effective, nationwide electronics recycling. Additionally, the biggest environmental footprint for electronics arises out of their production. Enabling consumers to use (or re-use) these products longer could reduce the impact of this production on the environment. The draft legislation discussed at this hearing will address some of the challenges to increase recycling and re-use through R&D and education.

- While e-waste recycling is increasing in the U.S., the industry faces a number of challenges. These challenges include convincing consumers to recycle, the logistics of collecting e-waste, efficiently disassembling products, safely removing hazardous substances, efficiently processing materials, and recovering value from many of the e-waste constituent materials. For instance, the more commingled a stream of plastics becomes as casings and components from products are mixed together in processing, the less value it has for re-use. Improving the technologies that sort these plastics, or developing new processes and materials that can use non-homogeneous plastics will make e-waste recycling less costly and will reduce waste material. From research on influencing consumer behavior to automated methods of sending information to recyclers about the products moving through their plants, R&D could help make recycling more efficient and cheaper.
- The design of electronic products could also aid in making recycling more cost efficient. Many products are difficult to disassemble and the location of hazardous materials varies (i.e., mercury lamps in some flat panel displays). Product design for recycling would look at the needs of end-of-life management. Greater use of materials recycled from old electronics is another upfront design choice that would help make recycling more profitable. Researchers could examine the feasibility of different design schemes and recycled materials usage to help electronic product development become more of a closed loop process.
- Scores of different chemicals and materials comprise computers, televisions, cell phones and other electronics. Some of the substances used in electronics (e.g., lead and hexavalent chromium) have raised enough concern that the European Union adopted a measure to ban their use in electronics products sold in Europe.[2] Manufacturers have been able to comply with these requirements for most consumer electronics, but the process to ban substances sensitive to the environment and human health is on-going. For example, the risk to human health posed by certain types of brominated flame retardants used in electronics and other products has created a controversy over their continued use. Comprehensive data on the properties of substitutes for harmful materials would enable electronics designers to change their products more quickly in response to concerns raised by different materials. The availability of this type of comprehensive data, provided by the National Institutes of Standards and Technology, enabled manufacturers to quickly meet the challenge of eliminating ozone-layer depleting chlorofluorocarbons (CFCs) from their products in the 1980's.
- Increasing the amount of electronics headed to responsible recyclers is essential to reducing the impacts of e-waste. Also essential though is research to increase and encourage the re-use of electronic products. Estimates of the total amount of energy required over a computer's life cycle show that roughly 80 percent goes into the computer's production phase, and only 20 percent into the use phase.[3] Extending the amount of time a product is in use could not only reduce the volume of e-waste, but also lessen the impact of the production of these complex and sophisticated products on the environment. Often consumers buy new cell phones, laptops, or other devices because they want the functionality or 'look' of a new model, not because their current device is broken. Consumers are often wary of purchasing used electronics because they are unsure of a used product's value or they are afraid it will not meet their needs. Developing re-use markets that aid consumers in evalu-

[1] EPA Fact Sheet: management of Electronic Waste in the U.S., *http://www.epa.gov/epawaste/conserve/materials/ecycling/docs/fact7-08.pdf*

[2] The Restrictions on Hazardous Substances (ROHS) Directive, adopted buy the European Union in 2003.

[3] E. Williams (2002), "The 1.7 Kg Microchip."

ating used devices could help keep these devices in the hands of consumers for a longer period of time. Prolonging a device's use could also be accomplished by developing ways for consumers to easily upgrade their current products.

- Improving the training of students equips the future workforce to design products with a minimal environmental impact. Continuing education of the existing workforce in the electronics and recycling industries informs these individuals of best-practices in their fields. Similarly, collaboration between academic researchers and those in industry can help transfer solutions to the problems identified above as fast as possible.

Background

Regulations

No federal law or national framework exists to handle the growing volume of e-waste generated by U.S. consumers. At least since 2000, with the convening of the National Electronics Stewardship Initiative, electronics producers and other stakeholders have been aware of the e-waste problem. However, because of competing interests over financing mechanisms, electronics producers, environmental groups, and consumer representatives have not been able to reach a consensus on how a national e-waste program should be implemented. In the absence of federal regulations, some states and localities have instituted mandatory e-waste recycling. California implemented a program in 2005. Maine, Washington, and Minnesota implemented e-waste programs in 2007. Other states, like Oregon, are slated to begin their programs this year. Each State program is slightly different, creating a challenge for electronics companies that now must finance the take-back and recycling of products in all states with programs (except California, where consumers pay a fee for recycling at the time of purchase). In addition, many of these companies have extended this take-back service to consumers in states without specific e-waste programs, though the service is not always free of charge.

The European Union has been ahead of the U.S. in dealing with e-waste, passing the Waste Electrical and Electronic Equipment Directive (WEEE) in 2000, which banned disposal of e-waste in landfills and required producers to take-back their used products. The actual implementation of this directive has varied country by country. In Europe, just as in the U.S., the cost of recycling is also a challenge.

Export

Another significant problem is the export of e-waste from the developed world to China and other developing nations, where low-paid workers pull apart the products to extract any valuable materials. Using crude methods, these workers are exposed to toxic substances, carrying a heavy burden on human health and the surrounding environment. While some exported electronics can be legitimately refurbished and re-used, an overwhelming quantity has no re-use value and is improperly and unsafely recycled or discarded. According to the Basel Action Network (BAN), approximately 80 percent of the e-waste directed to recycling in the U.S. is not recycled, but is instead exported. Much of this export is not illegal, though the EPA requires that any exporter of the leaded-glass cathode ray tubes (CRT) from old television certify that all CRT exports are going to legitimate processors overseas. This rule is frequently ignored and only minimally enforced. Both BAN and the Institute of Scrap Recycling Industries are working on separate standards that would promote accountability within the electronics recycling community. These standards will be available sometime this year.

Federal Activity

When safely handled, e-waste can be a valuable source of commodities like gold and silver. These items are more enriched in these precious metals than a comparable weight of naturally occurring ore.[4] To encourage recycling, the Environmental Protection Agency (EPA) offers facts on e-waste and information to consumers about where they can find recyclers in their area on their website. EPA also has the "Plug Into eCycling Program" which is a partnership between EPA, manufacturers, and retailers to offer consumers more opportunities to recycle or donate their old electronics. An example of an initiative under the program is the campaign "Recycle your cell phone. It's an easy call." This is a national campaign supported by major manufacturers, carriers, and retailers to educate consumers about cell

[4] USGS Fact Sheet 060–01: Obsolete Computers, "Gold Mine" or High-Tech Trash? Resource Recovery from Recycling, *http://pubs.usgs.gov/fs/fs060-01/*

phone recycling. The EPA has also supported a Design for the Environment Program and Electronics Products Assessment Tool (EPEAT).

EPEAT

EPEAT receives EPA funding, and is a product of the not-for-profit Green Electronics Council. EPEAT is an assessment tool that compares the environmental attributes of different brands and models of desktop and laptop computers. Many large institutional buyers, including sectors of the Federal Government, will only buy equipment that is ranked highly by EPEAT. EPEAT convenes manufactures, environmental representatives, and other stakeholders to establish performance criteria the products must meet to attain rankings of bronze, silver, or gold. Products are rated in such categories as to the amount of environmentally sensitive material they contain, ease of disassembly for recycling, and energy conservation.

Opportunities for R&D and Education

As identified above, by supporting R&D and education, the proposed legislation can help reduce the impact of electronics products on the environment through recycling and re-use.

Discussion Draft—Electronic Waste Research and Development Act

SECTION-BY-SECTION

Section 1. Short Title

Provides the short title of the legislation, the Electronic Waste Research and Development Act

Section 2. Findings

Outlines the current background information, concerns, and impacts of electronic waste on the environment.

Section 3. Definitions

Defines the terms Administrator as the Administrator of the Environmental Protection Agency; a consortium; the term e-waste; an institution of higher learning; and the Director as the Director of the National Institute of Standards and Technology.

Section 4. Electronic Waste Engineering Research, Development and Demonstration Projects

Directs the Administrator to provide grants through a competitive, merit-based process to be done jointly with institutes of higher education, non-profit research institutions, government laboratories, and for-profit entities (i.e., manufacturers, designers, refurbishers, or recyclers) to find ways to manage electronic waste through reduction, reuse, and recycling, and make the findings of the research available to the public. The section requires a report to Congress within two years after enactment and every two years thereafter of the grants awarded and a list of the projects and their findings.

Section 5. National Academy of Sciences Report on Electronic Waste

Directs the Administrator to arrange a study by the National Academy of Sciences to look at the current research programs and the barriers and opportunities available to reduce electronic waste, reduce the use of hazardous materials in electronic products, and better product design for efficient re-use and recycling.

Section 6. Engineering Curriculum Development Grants

Directs the Administrator to provide grants through a competitive, merit-based process to institutes of higher education and community colleges to reduce electronic waste through better teaching and training of students and current workforce by developing a green engineering curricula and creating internships.

Section 7. "Green" Alternative Materials Physical Property Database

Directs the Director to establish a physical property database for green alternative materials for use in electronic products.

Chair GORDON. This hearing will come to order. Good morning and welcome to today's hearing on electronic waste. I would like to extend a special thanks to our witnesses, and today we will consider a draft legislation to establish programs to address the challenge of e-waste.

Last April, the Committee held its first hearing on this topic. We explored the challenges of managing the discarded old computers, cell phones, TVs, and other electronic products. These obsolete and inoperable products are being discarded to become what we commonly refer to as e-waste, or electronic waste.

As consumers move on to flat-screen displays and the latest smart phones, older products are likely to be discarded by the millions. However, as I am sure we will learn today, these old products still have value. They either are still functional or they contain valuable materials. So perhaps terming these sophisticated products as "waste" is a bit of a misnomer.

However, only a small percentage of these products make it to the e-waste recyclers. Most of us put our old electronics out on the curb or store them in a closet or dresser drawer. Perhaps the most egregious practice is the export of e-waste to workers in the developing world. There the valuable commodities are stripped from the products and processed using primitive methods. These practices endanger people's health and pollute the areas where they live.

This bill represents what I hope will be the first step at the federal level in addressing this growing crisis. As the Committee learned last April, over a dozen states, local governments, and many companies have begun to increase e-waste recycling, and through the international laws and regulations, companies have removed lead, mercury and other toxic materials from their electronic products.

But the Committee also learned that these efforts are not without their challenges and much could be done better if we knew how to do it. The bill we are discussing today provides support for academic researchers to start tackling some of the barriers to making electronics greener.

The recycling of plastics from electronics is a good example of where this type of research could make a difference. Current technology to sort plastics coming into the recycling plants cannot differentiate between all types of plastics. Plastic streams end up mixed and the reprocessing plastics can no longer be used in high-value applications. This is a problem that can be attacked from both sides.

Technology to sort plastics can be improved and research can be done to figure out how to make mixed recycled plastics more suitable for use in new products. Creating more demand for recycled materials will make recycling more profitable and create less waste.

This bill provides a mechanism for bringing together academic researchers and the industry partners. It is important that we are able to implement the new technologies to reduce waste and to manufacture products with environmentally friendly materials.

And finally, the bill before us today addresses the need to educate both future and current workers. We need to get engineers thinking about green design of products and recycling. This should become central to the way we approach their jobs. To that end, the bill creates curriculum development and professional development opportunities.

With that, I look forward to the testimony we are going to receive today, and I now recognize our distinguished Ranking Member, my friend from Texas, Mr. Hall.

[The prepared statement of Chair Gordon follows:]

PREPARED STATEMENT OF CHAIR GORDON

Good morning and welcome to today's hearing on Electronic Waste. I would like to extend a special thank you to our witnesses. Today we will consider draft legislation to establish programs to address the challenge of e-waste.

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This bill represents what I hope will be a first step at the federal level in addressing the growing crisis. As the Committee learned last April, over a dozen states, local governments, and many companies have begun to increase e-waste recycling. And through international laws and regulations, companies have removed lead, mercury, and other toxic materials from their electronic products.

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With that, I look forward to the testimony we are going to receive today. I now recognize our distinguished Ranking Member and my good friend from Texas, Mr. Hall.

Mr. HALL. I thank you, Mr. Chair. I am very pleased that we are having this very interesting hearing today. Sixty-three years ago this week, the United States Army unveiled the world's first general purpose electronic computer. I remember it well. This Electronic Numerical Integrator And Computer, or ENIAC, was designed to be capable of solving a full range of computing problems.

ENIAC took up to 680 square feet of space, weighed 30 tons and consumed 10 kilowatts of power. We have obviously come a long way since February 14, 1946. As electronic products have become faster and more reliable, they have also become more significantly smaller and more disposable. I just think that today's level of computational ability is hardly used by most people and yet still highly sought after in the marketplace. Advances in flat-screen technologies have led to a new generation of televisions. With each new technological advance and model replacement, we face an inevitable problem of electronic waste, or e-waste.

There are a lot of aspects to the e-waste dilemma—the definition of e-waste, reuse and recycling of electronics, landfill disposal and hazardous waste, regulatory issues and export economies. The EPA has already instituted several programs to deal with these problems. They include EPA's Product Stewardship, which supports stake holder dialogues, pilot programs, public education and international cooperation to foster coordination of electronics use and recycling, EPA's Design for the Environment Program, which works with electronics manufacturers to incorporate environmental considerations into product design, also, EPA's Environmentally Preferable Purchasing Program, which helps federal agencies purchase environmentally preferable products, the Energy Star Program, which promotes energy-efficiency products through a labeling campaign, and EPA's WasteWise Program, which challenges its partners to set goals for reducing e-waste.

I am grateful to the Chair for circulating the discussion draft that we have before us today and bringing this topic to the forefront. I am curious to see how some provisions in the draft fit with existing programs already at EPA. Clearly, none of us want to duplicate efforts already underway as we try to effectively and efficiently deal with this challenge.

I am intrigued with a number of aspects of this bill. I am hoping to get some clarification and hear our panelists' thoughts on the "Green Alternative Materials Physical Property Database." Would this database replicate the structure and functions of the OSHA/EPA Occupational Chemical Database or would it resemble the pollution prevention—what is that noise I hear?

Chair GORDON. Electronic waste.

Mr. HALL. Or would it—I thought you were fixing to get the hook after me. Or would it resemble the Pollution Prevention Resource Exchange? They write these things and I read them, Mr. Chair.

I am hoping that the highly qualified panel we have here this morning will be able to shed some light on some of the gaps in electronic waste research, and if the discussion draft appropriately addresses these shortcomings, it would be good to know. I look forward to hearing from our witnesses today about this important issue, and I yield back my time.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Thank you, Mr. Chairman. I am pleased we are having this hearing today. Sixty-three years ago this week, the United States Army unveiled the world's first general-purpose electronic computer. The Electronic Numerical Integrator and Computer, or ENIAC (in-e-ack), was designed to be capable of solving a full range of computing problems. ENIAC took up 680 square feet of space, weighed 30 tons, and consumed 150 kilowatts of power. We have obviously come a long way since February 14, 1946. As electronic products have become faster and more reliable, they have also become significantly smaller and more disposable.

Blackberry devices, iPods, cell phones and other small electronics are rapidly replaced by newer models with more gadgets. Computers and laptops provide a level of computational ability that is hardly used by most people, yet still highly sought after in the marketplace. Advances in flat-screen technologies have led to a new generation of televisions. With each new technological advance and model replacement, we face an inevitable problem of electronic waste, or e-waste.

There are many aspects of the e-waste dilemma: the definition of e-waste; reuse and recycling of electronics; landfill disposal and hazardous waste; regulatory issues and export economies. The EPA has already instituted several programs to deal with these problems. They include:

- EPA's Product Stewardship which supports stakeholder dialogues, pilot programs, public education and international cooperation to foster coordination of electronics reuse and recycling.
- EPA's Design for the Environment Program which works with electronics manufacturers to incorporate environmental considerations into product design.
- EPA's Environmentally Preferable Purchasing Program which helps federal agencies purchase environmentally preferable products.
- The Energy Star Program which promotes energy-efficiency products through a labeling campaign.
- EPA's Waste Wise Program which challenges its partners to set goals for reducing e-waste.

I am grateful to the Chairman for circulating the discussion draft we have before us today and bringing this topic to the forefront. I am curious to see how some provisions in the draft fit with existing programs already at EPA. Clearly, none of us wants to duplicate efforts already underway as we try to effectively and efficiently deal with this challenge.

I am intrigued with a number of aspects of this bill. I am hoping to get some clarification and hear our panelists' thoughts on a "Green Alternative Materials Physical Property Database." Would this database replicate the structure and functions of the OSHA/EPA Occupational Chemical Database? Or, would it resemble the Pollution Prevention Resource Exchange, a clearinghouse that brings together information from a consortium of regional pollution prevention information centers funded by the EPA?

I am hoping that the highly qualified panel we have this morning will be able to shed some light on some of the gaps in electronic waste research and if the discussion draft appropriately addresses these shortcomings. I look forward to hearing from our witnesses today about this important issue. I yield back the balance of my time.

Chair GORDON. Thank you, Mr. Hall, and your staff wrote some very good information there. We want to follow up on that.

Additional Members may submit statements that they have at this time, including records at this point, and I will submit one from my friend, the Congressman from the 1st District of California, Mike Thompson, who has been very active in this issue. He has a written statement that we will include. [See *Appendix 2: Additional Material for the Record.*]

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Thank you, Chairman Gordon, for convening this hearing on a public policy issue that as of yet, has remained mostly unaddressed.

E-waste is a somewhat new term to our lexicon, but it is evident that it is one that we will increasingly hear near future. As consumers buy new cell phones, computers, iPods and other electronic devices with increasing frequency, we must address the issue of what to do with these discarded items, some of which contain harmful and ever-lasting materials.

Some states have already taken steps to regulate and promote the recycling and re-use of e-waste and I believe it is time for the Federal Government to evaluate its role in this issue as well. We need to ensure that an e-waste policy is streamlined so that participation can extend across industries and products.

While it's true that new technologies are reducing the relative sizes of electronics and appliances, the problem of e-waste is one to which relatively little research has been devoted. Manufacturers, when economically and technologically feasible, should phase out products that are proving to be particularly durable and potential health hazards. It's clear that a national framework to address these concerns is needed.

In the tradition of the Science and Technology Committee, we have sought to address an issue on the forefront of the technology discussion. I look forward to hearing testimony today and thank you, Mr. Chairman for my time.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Good morning, Mr. Chairman and Ranking Member.

It really is stunning to know that the United States exports 80 percent of its electronic waste to other countries.

It is shameful that much of that waste goes to developing countries like China, where workers disassemble televisions and computers, often at great hazard to their health. The waste then goes into landfills in those countries, putting vulnerable people at risk for toxic ground and water pollution.

The Committee on Science and Technology has held hearings in previous years on this issue, and I want to thank the Chairman and Ranking Member for their work to help inform Members.

Now, we have legislation with the intention to begin to address this problem. Section 4 of the bill will be particularly helpful.

This section provides for a competitive grants program fostering collaborations between institutes of higher education, non-profit research institutions, government laboratories, and for-profit entities (i.e., manufacturers, designers, refurbishers, or recyclers).

Grant money will help fund ways to manage electronic waste through reduction, reuse, and recycling.

Mr. Chairman, I am in strong support of this program within the Environmental Protection Agency.

Although the Agency is making some efforts to encourage and educate consumers about proper disposal of electronic waste, those efforts do not go nearly far enough.

What we need is for technology manufacturers to make computer parts, digital music players, televisions, mobile phones, photocopiers and other equipment that is more environmentally sustainable.

If the Longworth Cafeteria can serve cups and plates that are made of biodegradable material, then the high-tech industry can make products that won't end up in landfills or harm workers who are trying to recycle them.

Mr. Chairman, I also appreciate Section 6 of the bill. This section will establish a competitive grant program for institutions of higher education to improve teaching methods regarding "green engineering."

Stimulating our education system to prepare experts who can tackle these problems will be a key component for success.

Although the bill does specify community colleges as target recipients of the grant funding, I don't see provisions encouraging minority-serving institutions to apply.

This committee may expect future interest from me in amending the legislation to encourage applicants from minority-serving institutions. These colleges and universities receive less research grant money and have traditionally struggled to compete with the larger universities. It is my intention to provide them with opportunities to increase research and graduate-level training.

Mr. Chairman, I thank you again for holding today's hearing, and I wish the witnesses a warm welcome.

I yield back the remainder of my time.

[The prepared statement of Mr. Carnahan follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUSS CARNAHAN

Mr. Chairman, thank you for hosting this important hearing on investing in research and development technologies in regard to electronic waste in the United States.

In the U.S. and around the globe, everyday new technologies and electronics enter the marketplace and retire older models. These disposed electronics can contain lead, mercury, and other harmful substances that, unless properly disposed of, can contaminate our environment and present health dangers to our citizens. Estimates from the Environmental Protection Agency have shown that the majority of these retired products are inevitably sent to landfills while only small amounts are recycled. This is partly due to the general lack of public awareness of the potential danger that these electronics pose to the environment, as well as a lack of any coherent strategy from which to deal with electronic waste. This must change and I hope that this draft legislation is an important first step in bringing about this change.

Also, I believe it is our responsibility to fundamentally change the way we think dealing with electronic waste. We cannot solely focus on electronic waste from a recycling perspective; sustainable design which takes into account the entire life cycle of an electronic must be a part of any new research and development that goes into reducing, reusing and recycling our electronic waste.

To the witnesses before us today, I want to thank you for taking the time out of your busy schedules to appear before us and I look forward to hearing your testimonies.

[The prepared statement of Mr. Mitchell follows:]

PREPARED STATEMENT OF REPRESENTATIVE HARRY E. MITCHELL

Thank you, Mr. Chairman.

As American consumers attempt to keep up with the latest technology trends by purchasing the newest cell phones and laptops, the number of discarded electronic products is rapidly increasing.

When electronic products are properly handled, these products can transform into a valuable source for reusable equipment.

However, if these products are not disposed of properly, they are potentially harmful to both human health and the environment.

Currently, there are no federal regulations in place for the appropriate disposal of electronic waste (e-waste).

I look forward to hearing from our witnesses about potential practices for handing e-waste.

I yield back.

[The prepared statement of Mr. Bilbray follows:]

PREPARED STATEMENT OF REPRESENTATIVE BRIAN BILBRAY

Chairman Gordon and Ranking Member Hall:

Thank you very much for holding this timely and important hearing. History will show that the steps we take now on the issue of electronic waste (e-waste) will pay monumental dividends down the road.

Throughout our living rooms and newspapers we are reminded about the effect that greenhouse gas emissions, water pollution and wasteful habits are having on polluting our environment. Climate change is a frequent term from playgrounds to nursing homes. Yet, one area we are fundamentally ignoring is the effect our race to be technologically superior is having on our world.

According to the Environmental Protection Agency (EPA) between 1980 and 2004, two billion electronic products were sold in the United States. Of these, EPA estimates that just over half are still in use, while 42 percent had been disposed of and nine percent were in storage. These products contain harmful carcinogens and deadly plastics that are a threat to mankind and the environment when not properly disposed.

Creating an efficient and safe recycling program, along with research and development to reduce the toxic components of e-waste will be required to mitigate this problem. I am pleased to see that Sony Corporation, located in my district, has undertaken one such effort.

On August 20, 2007, Sony Corporation launched their nationwide program titled "The Sony Take Back Recycling Program." This innovative recycling approach will allow consumers to recycle all Sony products for free at 75 Waste Management Recycle America eCycling drop-off centers across the United States. Stan Glasgow, President and CEO of Sony Electronics, noted in a statement announcing the program: "Providing the highest level of service and support doesn't stop once a purchase is made. We believe it is Sony's responsibility to provide customers with end-of-life solutions for all the products we manufacture." Glasgow further stated, "Through the Take Back Recycling Program, our customers will know that their Sony products will be recycled in an environmentally responsible manner."

Private corporations alone should not be required to do all the heavy lifting. The Federal Government has a role to play in these efforts as well. It is estimated that the Federal Government purchases up to $60 billion worth of electronic equipment. This is millions of computers, televisions, telephones, and copiers. If we are going to ask private citizens to take part in cleaning up their electronic waste, the government must do the same.

This month I will be re-introducing legislation that will require the Federal Government to purchase products that meet EPA's Electronic Product Environmental Assessment tool (EPEAT) standards. EPEAT is a system to help purchasers in the public and private sectors evaluate, compare and select desktop computers, notebooks and monitors based on their environmental attributes. EPEAT also provides a clear and consistent set of performance criteria for the design of products, and provides an opportunity for manufacturers to secure market recognition for efforts to reduce the environmental impact of its products. By procuring environmentally safe products the Federal Government will do its part in protecting the environment.

As this committee goes forward with its work, I hope that we will have additional opportunities to explore ways to prevent electronic waste from contaminating our great nation.

Chair GORDON. Now, Ms. Biggert, I understand you are on a short leash here today, and so we will now introduce the witnesses and we will begin with you.

Ms. BIGGERT. Thank you very much, Mr. Chair, and thank you for the opportunity to introduce one of our witnesses to the Full Committee today. It is my pleasure to welcome and recognize Mr. Willie Cade, a native of my hometown, Hinsdale, Illinois, and owner of PC Rebuilders and Recyclers of Chicago. The final addition to our panel on electronic waste, his testimony promises to be both informative and enlightening from his career in recycling electronics.

Since he founded his business in 2000, Mr. Cade has refurbished and delivered over 40,000 computers for use in schools and not-for-profit organizations. He was quickly recognized for his hard work and talent when he was selected as the first Microsoft-authorized refurbisher in the United States. Recognizing the growing prevalence of e-waste, Mr. Cade went a step further and co-founded the International Computer Refurbishers Summit, now in its sixth year since inception. With obvious hands-on experience, Mr. Cade is in a unique position to educate policy-makers and the industry on the realities of mitigating the electronic waste stream. He has some terrific suggestions on research and collaboration efforts as well as ways to increase consumer awareness and participation.

So Mr. Cade, we look forward to your testimony and thank you for joining us today, and I yield back.

Chair GORDON. Thank you, Ms. Biggert.

To help offset Dr. Ehlers' intellect, we have a top draft choice here today, and I would like to ask unanimous consent that Congressman Rush Holt from New Jersey be permitted to introduce a witness. Mr. Holt—or Dr. Holt, I should say.

Mr. HOLT. Thank you. "Representative" is fine.

Thank you, Mr. Chair, and I am pleased to introduce, to commend and to recommend to my colleagues here on the Committee, Dr. Valerie Thomas to talk to you today. I have known Dr. Thomas in a number of capacities over decades now, first as a stellar student in my electrodynamics course at Swarthmore College and as a participant in my physics and public policy seminar, later as a superbly active citizen when she and her family lived in the 12th Congressional District in New Jersey, also as a fine musician and a wonderful mother. Dr. Thomas completed her Ph.D. in physics at Cornell after graduating from Swarthmore, and now serves as the Anderson interface associate professor at Georgia Tech. Her research, among other things, looks at efficient use of materials and innovative ways to manage electronic waste. Over the years she has conducted really outstanding research in a number of areas of interest to this committee.

In addition to her excellent science, I think Dr. Thomas really exemplifies the potential for scientists to be involved in public policy in an effective way. A few years back, Valerie was a Congressional Science Fellow of the American Physical Society and worked as a staff member in my office. So I have seen her from a variety of perspectives and she really is superb. Before her service in my office, she served as a lecturer at the Woodrow Wilson School of Public and International Affairs, and as a research scientist there at Princeton University. She continues her commitment to bridge science and public policy as a faculty member now at the School of International and Systems Engineering and the School of Public Policy.

Mr. Chair, I recommend Valerie Thomas to your consideration today.

Chair GORDON. Thank you, Congressman Holt, although you failed to mention that you are also the godfather to her children, and so for that reason you are going to be recused today.

Our next witness is Dr. Paul Anastas. He is the Teresa and John Heinz III Professor in the Practice of Chemistry for the Environment and the Director of the Center of Green Chemistry and Green Engineering, the School of Forestry and Environmental Studies at Yale University, and Mr. Phillip Bond is the President of TechAmerica. I would like to yield to our friend, Congressman Wu, for an introduction.

Mr. WU. Thank you very much, Mr. Chair, and it is my pleasure to introduce a fellow Oregonian at today's hearing. Mr. Omelchuck is the Executive Director of the Green Electronics Council located in Portland, Oregon. The Green Electronics Counsel oversees the Electronic Product Environmental Assessment Tool, which helps manufacturers and consumers market and purchase environmentally friendly electronic products. So welcome, Mr. Omelchuck, and I also want to extend a warm Oregon welcome to Mr. Bond, who is a graduate of, and a trustee of, Linfield College in McMinnville, Oregon.

Chair GORDON. Well, the West Coast is well represented here today, and as witnesses know, we try to limit our testimony to five minutes in terms of the spoken testimony. We have a copy of your written testimony already. So we will now start with Dr. Thomas.

STATEMENT OF DR. VALERIE THOMAS, ANDERSON INTERFACE ASSOCIATE PROFESSOR OF NATURAL SYSTEMS, SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING, AND SCHOOL OF PUBLIC POLICY, GEORGIA INSTITUTE OF TECHNOLOGY

Dr. THOMAS. Chair Gordon and Ranking Member Hall and Members of the Committee, thank you for the opportunity to testify today, and also I would like to thank Representative Holt for his very kind introduction. I am Valerie Thomas and I am an associate professor at Georgia Tech in the School of Industrial and Systems Engineering.

It is widely recognized that electronics are not well designed for recycling. The valuable components are hard to extract and difficult to reuse. What is less well understood is that the electronics supply chain has not been designed for recycling either. The supply chain for making and selling electronics is a model of efficiency managed with electronic data interchange, electronic manifests, radio-frequency tags on pallets and cartons, and UPC codes on every single package. In stark contrast, the end-of-life supply chain is managed almost entirely by hand with little recordkeeping or even potential for monitoring or oversight. That the results have included unsafe, polluting, and illegal activities at the end-of-life should not be a surprise.

Electronics are just one example of the myriad products that consumers and businesses are increasingly expected to recycle. Major efforts to increase electronics recycling have brought the rate up to about 18 percent. Major efforts to encourage battery recycling including the 1996 *Mercury Containing and Rechargeable Battery Management Act* have been even less successful. If electronics or any other complex or hazardous products are going to be recycled at high rates, innovation and creative use of technology will be needed.

Electronics could have a standard label that would allow recyclers to identify the make and model of the product and manage its recycling or refurbishment. These labels could be something like UPC bar codes or they could be radio frequency ID (RFID) tags. In a small project sponsored by the U.S. EPA (Environmental Protection Agency), electronics manufacturers, retailers and recyclers, and in fact Willie Cade at the other end of the table from me and I are working together on this, are beginning to work out how to use RFID to make electronics recycling work better.

Recycling rates for electronics are low because collection programs are difficult to use and because products are difficult to recycle. Products need to be designed for recycling and collection programs need to be very easy, almost automatic, regardless of how complex the product is. Currently, consumers are mainly responsible for managing recycling. There have been efforts to make producers responsible for recycling.

A third way might work better: improve both product design and collection systems so that products can manage their own recycling. Rather than having to continue to work so hard to educate consumers about how to recycle each and every one of their purchases, products could almost manage themselves. For example, consumers could recycle electronics just by putting them in their curbside recycling bin. The bin could, or should, be able to automatically read the label on the product and automatically arrange for pickup. The recycler or the recycler's computer system would automatically arrange for resale or recycling and the consumer would get a rebate for that item. Basically the consumer would not have to do much of anything. The tag on the product would put everything in motion.

Electronics recycling is important but it occurs in a larger context of energy use and manufacturing impacts, impacts of recycling and of reuse. Good recycling research is done in the context of all of the impacts of electronics and considers all alternatives.

And I would like to make one last point. Environmental problems are among the key challenges facing the world. Students want to solve environmental problems. Courses related to energy, environment, and sustainability draw students in to the study of engineering. At Georgia Tech, our environmental courses are packed. Section 6 of the draft E-waste R&D Act supports environmental training for engineers. This would not only help to solve environmental problems, it would also attract more students to engineering.

Thank you for your attention, and I would be happy to answer questions.

[The prepared statement of Dr. Thomas follows:]

PREPARED STATEMENT OF VALERIE THOMAS

Disposal or recycling of electronics can have significant human health and environmental impacts. Electronics can contain lead, brominated flame retardants, cadmium, mercury, arsenic and a wide range of other metals and chemical compounds. The recycling rate is, at best, about 18 percent, and most electronics collected in the U.S. for recycling have been sent to other countries for processing (US EPA 2008). In a 2008 report, the GAO found that a substantial fraction of these end up in countries where disposal practices are unsafe to workers and dangerous to the environment. Used electronics exported from the United States to some Asian countries are dismantled under unsafe conditions, using methods like open-air incineration and acid baths to extract metals such as copper and gold (US GAO, 2008; Williams et al., 2008).

If it is carried out correctly, electronics recycling can prevent pollution, create jobs and save resources. Keeping activities such as sorting and reprocessing of electronics in the urban areas where they have been used and collected can provide significant economic and social benefits (Leigh et al., 2007a, 2007b). These benefits could be significantly enhanced if plans for recycling and refurbishment were incorporated into the design of the product and its supply chain.

It is widely recognized that electronics have not been designed for recycling: the valuable components are hard to extract and difficult to reuse, and the valuable constituents are mixed with a complex set of low value and potentially hazardous materials.

What is less well recognized is that the electronics supply chain also has not been designed for recycling. The existing supply chain for manufacturing, delivery, and retailing of electronics is a model of efficiency, managed with electronic data interchange, electronic manifests, radio-frequency tags on pallets and cartons, and UPC codes on individual product packages. These kinds of supply chain innovations, developed over the past thirty years, have saved money and allowed for the efficient production and retailing of tens of thousands of products. In stark contrast, the end-of-life supply chain is managed almost entirely by hand, with little record-keeping or even potential for monitoring or oversight. That the result has included unsafe, polluting, and illegal disposal activities should not be a surprise.

Electronics are just one example of the myriad products that consumers and businesses are increasingly expected to recycle. Recent major efforts to encourage electronics recycling have brought the recycling rate up to about 18 percent. Major efforts to encourage recycling of batteries—including passage of the 1996 *Mercury-Containing and Rechargeable Battery Recycling Act*—have been even less successful. The draft E-Waste R&D Act proposes to address low recycling rates by “studying factors that influence behavior and educating consumers about electronic waste.” This will not be nearly enough. To achieve high collection rates, recycling programs for consumer products such as electronics and batteries will need a different approach to collection.

If electronics—or any other complex or hazardous product—are going to be recycled as part of a planned and well managed system, supply chain innovation is needed. Use of information technology to manage the end-of-life supply chain will be especially important because there are thousands of different makes and models of electronics products that enter the waste stream every year.

Electronics—and other complex products that need to be recycled—could have a standardized label that would allow recyclers to identify the make and model of the product and manage its recycling or refurbishment. These labels could be something like a standard UPC bar code (Saar et al., 2004). Alternatively, a radio-frequency identification code (RFID) could be installed inside the product and serve the same function while being easier to read and providing more information (Thomas, 2008, 2009).

In a small project sponsored by the US EPA and convened by the RFID standards organization, EPCglobal, recyclers, electronics manufacturers, and retailers are beginning to think through how electronics recycling could be improved by use of RFID tags. This is an ongoing project, but in our preliminary report (Maxwell, 2008), the group has concluded that potential benefits for manufacturers and retailers include:

- increased efficiency and lower cost for recycling,
- opportunities for recycling incentives, rebates, coupons and trade-ins,
- improved warranty management, and
- better after-sale services.

Potential benefits for recyclers include:

- improved inventory control,
- more efficient product sorting and management,
- improved audit capabilities,
- integration of product data into online markets, and
- easier and less costly reporting to regulators and clients.

Better management of today's recycling programs is only the beginning of what could be accomplished. The end-of-life management of electronics and other products could be transformed by a combination of improved product design, innovative online markets, integration of information technology into product management, and supply chain innovations. Already, online markets such as eBay, Craig's List, and Freecycle have made the reuse and refurbishment of electronics easier and more common. Already, companies like Recycle Bank use RFID codes on recycling bins to reward consumers for recycling.

In the future, consumers could start the process of recycling, reuse or resale simply by putting their unwanted item in their own "smart" recycling bin: the bin would automatically read the label on the product, and automatically arrange for recycling pick-up; the recycler, receiving information in advance about the items in the bin, would be able to automatically arrange for sorting and resale or recycling, and the consumer would receive a rebate for recycling that specific item, based on its value or hazard. This kind of system places the capability to enter the collection system within the product itself. Rather than having to continue to work so hard to educate consumers about how to recycle each and every one of their purchases, consumer products could, almost, manage themselves (Saar and Thomas, 2002; Thomas, 2003).

Today, recycling programs for electronics and other consumer products have low recycling rates both because collection programs are difficult for consumers to use and because the products are difficult to recycle. To achieve high recycling rates, products need to be designed for recycling, and collection programs need to be designed to be very easy, almost automatic, regardless of the complexity of the product. Currently, *consumers* are mainly responsible for managing the recycling or disposal of their products. In some locations there have been efforts to make *producers* responsible for managing the recycling or disposal of their products. A third approach might work better: improve both product design and collection systems so that *products* can increasing manage their own entry into the collection and recycling system.

With respect to the specifics of the legislation: The draft E-Waste R&D Act will be most effective if it takes into account the entire life cycle of electronics products. Electronics can have environmental impacts in manufacturing and in use as well as in disposal. Use of recycled materials or components can reduce the environmental impact of electronics production. In some cases reusing or refurbishing electronics will result in more energy use than would purchase of a new model; in other cases used or refurbished electronic devices can provide more environmental, economic and social benefit than recycling. A research program that focuses only on end-of-life has the potential to overlook major opportunities for reducing the environmental impacts of electronics, and could be counter-productive. The research program should consider the full life cycle of electronics.

With respect to engineering education: The Engineering 2020 study from the National Academy of Engineering has identified environmental issues as one of the key challenges facing the world and the engineering profession now and in the coming decades (NRC, 2002). Equally importantly, students realize that this important, and courses related to energy, environment, and sustainability can draw students in to the field of engineering. Section 6 of the draft E-Waste R&D Act supports the consideration of environmental consequences in undergraduate and graduate-level engineering curriculum. Many institutions of higher education have already made substantial progress in this area. A recent survey shows that teaching and research in sustainable engineering are part of the activities of most of the top 100 engineering programs in the United States (Murphy et al., 2009). At my own institution, the Georgia Institute of Technology, almost every school in the College of Engineering has environmental offerings at both the undergraduate and graduate level. Yet there is much to be done. By and large, the environmental aspects of the engineering curricula are at an introductory level. The next step is to develop the depth and rigor that engineers will need, and that engineering departments will require for environmental material to be adopted into their core curricula. Engineering schools are well-prepared to take the next steps, and support for this work would be welcomed.

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BIOGRAPHY FOR VALERIE THOMAS

Valerie Thomas is the Anderson Interface Associate Professor of Natural Systems in the H. Milton Stewart School of Industrial and Systems Engineering at the Georgia Institute of Technology, with a joint appointment in the School of Public Policy. She has a Ph.D. in physics from Cornell University, and a B.A. from Swarthmore College. She has previously worked at Carnegie Mellon University and Princeton University, and in 2004–05 she was a Congressional Science Fellow, sponsored by the American Physical Society.

Chair GORDON. Thank you, Dr. Thomas.

Dr. Anastas.

STATEMENT OF DR. PAUL T. ANASTAS, TERESA AND H. JOHN HEINZ III PROFESSOR IN THE PRACTICE OF CHEMISTRY FOR THE ENVIRONMENT, SCHOOL OF FORESTRY AND ENVIRONMENTAL STUDIES; DIRECTOR, CENTER FOR GREEN CHEMISTRY AND GREEN ENGINEERING, YALE UNIVERSITY

Dr. ANASTAS. I would like to thank you, Chair Gordon and the Members of the Committee for the opportunity to comment on this draft bill. My name is Paul Anastas. I am the Director of the Center for Green Chemistry and Green Engineering at Yale University, and I offer this testimony on behalf of myself and my Associate Director, Professor Julie Zimmerman. I want to compliment the Committee on addressing this serious issue of e-waste and the draft bill has many excellent professions that I certainly endorse.

The main message that I would like to make to the Committee today is really threefold. One is that if we are going to look at the issue of waste—electronic waste—it cannot be waste alone but design throughout the entire life cycle of electronics; second, that there are design frameworks that exist currently to ensure that electronics are able to be green and sustainable; and third, that through research and development, we are able to not only ensure that they meet environmental goals but also economic goals and performance goals.

So first a few words about waste. When we look at the issue of how you design any electronic, it is important to know that looking at waste alone is not going to do anything for the manufacturers and assemblers and exposing them to hazardous substances. We know that in a typical cell phone, there are approximately 60 elements in the periodic table that are used in cell phones today, and focusing on waste is not going to address that issue. It is also of note that we only have reliable information on approximately seven of those elements in terms of what our supplies are and what our usage is. So focusing on the design allows us to not only meet our waste goals but also build in performance, build in capabilities and build in profitability while addressing these hazardous waste substances. It allows us to ensure the materials that are used are benign, non-bioaccumulative, non-endocrine disrupting and allows us to get higher performance at the same time.

The sustainable design frameworks, there have been principles of green chemistry and green engineering in the literature for some time that have been used across industry sectors. It is often said that the compass is more important than the speedometer and that we need to know what the "true north" of sustainable design is. Just in the past few years, Presidential Green Chemistry Challenge Awards have shown that companies across industry sectors from chemicals to plastics to polymers to pharmaceuticals to agriculture and, yes, to electronics, have eliminated enough hazardous substances, according to the EPA, to fill a train car hundreds of miles long. Now, they didn't do this because of a regulation or 'thou shall do green chemistry and green engineering,' it is because you can meet environmental and economic goals simultaneously.

So with all of these good news stories, with all of these historic accomplishments, that is good news, but the better news is, this represents a fraction of the power and the potential of these green design frameworks, and for every one product that has been redesigned in this way, there are hundreds, perhaps thousands, that have not even been considered in these new frameworks. So the potential is immense, and one of the things that is absolutely required is fundamental research. I could list off the various areas necessary for dematerialization such as nanotechnology, benign materials, alternative chemicals that are not persistent, bioaccumulating and toxic, molecular self-assembly, but that is detailed in my written testimony.

There are examples of very productive industry-university cooperative research programs that can be used as models for this bill including the technology for sustainable environment at EPA and industry-university partnerships out of the NSF (National Science Foundation).

I would just like to conclude by saying that I view the fundamental research areas that I briefly listed as the bricks that make up the structure of sustainable electronics. The framework for sustainable design, the green chemistry and green engineering principles, are the mortar that hold those bricks together. The structure can only stand, can only be strong, can only be stable with both of these elements, that is, the fundamental research within the sustainable design frameworks.

That said, I would like to thank you again and I would be happy to answer questions at an appropriate time.

[The prepared statement of Dr. Anastas follows:]

PREPARED STATEMENT OF PAUL T. ANASTAS AND JULIE B. ZIMMERMAN

Chairman Gordon, Members of the Committee, I am pleased to testify today on the topic of the proposed E-Waste R&D program. My name is Paul Anastas and I am the Teresa and H. John Heinz III Professor in the Practice of Chemistry for the Environment and the Director for the Center for Green Chemistry and Green Engineering at Yale University.

The bill under discussion today centers on the problem of e-waste. My testimony focuses on considering solutions to this problem from a broader context. E-waste, like waste of any kind, is fundamentally an end-of-pipe problem. To truly address this issue in a meaningful and permanent sense, a research program should be designed to tackle it at its source—at the design-level of the products. Though creating the infrastructure and technologies necessary to manage and reuse waste materials is an important short-term goal, the enormous growth projected for the electronics sector is also an opportunity to re-imagine how these products are designed and attempt to eliminate not only the notion of waste, but also the environmental impacts of electronics on humans and the environment throughout their life cycle. My testimony seeks to make the following key points:

1. E-waste is a serious and growing problem and yet it is only one aspect of the much larger issue as we seek to move toward sustainable electronics.
2. Waste is one egregious symptom of flawed design. With improved design, we can address not only the waste issue but also the important issues of energy usage, worker/assembler safety, depletion of scarce, rare, and precious metals, and the reduction of toxics use and replacement with benign alternatives.

3. Sustainable design frameworks exist to achieve these goals including the Principles of Green Chemistry and the Principles of Green Engineering.
4. Significant research challenges exist and can be addressed through thoughtful investment by the Federal Government in academic research in partnership with the private sector.
5. Advances in sustainable design of electronics can lead to improvements in overall environmental performance, including waste, while at the same time creating innovations in functional performance that enhances jobs and competitiveness.

Introduction

Electronic devices are a central feature of our daily lives. We rely on them for everything from communicating with our loved ones to monitoring our blood glucose to ensuring that our cars respond intelligently to changing road conditions.

Not only do electronics provide us with a vast array of personal benefits, but they also have a potentially significant role to play in sustainable development. For example, electronics could lead to greater environmental sustain ability by significantly reducing the need for transport, leading to the dematerialization of certain products (such as the virtual provision of multimedia), or providing improved environmental monitoring capacity. With recent concern over global climate change, large-scale efficiency gains resulting from information and communication technology (ICT) use across sectors are seen as a key tool for transitioning to a lower-carbon world and facilitating low-carbon development.[1] On the social development side, ICT can facilitate general access to knowledge, build community-organizing capacity, and provide access to local and global markets. All of these are dramatically under-served needs in the developing world.

Sustainable development will require that the services provided by electronics continue to be made available to an ever-widening pool of consumers. The importance and value of electronics and their ability to offset other environmental problems are often used to excuse their own environmental impact. However, even a small impact subject to the scale of production that electronic devices will see in the coming decades would be unacceptably large. It is even more daunting to consider that electronics have one of the largest impacts per unit mass out of any product category. Electronic devices are inherently complex—they contain hundreds of materials, many of which are toxic, and require extremely precise structure and assembly on a minute scale, making them very resource-intensive to produce. As electronic devices become increasingly central to human life, we need to develop ways to sustainably provide their key services without tacitly accepting the problems they currently bring with them.

Thus far, industry's understandable initial response to these concerns has been to embark on a program of incremental improvement—making each generation of products slightly less toxic, slightly more energy efficient, slightly "less bad." However, in a time characterized by explosive growth in the worldwide use of electronics, a commitment to incremental improvement is not sufficient. Nor will even a reasonably effective end-of-pipe waste management system for the e-waste stream sufficiently address the material throughput or toxicity issues that are already apparent. We cannot solve an exponential increase in problems with a linear decrease in impact.

Our longer-term research priorities must be targeted toward the drastic reduction of both the volume and the toxicity of this waste stream through concerted efforts at *better design.* We need to clearly define the challenges we hope to tackle, and then address them in a more creative and innovative manner than has thus far been applied. This approach will also require efforts to build our long-term capacity for innovation, through the building of a sustain ability knowledge base throughout our nation's engineering programs. The good news is that sustainable electronics are possible. We have the tools and design frameworks required for getting on the right path. However, to overcome a challenge, we must first recognize it as a challenge—and define our targets appropriately.

[1] Smart 2020: Enabling the low carbon economy in the information age. The Climate Group, on behalf of the Global eSustainability Initiative. 2008. ICT's potential role in mitigating climate impacts was the subject of the recently-published "SMART 2020" report, which concluded that ICT's potential for increasing the efficiency of other sectors is so great that it beyond offsets the use-phase emissions of the ICT sector itself, though the CO_2 emissions reductions needed to stabilize atmospheric greenhouse gas levels still exceed what those gains would represent.

The Electronics-Manufacturing Sector: Historic & Current Problems

The electronics-manufacturing sector is characterized by quick product turnover, complicated and globalized production chains, capital intensity, a high level of outsourcing, and a global material footprint. A typical computer contains over 1,000 components, whose raw materials draw on the majority of the periodic table. It's usual for these components to be manufactured and assembled in different parts of the world—for example, semiconductor chips made in Scotland, a disk drive made in the Philippines, an LCD monitor made in South Korea, circuit boards fabricated in China and assembled in Taiwan, and the final product assembled in Mexico.[2] In 2005, only 25 percent of production was done "in house," with 75 percent outsourced to contract manufacturers, primarily in Asia.[3]

Environmental concerns for electronic devices, can be broken down into three major categories:

— The use of hazardous and toxic substances

— Resource and energy intensity

— The loss of materials and their embedded value to the waste stream

The complexity of electronic products represents an investment of energy, water, and processing time that goes far beyond the basic value of their structural materials. For example, the production of a memory chip requires about 600 times its weight in fossil fuel. This is at least an order of magnitude higher than any other product category—for comparison: the production of a car requires 1–2 times, and an aluminum can requires 4–5 times its weight in fossil fuel.[4]

Many electronic products, especially older models, contain substantial quantities of hazardous substances. For example, older cathode ray tubes (CRTs) contain between four and seven pounds of lead.[5] In 2003, the High Density Packaging User Group (HDPUG) conducted an industry-wide survey of the material composition profiles of certain IT components. Using methodologies ranging from analytical testing to surveys and literature reviews, they categorized what they considered to be the environmentally relevant materials present in electronic equipment based on toxicity and volume. The chart below presents a summary of their findings.

[2] Example adapted from Schipper, Irene and de Haan, Esther. "CSR Issues in the ICT Hardware Manufacturing Sector" SOMO ICT Sector Report. September 2005.

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[5] EPA 67 FR 40509, June 12, 2002. California Environmental Protection Agency, *Managing Waste Cathode Ray Tubes,* Fact Sheet August 2001. From the "Recycling Technology Products" Paper.

Summary of Potentially Environmentally Relevant Chemicals[6]

Chemical	Primary Use	Environmental Relevance
Antimony	Solder, flame retardant	Concerns about toxicity
Arsenic	Dopant in semiconductor manufacturing	Concerns about toxicity
Beryllium	May be found in select connections	Concerns about toxicity
Bismuth	Solder	Contaminant to copper recycling
Brominated compounds	Flame retardants in printed circuit boards, ICs, and plastics	Concerns about incineration byproducts and toxicity
Cadmium	Identified as stabilizer additive to some cables; present in trace amounts in some telecom boards	Restricted by EU RoHS
Chromium	Found as chromium (III) in stainless steel. Chromium VI may be present in trace amounts	Chromium VI restricted by RoHS
Lead	Solder, stabilizer in cords	Restricted by RoHS
Mercury	Identified in bulbs used in backlighting of LCD	Restricted by EU RoHS
Nickel	Plating	Concerns about toxicity
Silver	Solder	Leachability at end of life

[6] High Density Packaging User Group (HDPUG). "Material Composition Profiles of Select IT Components, A Design for Environment Project with the High Density Packaging User Group (HDPUG). 2003 IEEE International Symposium on Electronics and the Environment, Conference Record, pp. 125 - 130.

In addition to these substances of concern identified by the HDPUG group, many others are often highlighted, including: halogenated and other ozone-depleting substances (i.e., CFCs), plasticizers, refractory ceramic fibers, asbestos, lithium, and copper (which, along with arsenic and nickel, can catalyze the increase of dioxins during incineration).[7]

The loss of material to the waste stream is really a problem with three distinct sub-categories, which build on the problems already discussed:

— reducing the volume of waste entering landfills
— reducing pollution caused by the toxic content of disposed electronics
— closing material loops and recovering the economic value of materials

The disposal and recycling of waste electronics has become an international and multidimensional issue. A great deal of attention is often paid to the volume of e-waste entering the waste stream. The volume is significant—the U.S. EPA estimates that more than 3.2 million tons of electronic waste enters U.S. landfills every year[8] and that this volume will continue to grow rapidly in the coming decades, the more significant problem with e-waste relates to its qualitative characteristics. E-waste is expensive to manage properly because of its bulk, small components, and toxic constituents. This distinguishes e-waste from ordinary garbage, while simultaneously making it particularly important to manage properly. However, from an economic perspective, only some subsets of e-waste make financial sense to recover, while the bulkiest ones (plastics) must be dealt with at a cost.

The off-shoring and improper recycling of e-waste has resulted in unsafe working conditions for thousands of workers in the developing world. In a many cases, "recycling" of e-waste involves burning parts over open pit fires in order to melt solder and separate out valuable components. A recent study examining heavy metal contamination levels in Guiyu, China, a village heavily involved in e-waste recycling, found that levels of lead and copper in road dust were 371 and 155 times higher, respectively, than in a non-e-waste recycling site 30 kilometers away. The contamination levels in the village were likely to pose significant health risks, particularly to children, which the authors correlated with body loading studies done in the same region.[9] Exposure to high levels of heavy metals can result in both acute and

[7] WEEE and Hazardous Waste. A report produced for DEFRA. March 2004.
[8] Environmental Protection Agency. *www.epa.govjepaoswerjoswjconservejpluginjindex.htm*
[9] Leung AOW, Duzgoren-Aydin NS, Cheung KC, Wong MH. "Heavy Metals Concentrations of Surface Dust from e-Waste Recycling and its Human Health Implications in Southeast China." *Environmental Science and Technology.* January 2008, in press.

chronic health conditions ranging from damage to the nervous system, and changes to blood composition, lung, kidney, and liver functioning.[10]

Rapid technological advances in the electronics sector result in quick product turnover. This rapid turnover is exacerbated by fashion- and software-driven hardware obsolescence. The average lifespan for a PC manufactured in 2005 was estimated to be two years.[11] Though demand for electronic devices in the industrialized world continues to grow, the most significant growth is occurring in developing countries. Today only 10 percent of China's population of 1.3 billion owns a computer. By 2020 that number is projected to rise to 70 percent. By that same year, half the world's population will own a mobile phone and almost a third of the global population will have a PC (currently one in 50).[12] This translates to over four billion PCs in active use worldwide.

Not only does this imply a massive increase in the production of electronic devices, but it will also necessitate greater network capacity to support their energy needs, more materials to allow for their manufacture, and the creation of an infrastructure for their end-of-life management.

The topics touched on here are likely to be covered in more detail in other testimonies. However, I would like to draw attention to a few areas, which I believe do not get sufficient attention, and which should guide the development of research priorities in this field.

The first is what I believe to be an insufficient focus on the toxicity of some of the material components of electronic devices. Many industry representatives point to the incremental improvements achieved in recent generations of electronic products and consider this a successful stopping point for the elimination of toxic and hazardous materials. However, the fact remains that electronic devices still contain many hazardous materials. What we should ultimately be aiming for is the total elimination of toxic and hazardous materials in these products. Only when products are truly benign will their mass production not pose a substantial threat to workers, users, and those handling the equipment at end-of-life. Truly benign products do not pose an inherent risk—they can be handled properly or mishandled without any threat to humans or the environment. This is not an easy or short-term proposition, but it is the goal that we should at least be aspiring to achieve. Perhaps, and likely, this cannot be achieved through the search for direct analogues of existing toxic materials. Instead, we can focus on shifting towards new technological avenues. For example, rather than replacing the lead in cathode ray tubes with a benign alternative, we instead replaced CRTs with an entirely different technology.

Another issue, which is only infrequently touched upon, is the question of material scarcity. The operating assumption within the high tech manufacturing industry is that sufficient material exists to continue satisfying the enormous and growing demand for electronics. However, these assumptions are not always grounded in firm data—because in many cases, the data does not exist. We generally have a very poor understanding of the material quantities that we consume, or how consistently we can expect those flows to continue. One example particularly relevant to the electronics sector is that of tantalum, a scarce metal that is essential for the manufacture of capacitors and resistors. At the very least we should attempt to better quantify the stocks and flows of various resources through the electronics sector to improve our capacity for impact assessment.

Finally, I would like to draw attention to the potential of emerging technologies. These nascent technologies including molecular self-assembly, nanotechnology and nanomaterials, self-healing polymers, organic batteries and others, offer the promise of not merely meeting environmental goals but also dramatically increasing performance and competitiveness. Only though proper support for the basic research and development of these innovative new fields can the power and potential of these green chemistry and green engineering solutions be realized.

Frameworks for Sustainable Design

It has become widely accepted that any consideration of product sustainability should take into account the entire product life cycle—from raw material acquisition and manufacturing, through use, to disposal.

Looking at the entire life cycle helps prevent "problem shifting." For example, energy-saving compact fluorescent light bulbs save a great deal of electricity, but represent a life cycle trade-off because they contain mercury—thus shifting environ-

[10] *Ibid.*

[11] National Safety Council, "Electronic Product Recovery and Recycling Baseline Report: Recycling of Selected Electronic Products in the United States," May 1999.

[12] Smart 2020: Enabling the low carbon economy in the information age. The Climate Group, on behalf of the Global eSustainability Initiative. 2008.

mental burden from the use phase to manufacturing and end-of-life. Examining the whole life cycle also helps standardize the environmental burden against the unit of service provided—for example, a disposable cup may have a much lower environmental cost than a metal travel mug, but the metal travel mug is capable of providing hundreds of uses in comparison with the disposable's single use. A key step in optimizing any system requires an objective look at where the largest areas for improvement lie within the system as a whole.

Several frameworks for sustainable design, all of which take a life cycle perspective, have become well established over the past decade, among them the 12 Principles of Green Chemistry and the 12 Principles of Green Engineering.[13] Though it is unnecessary to go into the details of this design framework here, it implies some key approaches for responding to the problems outlined above through re-design:

1. **Eliminate or severely reduce toxicity (toward zero hazard)**
   - **Materials and energy sourcing—**By changing the nature of the materials and energy that are input into the process of making electronics, we can dramatically improve all aspects of the life cycle stages of electronics including that of e-waste.
     - Reduce the use of hazards wherever possible (i.e., replacing toxic flame retardants, plasticizers, mercury, lead, and arsenic—containing substances, etc.).
     - Design new materials, plastics, composites and alloys that increase performance while reducing toxicity.
     - Ensure that the new materials are designed such that included as part of functional performance are things like non-persistence, non-bioaccumulation, degradability, non-mutagenic/non-carcinogenic, and non-endocrine disrupting.
2. **Close the material loop (achieve zero waste)**
   - **Design for reuse and end-of-life.** The primary goal for end-of-life design for electronics should be to retain the embedded complexity of these products because they are so resource-intensive to produce. Functional components should be re-used whole as a first priority, recycled for their raw materials as a second priority, and appropriately disposed of as a last resort.
     - Incorporate take-back schemes
     - Reduce material diversity
     - Improve the ease of product disassembly
     - Incorporate renewable/biodegradable materials wherever possible and advisable
   - **Think broadly about possible material synergies outside of the industry.**
     - Can waste products be sold as feedstock to other industries? Example: IBM is reported to have recently begun selling its information-scoured silicon chips as a feedstock for solar panels.[14]
     - Can other industries' wastes be purchased as feedstock?[15] Example: University of Delaware Professor Richard Wool's chicken-feather-based circuit boards, which take an existing waste-stream (three billion pounds of chicken feathers are disposed of annually) and use it as a feedstock to make a more efficient circuit board than the conventional version.[16]
3. **Optimize resource use at the design stage (for energy, materials, and time)**

[13] Anastas, P.T., and Zimmerman, J.B., "Design through the Twelve Principles of Green Engineering," *Env. Sci. and Tech.,* 37(5):95–101, 2003. Anastas, P.T., Warner, J.C., *Green Chemistry: Theory and Practice,* Oxford University Press, 1998.

[14] The Associated Press. "IBM to Recycle Chips for Solar Panels." *The International Herald Tribune.* 30 October 2007. <*http://www.iht.com/articles/2007/10/30/business/ibm.php*>

[15] De la Pena, N. "Sifting the Garbage for a Green Polymer." *The New York Times.* 19 June 2007. <*http://www.nytimes.com/2007/06/19/science/19poly.html*>

[16] Frazer, L. "Chicken Electronics—A Technology Plucked from Waste." *Environ. Health Perspect.* 112(10):A564–A567, July 2004.

- **Determine and design for optimal product lifetime—**Extending useful product life for most electronics would lead to overall energy and resource savings. This is also supported by recent life cycle analysis studies that have shown that the use phase only comprises about 20 percent of total energy consumption over the lifetime of an electronic device.[17] However we must also balance this with the concerns of "locking-in" resources into technologies that may become obsolete or that may be perceived to be obsolete by style-conscious consumers.
  - Therefore, product lifetimes should be increased, but provisions should be made for adaptability and upgradeability.
  - Modular options could provide trend-conscious consumers with exchangeable components for a new product appearance. These style upgrades could largely go on within companies out of customer view.
- **Select production methodologies that are as efficient as possible**
- **Select materials that deliver functionality with minimal resource input**
- **Expand the number of services delivered by any single device**

Specific Research Priorities

The high turnover in the electronics sector is often framed as a problem, but from a sustainable design perspective it can also be seen as an opportunity. With technology advancing rapidly, each new generation of products is the chance to try something new and truly break out of existing technological paradigms. However, there are certain problems that will need to be dealt with sooner than others.

Innovations in areas ranging from chemistry and materials science to systems engineering and policy will be required to effectively address the problem of e-waste.

- **Short-term**
  - **Up-cycling historic wastes—**
    - Research on the transformation or destruction of current toxics.
    - Determine the applications for the direct re-use of electronics, component re-use, or recycling—with the goal of retaining as much embedded complexity as possible.
    - Nanotechnology has the potential to revolutionize a number of industries through the creation of materials with novel physical properties. This area needs to be thoroughly investigated in order to maximize its potential benefits in the electronics sector while designing through newly emerging Green-Nano programs to reduce the intrinsic of toxicity and eco-toxicity.
  - **Improve design for disassembly to enhance the reuse and recyclability of new products—**both through new recycling technologies and new product design.
    - Research new material joining options such as fasteners, welds, adhesives
    - Examine the potential for the use of new materials developed through bio-based and molecular self-assembly techniques
  - **Improve the recycling infrastructure**
    - Educate consumers about electronic waste
    - Facilitate the collection of electronic products
  - **Extend useful product life**
    - Determine the factors that lead to technological failure
  - **Conduct basic research on materials and life cycle impacts**
    - Support data-gathering programs that will allow for the completion of Life Cycle Analyses (LCAs) and Material Flow Accounts (MFAs)

The toxic materials contained in older electronic products that will hit the waste stream in the next 10 years are a potentially serious environmental problem. Effec-

[17] Williams, Eric. Energy Intensity of Computer Manufacturing: Hybrid Assessment Combining Process and Economic Input-Output Methods. *Environmental Science and Technology.* 2004; 38(22):6166–6174. *http://dx.doi.org/10.1021/es035152j*

tive ways of managing these legacy products remain an unresolved challenge. Improving recycling technology to be able to safely extract valuable materials from this waste stream will be one of the earliest priorities.

Plastics present another challenge because although they constitute a large part of the volume of the e-waste stream, however they represent a low fraction of the value, which does not create economic incentive for their recovery. In the near-term, one of the solutions to this problem will be to research alternative uses for the mixed plastic stream that can be extracted from legacy electronics. A market for these materials needs to be established if we wish to successfully divert them from landfills and other disposal options.

To avoid these very problems with future generations of electronic products, an immediate, concerted research effort should be directed at designing components and materials that are easily separable and recoverable. For materials used in very minute quantities, advanced separation techniques should be explored. This is, a key priority for putting an immediate dent into the future e-waste stream.

Historically, the "use phase" of electric and electronic equipment has been considered the most important energy-consuming phase of the product life cycle. Though this holds true for large appliances such as washing machines and refrigerators, in the case of most personal electronic devices such as computers, the majority of resource consumption and energy usage occurs before the product even reaches the consumer. A now widely cited study found that the life cycle energy burden of a computer is dominated by the production phase (81 percent) as opposed to operation (19 percent).[18] This is one of the major reasons that extending the usable lifespan of ICT devices has been identified by many groups as a potentially promising approach to mitigating their environmental impact.[19]

An important problem for evaluating the environmental sustainability of electronic products is the lack of sufficient information on life cycle impacts. Because of insufficient data, we don't even know how much of certain materials (such as precious metals) we are using, and how quickly we are depleting our existing stock. It is estimated that the typical mobile phone made today contains approximately sixty chemical elements from the Periodic Table. Of these, we may have adequate data on the supplies and usage rates of eight of them. This is something that needs to be remedied through basic research.

- **Mid-term**
  - **Begin to phase out toxics**
  - **Investigate new materials and improve existing functionalities**
    - **Develop new display technologies**
    - **Improve energy storage capability**
  - **Basic material research on polymers, composites, and conducting organic materials.**

A central tenet in the 12 Principles of Green Chemistry is that we should strive to eliminate toxic and hazardous materials to the greatest extent possible throughout their life cycle. Though the ultimate goal of product re-design should be the elimination of toxic and hazardous substances, this process will need to be carefully managed and not forced through by over-eager legislation. The trade-offs of eliminating certain toxic substances for alternative materials appear to be highly uncertain in some areas, and have often led to heated debates, particularly just prior to the adoption of definitive regulatory measures. Among several recent examples, one of the most prominent is the regulatory push to eliminate lead.

Consumer electronics constitute 40 percent of the lead found in landfills,[20] largely originating from cathode ray tube (CRT) monitors, but also present in significant quantities in printed circuit boards. Lead is well known to have neurotoxic effects and presents a particular risk for children. The recently adopted RoHS directive in the European Union, which has been in effect since July 1, 2006, has severely restricted the use of lead in any new electronic devices, particularly in solders, which forces manufacturers interested in continuing sales in the EU market to switch to alternatives.

[18] Williams, Eric. Energy Intensity of Computer Manufacturing: Hybrid Assessment Combining Process and Economic Input-Output Methods. *Environmental Science and Technology.* 2004; 38(22):6166–6174. *http://dx.doi.org/10.1021/es035152j*

[19] *Ibid.*

[20] Silicon Valley Toxics Coalition, "Fourth Annual Computer Report Card," January 9, 2003; *http://www.svtc.org/cleancc/pubs/2002report.htm*

Tin-lead solders have been used for over half a century, and shifting to alternatives has raised concern about the performance of the alternatives.

Therefore, it is important to innovate truly better alternatives to existing toxic products, and not prematurely stifle the process through legislative bans in the absence of the necessary research on the green chemistry alternatives. This fundamental research is essential to meeting the genuine goals of moving away from toxic materials in ways that don't cause unintended environmental, health, and economic consequences.

- ○ **Long-term**
  - **Material basis of computers**
    - ○ Non-depleting
    - ○ Non-rare, scarce, toxic metals
    - ○ Non-persistent, non-accumulating, non-toxic materials
  - **Focus on new dematerialized product conceptions**
    - ○ Nanoscale materials and components
    - ○ Molecular self-assembly
    - ○ Biomimetic devices
  - **Strive for holistic applications of green design**
    - ○ Dematerialize—use fewer devices with less overall material to provide the same services
    - ○ Close material loops—cease to design products whose components cannot be fully recovered for some kind of use

The ultimate message is that green chemistry and engineering principles can only lead to sustainability if they are applied systematically. Incremental improvements along specific problem trajectories are essential stepping stones, but the full-fledged, system-wide adoption of these design foundations calls for transformative breakthroughs—both in products themselves and in the logistical systems we have in place for managing them and their waste streams. This integrated approach to design is the only way to truly address the e-waste problem.

These key transformative innovations will likely rely heavily on dematerialization and will probably make use of technologies that are currently unknown or just emerging, such as nanoscale self-assembly, self-healing materials, programmed decomposition, biological mining and recovery (for minute quantities of valuable materials).

The ultimate goal is to create products that can provide increased benefits to our society and our economy—on energy that is renewable, made of materials that are benign, and based on renewable and reusable feedstocks. This vision is the goal of perfection we seek through green chemistry and green engineering and it is only through holding out goals of perfection—the "true north"—that we guarantee continuous improvement rather than settling for half-solutions and comprises.

The E-Waste R&D program that is ultimately established should be as visionary and broad looking as possible in its scope, and avoid treating the problem of e-waste as a single, narrow challenge.

Program Structure

Research and Education—There are many models in the Federal Government that have been successful in ensuring the same general goals that are sought by this legislation:

1. Excellence in research
2. Partnership with industry
3. Integrating education
4. Sound science basis for policy inputs

Some of the outstanding models that could be considered in this research include the Industry—University Cooperative Research Centers that are funded out of the National Science Foundation; the Technology for a Sustainable Environment Program that until recently was funded out of the U.S. Environmental Protection Agency and part of an interagency program with NSF had an excellent track record; and the Integrated Graduate Education and Research Training (IGERT) grants provide and excellent model that could be adapted to partnerships with industry. There are also the excellent examples of Engineering Research Centers (ERCs) and Science and Technology Research Centers (STCs) that have very productive industry/academic partnerships for research and education.

Leveraging research—In addition to the establishment of centers dedicated to this important area, it would also be worth considering how to leverage the portfolio of existing research that will greatly impact future electronics. Those projects in areas such as nanotechnology, polymers and materials, electrical engineering, product design, metallurgy, and others currently funded by federal research programs because of their direct and important relevance to electronics. By ensuring that the next round of program solicitations supporting this research contain requirements for the principal investigator to discuss potential environmental and human health benefits of their work and the use of this information as criteria in a funding decision. This could have a tremendous positive impact on funding for the field.

Policy Issues

The successful implementation of the outcomes of this endeavor will additionally need to be supported by innovative policy frameworks in order to function efficiently and to provide incentives for the adoption of environmentally superior designs.

It should be noted that "product stewardship" or Extended Producer Responsibility (EPR) concepts as implemented in existing e-waste legislation have not been effective, and seem unlikely to become effective, at changing product design. This is because, for both economic and environmental reasons, almost all product recovery and recycling systems are collective—they handle all manufacturers' products collectively. While manufacturers may pay for their share of the waste collected, or their share of products produced, no system has yet been developed to provide a financial incentive for individual manufacturers to make their products easier to recycle. In addition, the collective nature of both the end-of-life system and the component supply chain makes it difficult for individual electronics manufacturers to adopt dramatic innovations for the reduction of environmental impact.

Another big source of contention regarding electronics recycling has been the search for an appropriate financing system. State and local governments would like to see manufacturer-financed recycling programs because not enough funding is available for government-financed options.[21] However, the cost of compliance with even a single law can be a challenge for industry, and with the recent barrage of new regulations, industry has voiced that it cannot bear these costs alone. The National Electronics Product Stewardship Initiative (NEPSI)—a dialogue between stakeholders convened by the EPA in 2001 to devise a single national solution to electronics take-back and recycling was brought to an unsuccessful close when participants could not reach a consensus on the financing system for e-waste recycling.

The key challenge has been that all of the proposed industry funding schemes burden different manufacturers unequally, and in every case the burdened companies have vigorously opposed the specific scheme that would disadvantage them. In response to the lack of a national solution, many U.S. states have developed their own systems, creating a regulatory patchwork. This is in addition to the emerging international patchwork of regulations creating an uncertain regulatory environment making it difficult for the industrial sector to continue to innovate in a clear direction.

These are all overlying issues that need to be addressed to ensure the ultimate effectiveness of any proposal.

Conclusion

This bill provides a tremendous opportunity to address the important and growing issue of the impacts of electronics on our environment, our health, and our economy. It is essential that the legislation incorporate the following elements.

1. Do not focus merely on waste since the only effective and economically beneficial way to address the issue is through redesign of the life cycle of electronics.
2. Funding for research is essential on the green chemistry and green engineering solutions for the sustainable design of electronics. Initially this research will focus on removing some of the most problematic toxic, bio-accumulating, persistent substances and later can address the key systems approaches of biomimicry, organic energy storage, and dematerialization all fundamental to a sustainable ICT enterprise.

[21] From recycling doc—Oregon Department of Environmental Quality *Federal Register* comments in Appendix VII.

3. Models for government funding for successful industry-university partnerships exist and those should be considered.
4. Policy research to provide the incentives for the design, development, purchasing, recycling, reuse, and remanufacturing of electronics, is an important element.

Thank you for the opportunity to comment on this important legislation.

BIOGRAPHY FOR PAUL T. ANASTAS

Degrees

B.S., Chemistry, University of Massachusetts at Boston

M.A., Chemistry, Brandeis University

Ph.D., Chemistry, Brandeis University

Paul T. Anastas is Teresa and H. John Heinz III Professor in the Practice of Chemistry for the Environment with appointments in the School of Forestry and Environmental Studies, Department of Chemistry, and Department of Chemical Engineering. In addition, Prof. Anastas serves as the Director of the Center for Green Chemistry and Green Engineering at Yale. From 2004–2006, Paul Anastas served as Director of the Green Chemistry Institute in Washington, D.C. He was previously the Assistant Director for the Environment in the White House Office of Science and Technology Policy where he worked from 1999–2004. Trained as a synthetic organic chemist, Dr. Anastas received his Ph.D. from Brandeis University and worked as an industrial consultant. He is credited with establishing the field of green chemistry during his time working for the U.S. Environmental Protection Agency as the Chief of the Industrial Chemistry Branch and as the Director of the U.S. Green Chemistry Program. Dr. Anastas has published widely on topics of science through sustainability, such as the books *Benign by Design, Designing Safer Polymers, Green Engineering,* and his seminal work with co-author John Warner, *Green Chemistry: Theory and Practice.*

Chair GORDON. Thank you for your testimony.

Mr. Bond.

STATEMENT OF MR. PHILLIP J. BOND, PRESIDENT, TECHAMERICA

Mr. BOND. Thank you, Mr. Chair and Members of the Committee and the staff for inviting us here today for an important hearing. I also want to commend the Committee for a hearing that it held April 30 of last year on e-scrap and would commend to you the testimony of HP, which gave, I think, relevant testimony at that. I am here on behalf of TechAmerica, and you may not know TechAmerica but you know who we are. It is a result of a merger of AEA, the American Electronics Association, ITAA, the Information Technology Association of America, and two others, which just last night, with Mr. Wu in our presence, unveiled the new name of TechAmerica, this merger of four associations which touches almost every State capital across the United States as well as offices here, Brussels, and in Beijing, so really a grassroots-to-global representation of the technology industry.

As Mr. Hall said in his opening comments, the technology sector has dramatically overhauled our economy. Even ten years ago if I had been here and mentioned companies like Google or eBay, that would have drawn a blank from everyone, and yet today they are ubiquitous brands. He mentioned the ENIAC computer, which filled a room, and today we wear on our hips more computing power than that had. Technology has also become a fundamental enabler, not just in the economy and innovation but in the energy and environmental challenges facing us today. The industry is helping to lead the way in producing new and sustainable contributions. For instance, electric motors that use variable speed drives happen to be powered by chips from companies like Texas Instruments and they are estimated to annually prevent emissions of 68 million tons of greenhouse gases. Recently a study by the American Council for an Energy Efficient Economy concluded that electronics and widespread IT had been among the principal drivers of increased energy productivity over the last 15 to 20 years, and now the transition to energy independence will also include a reliability upon more of these devices critical to the functioning of energy systems, electric cars, and a smart grid. For instance, computer chips are being developed by National Semiconductor to improve the conversion efficiency for photovoltaic solar power, smart grid technologies that allow two-way communications and thus less energy burned in the home or business. Migration to new computing models—you have heard of cloud computing—will result in a lower societal energy use for computing. Our industry has been a part of these, helping to drive them, and looks forward to contributing innovation and advances in this area as well. Now, as we have gone about this, as the Committee recognizes, there has been a byproduct of the industry's growth in terms of e-scrap or e-waste and we are actively working in that arena as well. Dr. Thomas has referenced the work going on to remove substances such as lead and mercury from designs. HP, Apple, and Dell, among others, have introduced notebook computers that use LED technology instead of mercury-containing fluorescent lamps, and such innovations, which continue nonstop, are notably and importantly almost always done in conjunction with our higher education system. The legislation being proposed by Chair Gordon recognizes that, embraces that, and in our view, goes a long way toward helping enable some real solutions, first by authorizing the National Academy of Sciences report, because we have got to get the science right; secondly, by funding R&D for green alternatives; and finally, requiring work with universities to improve the training of undergraduate and graduate students, and I just want to endorse what Dr. Thomas said earlier: what a great magnet this particular area can be for a new generation of students. I believe the key will be the ability of the private sector to work with the leading universities. Merely funding the research is not enough. We need to make sure it provides concrete, implementable solutions that the private sector can use.

There are specifics in the bill requiring academic institutions to partner with companies to include participation by industry in the reviewing body that will evaluate proposals to ensure that they are practical. Applications must reference the companies and associations that contribute to a project. We think that collaboration is critical, and the application must include important transfer research results, again, making it relevant to the real world, which we think is so critical.

We stand ready to be of an assist to the Committee and the Members in any way that we can, believing that more innovation is going to be part of the solution going forward. Thank you, Mr. Chair.

[The prepared statement of Mr. Bond follows:]

PREPARED STATEMENT OF PHILLIP J. BOND

Mr. Chairman and Members of the Committee, good morning. My name is Phil Bond and I am the President of TechAmerica. Thank you for this opportunity to testify today in support of legislation that would authorize federal programs to study and conduct research on ways to reduce the environmental impacts posed by discarded electronic products.

Many of you may not know TechAmerica, but you know who we are. TechAmerica was launched as a result of the mergers of AeA, the Information Technology Association of America, the Cyber Security Industry Alliance (CSIA), the Information Technology Association of America (ITAA), and the Government Electronics & Information Association (GEIA). TechAmerica is the leading voice for the U.S. technology industry, which is the driving force behind productivity growth and jobs creation in the United States and the foundation of the global innovation economy. Representing approximately 1,500 member companies of all sizes from the public and commercial sectors of the economy, it is the industry's largest advocacy organization. It offers the technology industry's only grassroots-to-global network, with offices in State capitals around the United States, Washington, D.C., Europe (Brussels) and Asia (Beijing).

For the last few decades, the high tech industry has produced innovative and revolutionary products that have powered the U.S. economy and dramatically changed the way Americans live, work, and play. Just think, in 1996 if I had testified before this committee, names like Google and Oracle would mean very little to you. Today, they are two of the most well known brands around and their innovations have changed the way Americans and business do pretty much everything. Over the last 25 years we have moved from Commodore 64s to Portable hand-held computers with exponentially more ability; we have gone from portable phones carried in suitcases to portable phones smaller than your hand; from giant jukeboxes and walkmans to iPods; from green screens to hi-definition; from copper phone service to massive high-speed networks.

More than improved technologies, technology has become a fundamental enabler, driving productivity and growth across every economic sector, from farmers using GPS to improve their crop yields to manufacturers using computer assisted design and manufacturing tools to improve productivity on the factory floor. Technology provides innovators with improved tools to help them do whatever they are doing in ways that were unimaginable only a few years ago.

The industry is now stepping up to lead the way in inventing and producing new technologies to make the economy more energy efficient and sustainable. Electric motors that use variable speed drives, powered by chips produced by companies such as Texas Instruments, are estimated to annually prevent the emissions of 68n million tons of greenhouse gases.[1]

A recent study conducted by the American Council for an Energy Efficient Economy for AeA found that high tech electronics and the widespread advancement of information and communications technologies have been among the principal drivers of increased energy productivity during the past 15–20 years.[2] These technological drivers of energy efficiency span the range from computers and cell phones to numerous types of sensors, microprocessors and other technologies embedded in every day products such as cars, lighting systems, motors and appliances. The report states that the continued development and expanded application of such technologies will help ensure that economic development continues to move in a direction that is both economically dynamic and environmentally sustainable.

The transition to energy independence in the United States will also depend upon the growth and proliferation of electronic devices, which are critical to the functioning of renewable energy systems, electric cars, and the "smart grid." Electronic circuitry is essential to the efficient functioning of hybrid cars just as semiconductor advances will be critical to expanding the consumer utility and acceptance of plug-in electric vehicles by substantially extending their range and performance. Com-

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[1] *"Doing Moore Using Less,"* Semiconductor Industry Association, available at *http://www.sia-online.org*

[2] *http://www.aeanet.org/aeacouncils/AeAEurope_Energy_Efficiency_Report_17Sep07.pdf.* Other recent reports highlight the positive contribution that information technology can make in improving the overall efficiency of the economy and combating climate change. See, e.g., American Council for an Energy-Efficient Economy (ACEEE), *"A Smarter Shade of Green,"* (2008) ("For every extra Kwh of electricity that has been demanded by ICT, the U.S. economy increased its overall energy savings by a factor of about 10. . ."); The Climate Group and the Global e-Sustainability Initiative, *"Smart 2020: Enabling the Low Carbon Economy in the Information Age,"* (2008) (ICT strategies could reduce up to 15 percent of global emissions in 2020 against a "business as usual" baseline.)

puter chips are being developed by National Semiconductor that improve the conversion efficiency of renewable energy sources such as photovoltaic solar power, increasing the cost-effectiveness and long-term sustainability of these installations.

Smart grid technologies will allow two-way communication between the home and our energy utilities that, when combined with networked home and electronic products and appliances, will lower energy usage by all Americans. This collaboration between our network providers, electric companies, hardware manufacturers, network equipment manufacturers and consumer electronics and appliance companies represents a who's-who of TechAmerica's membership of 1,500 companies—too numerous to list them all here. The Smart Grid will incentivize the production of energy-efficient and intelligent appliances, smart meters, new sensing and communications capabilities, and electric powered passenger vehicles—all of which will be produced by, or made possible by TechAmerica's member companies.

The migration to new computing models, such as cloud computing, will bring new economies of scale resulting from shared data storage and processing capabilities. The result will be significant decreases in societal energy usage while at the same time increasing our overall computing power. Such innovations in the high tech industry will allow greater energy productivity throughout the economy without any sacrifices in quality of life.

Our industry is also uniquely poised to create "green jobs" that will employ Americans and provide very good wages. One "career of the future" that will grow from new models of computing is an energy management coordinator, who would ensure that innovative, high-tech products are programmed and operating at levels that provide the most energy efficient result. TechAmerica's members are driving innovation in this sector.

Clearly, the technology industry will continue to play a critical and leading role in enabling energy efficiency and renewable energy. However, as the Committee recognizes, a by-product of the industry's growth has been an increase in the number of discarded, obsolete electronic products that require management. The United States Environmental Protection Agency has estimated that the electronic waste stream is growing 2–3 times faster than any other waste stream in the United States.[3] Clearly, something must be done.

The high-tech industry has been actively working to address this issue. Our greatest strength is the ability to innovate and create products. Designing for the environment has become an integral strategy in most companies' design and engineering efforts. Additionally, electronic products are fundamentally unique: In every product cycle, they become smaller, faster, more functional, and more energy-efficient. That phenomenon alone delivers significant benefits for the environment.

Furthermore, engineers are working to remove hazardous substances, such as lead and mercury, from product designs. These materials often provide unique benefits and functionality, including safety shielding and energy efficiency. Companies are developing substitute materials that can achieve the same functionality with fewer environmental impacts. For example, HP, Apple and Dell, amongst others, have introduced several notebook computer models that use LED technology instead of mercury-containing fluorescent lamps. Others are exploring the use of halogen free flame retardants in electronic products.

Products are becoming more recyclable. New techniques allow for easy and quick disassembly. Companies are exploring the use of plastic resins that can be reused in new products. They are also working with recyclers to help understand how product design impacts the recycling process. All of these efforts will help facilitate and promote more cost effective and efficient recycling operations for electronic products.

It's important to emphasize that our industry is a partner in this endeavor. One of the hallmarks of America's leadership in the global economy is collaboration between universities, private laboratories, government agencies and companies. Together we create innovative and marketable solutions in areas like defense, health care, the hard sciences and, of course, technology. Greening our products and solving the e-waste problem is no different—if all these communities can work together in committing resources to research and development of e-waste solutions, we will be able to tackle this problem without harming the industry's greatest strength—its ability to innovate.

The legislation being proposed by Chairman Gordon and before this committee today will go a long way towards reaching this goal. First, by authorizing a National Academy of Sciences report that will assess the environmental impacts caused by

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[3] See *http://www.epa.gov/NE/solidwaste/electronic/index.html.* ("While various reports estimate that electronic waste is less than four percent of the total solid waste stream in the United States (eCycling FAQs), electronic waste is growing 2–3 times faster than any other waste stream (i.e., paper, yard waste.")

the disposal of electronic products, the legislation will help fill a critical data gap that currently exists. It is important to understand the problem before effective policies can be constructed. Second, by funding the research and development of green alternatives to hazardous materials in electronics as well as research into product design to facilitate the disassembly and recycling of electronic waste, the legislation will address two of the most important challenges the technology industry is seeking to overcome: the development of "greener" products that are easier to recycle. Finally, by working with universities to improve the training of undergraduate and graduate engineering students in environmental considerations—the legislation will guarantee that future products will be designed with environmental considerations as priority design characteristics as opposed to being considered only when the products are discarded.

The key to this research and development being successful will be the ability for universities, labs and not-for-profit organizations to partner with the high tech industry in developing workable, efficient, and cost-effective solutions. Merely funding the research is not enough—ensuring that the research provides concrete and implementable solutions for the private sector will lessen, if not end, the environmental issues posed by the disposal of electronic products.

The current draft of the bill contains several important provisions that I believe will enhance public-private collaboration and ensure that the outcomes envisioned in the bill lead to concrete, beneficial innovations that improve the environmental profile of high tech products. We congratulate the Chairman for his foresight in including these provisions, and we urge that these principles be retained and strengthened in the bill.

Specifically:

- Section 4 calls for the academic institutions to partner with companies and associations involved in the production, sale, and recycling of electronic products. Requiring the research institutions to partner with companies and associations will improve the likelihood that the research projects will yield beneficial results.
- Similarly, Section 4(b) calls for industry participation in the reviewing body that will evaluate proposals and ensure they have merit. Once again, the explicit call for industry participation in the review of proposals will improve the prospects for projects that provide practical information to the companies that produce these products.
- Section 4(d)(1) states that the application must reference the companies and associations contributing to the project. We believe that requiring evidence of this type of collaboration and support is an essential element of successful partnership between universities, labs, not-for-profits and industry.
- Section 4(d)(3) specifies the application must include information on how the Centers for Electronic Waste Research will "transfer research results into practice to address the electronic waste issue, with emphasis on the feasibility of incorporating research results into industry practice." Making applicants expressly identify how the results will be transferred into practical outcomes in another important element of ensuring successful outcomes.
- Section 4(e)(6) requires that the evaluation of proposals consider the technology transfer plan and the feasibility of integrating the research into practice.

We believe that these provisions will further the goal of ensuring that the academic research will be meaningful and transferred into tangible improvements in the design, production and recycling of electronic products. This approach will improve the prospects for promoting research that is applied by companies and ultimately achieves the environmental benefits that are the goals of this bill.

Again, thank you for the opportunity to testify today. I look forward to working with the Chairman and this committee on passage of this legislation.

Biography for Phillip J. Bond

Phillip J. Bond is President of TechAmerica, the broadest U.S. technology association with 1,500 member companies and 17 regional councils across the country. TechAmerica is the new association resulting from the January 1, 2009 merger of the Information Technology Association of America (ITAA) and the American Electronics Association (AeA).

Previously, Bond was appointed President and Chief Executive Officer of ITAA in June, 2006. In that capacity, he engineered two earlier mergers that brought the Government Electronics and IT Association (GEIA) and the Cyber Security Industry

Alliance (CSIA) under the ITAA banner. Bond also is President of the World Information Technology and Services Alliance (WITSA), a network of industry associations representing more than 60 high-tech trade groups around the world.

Today, TechAmerica represents some 1,500 leading software, hardware, services, Internet, telecommunications, electronic commerce and systems integration companies. The association offers business services, networking, standards development, research and grassroots-to-global policy coordination for its members.

Bond is a highly accomplished executive in both government and industry. Prior to joining ITAA, he served as Senior Vice President of Government Relations for Monster Worldwide, the world's largest online career site, and General Manager of Monster Government Solutions. From 2001 to 2005, Bond was Under Secretary of the U.S. Department of Commerce for Technology and, from 2002–2003, served concurrently as Chief of Staff to Commerce Secretary Donald Evans. In his dual role, Bond worked closely with Secretary Evens to increase market access for U.S. goods and services and further advance America's technological leadership at home and around the world. He oversaw the operations of the National Institute of Standards and Technology, the Office of Technology Policy, and the National Technical Information Service. He has been recognized in Scientific American magazine in its list of the Top 50 Tech Leaders of 2003.

Earlier in his career, Bond served as Director of Federal Public Policy for the Hewlett-Packard Company, and previously as Senior Vice President for Government Affairs and Treasurer of the Information Technology Industry Council. From 1993 to 1998, Bond served as Chief of Staff to Congresswoman Jennifer Dunn (R–WA). He was Principal Deputy Assistant Secretary of Defense for Legislative Affairs from 1992 to 1999. Earlier, Bond was Chief of Staff and Rules Committee Associate for Congressman Bob McEwen (R–OH) from 1990 to 1992. From 1987 to 1990, he served as Special Assistant to the Secretary of Defense for Legislative Affairs.

Bond is a trustee and graduate of Linfield College in Oregon. He also serves on the board of the National Center for Women in Information Technology. He and his wife, Diane, have two daughters and reside in Fairfax Station, Virginia.

Chair GORDON. Thank you, Mr. Bond. I think we look forward to being a partner with you. You will be a great resource.

And now Mr. Jeff Omelchuck.

STATEMENT OF MR. JEFF OMELCHUCK, EXECUTIVE DIRECTOR, GREEN ELECTRONICS COUNCIL, ELECTRONIC PRODUCT ENVIRONMENTAL ASSESSMENT TOOL (EPEAT)

Mr. OMELCHUCK. Thank you, Mr. Chair. Thank you for holding this hearing on this important issue and for providing all of us the opportunity to testify today. My name is Jeff Omelchuck. I am the Executive Director of the Green Electronics Council, a nonprofit based in Portland, Oregon that works cooperatively with all stakeholders interested in electronics and the environment from manufacturers to NGOs to the purchasers and users of electronics and recyclers to try to realize the benefits of electronic products without saddling society with some of the negative aspects of it today. I am also the Executive Director of EPEAT (Electronic Product Environmental Assessment Tool) Inc., which Congressman Wu introduced, and thank you very much.

I wanted to highlight a few of the key issues that I think are emerging that make electronics rather unique products, that one, I think it is just striking that every advance we have made in society, nearly every advance in the last 50 years has been enabled largely by information technologies. At the same time, they are the most impactful product on the planet to manufacture. This is a striking kind of situation for a technology. Recent research indicates that probably about 80 percent of the environmental impact associated with desktop computers happens during the material extraction and manufacturing phase. Most of this impact occurs because of the chemicals and energy and water used in the manufacture of the product. The point is that these indirect materials can't be recovered during manufacturing because they are not present in the product. I think this argues for strong consideration of a program that emphasizes reuse of these products and trying to do what we can to extend the life of these products as long as possible to amortize this impact of manufacture of a longer use life. So if e-waste only deals with the waste end as it typically has in Europe, I think we are missing a huge opportunity to reduce the environmental impact of these products.

Electronics are different from many other commodities that we think about recycling. If you think of beverage containers or other things, the goal of recycling those is to recover the material out of those so we can reuse that material and recover the aluminum or recover the plastic for reuse. The issue with electronics is rather different. I think our highest priority needs to be to prevent inappropriate recycling, as Dr. Anastas described and Chair Gordon described. A lot of this material is shipped overseas where they make crude attempts to recover the expensive and valuable parts out of it and their attempts have grave environmental issues associated with them. We need to prevent the export of our own waste where it causes these problems. Secondly, as a secondary priority, I think we need to keep toxics out of the environment. We need to prevent the pollution caused by e-waste itself. This is an issue that we don't face with, say, aluminum cans or plastic bottles. Third, we need to recover the high value and rare materials out of electronics. They are available often in quite trace quantities but they are also very impactful materials too to create and extract and make available in our society, so recovering those is probably the highest priority. And finally, recovering the plastics and ferrous metals, which is what we do mostly today in the small percentage that we do recycle. It is probably the lowest priority.

I would like to further make the point that, as Dr. Anastas did, that e-waste systems are incapable of affecting product design and the product design greatly impacts the results of how well they are recycled but just collecting the waste and recycling at the end of the stream does nothing to affect product design, and there are recycling systems, electronics recycling systems, all over the world at this point. None of them affect product design. There is no incentive placed on the manufacturer to change product design to make them more recyclable. There is, however, an effective way to affect product design, and that is a green purchasing system, a specification placed by the purchasers of the product on green design, and there is a very powerful program in place today called EPEAT. It is a program that my organization manages. It is the program used by the U.S. Federal Government when they specify green electronics. Such programs do have the capacity and capability of affecting product design and doing so effectively today. Today EPEAT has created over $60 billion market incentive for manufacturers to design and manufacture greener products.

I would like to make one input on the bill. The reason that we do not today have an electronics recycling program in the United States is because of difficulties with the funding system. Each funding system that has been proposed affects different kinds of manufacturers differently, disadvantages some more disproportionately than others. Therefore, each possible funding solution is opposed by somebody, and that has prevented us moving forward collectively to have a system that works. Therefore, I suggest that in addition to the research proposed in the bill that we also include policy and economic research in trying to figure out the funding system that will enable progress.

Thank you very much for this opportunity to testify.

[The prepared statement of Mr. Omelchuck follows:]

PREPARED STATEMENT OF JEFF OMELCHUCK

Recycling the huge amount of legacy electronics that have already been produced is a critical environmental issue. A good e-waste system would keep the environmentally sensitive materials in electronics out of our landfills, groundwater, and air and would allow us to recover and re-use many of the valuable materials. In addition, it must prevent the export of American e-waste to countries and places that cannot, or do not, recycle it properly. There are many ways that the development of an effective national electronics system would benefit from further research. We strongly support the proposed "Electronic Waste Research and Development Act" and the creation of a national e-waste recycling system. Below we present some research and thinking about e-waste recycling and suggest some areas needing further research.

Research suggests that over 80 percent of the environmental impacts associated with Information and Communications Technology (ICT) occur during the manufacture of the product.[1] Much of this impact stems from the electricity, fossil fuels, chemicals, and water used to make semiconductors, printed circuit boards, and other components. While recycling recovers some of the material contained in the product, none of these indirect materials or energy can be recovered. This suggests that one of the best ways to reduce the environmental impacts associated with electronics is to amortize the high impact of manufacturing them over a longer use life. Thus, **it is critical that an e-waste "recycling system" encourage product and component re-use.**

While product design clearly affects recyclability, the reverse is not true. Electronic products are not designed for optimal End-of-Life (EOL) outcomes. Further, if there were comprehensive Design for EOL (DfEOL) guidelines it is not clear why manufacturers would follow them. While most recycling systems charge manufacturers a fee based on their market share or "collection share,"[2] it doesn't make environmental or economic sense to actually return each manufacturer's products to them or process them separately. Because of this, individual manufacturers have no incentive to make their products more easily or efficiently recycled. In fact, many of the innovations that any one manufacturer might make to improve recyclability (use of unique materials, novel connectors, disassembly methods, etc.) have the potential to actually reduce the overall recyclability of the common waste stream. **Innovation by individual manufacturers has not and will not improve product recyclability. Collective collection and recycling argues for common product DfEOL standards.**

Enforcing a common DfEOL standard via regulation would be very difficult, and once enacted it would be very slow to evolve in this fast-moving industry. However, electronics manufacturers are very good at listening to and meeting the needs of their customers. **An eco-label or "green purchasing system" that carries substantial market demand is the most practical and responsive way to implement a common DfEOL standard and is a necessary component of an e-waste solution.**

With EPA and the Federal Government's help, in two and a half years EPEAT has become the most influential green purchasing system for electronics on the planet. EPEAT registration is now required on over $60 billion of IT purchase contracts from the U.S. Federal Government, the Canadian Federal Government, many states and provinces, and a growing list of international businesses and public agencies. **EPEAT's DfEOL and other criteria are clearly affecting the design practices of IT manufacturers globally.**

EPEAT was developed by and for institutional purchasers—organizations that buy computers on purchase contracts. Retail consumers represent approximately 40

[1] E. Williams (2002), "The 1.7 Kg Microchip."

[2] Including the EU WEEE system, China's system, and the systems of the U.S. States that have implemented e-waste recycling programs.

percent of the market for laptops, desktops, and monitors yet EPEAT is not known or used by consumers. In addition, stakeholders have begun the process of developing EPEAT standards for other electronic product types with substantial consumer markets. If EPEAT is to be an effective tool for improving the recycling outcomes for consumer electronics then consumers must place a purchasing preference on EPEAT registered products, as the U.S. Government does. **Building consumer awareness of the importance of e-waste recycling and of buying products that are optimized for efficient recycling will require market research and likely public investment.**

Recent research conducted by GEC et al. and sponsored by EPA[3] shows that e-waste recycling technologies and practices vary considerably within the U.S., ranging from manual deep disassembly and materials sorting to whole product shredding. In addition, it appears that different types of electronic products are more efficiently recycled in different manners. Therefore, the DfEOL criteria may be different for different types of products that should be recycled in different ways. **Further research is needed to refine DfEOL criteria.**

The research report also describes a pilot project sponsored by GEC and the National Center for Electronics Recycling to create a "Close the Loop Registry" of recyclability information for many electronic products. **Further research and support for piloting and implementing this DfEOL registry are needed.**

Finally, research suggests that a significant amount of e-waste is caused by software driven hardware obsolescence. It is clear that the commercial models of both the software and hardware industries have no clear incentive to prevent or reduce this. **Further research is needed to determine if there are ways to change software and hardware product design practices, or the commercial incentives of these industries, to reduce material and energy churn without damaging the innovation and competitiveness of the industry.**

Comments on proposed "Electronic Waste Research and Development Act"

The primary reason that the U.S. does not have a comprehensive e-waste recycling program is disagreement between manufacturers as to how such a system would be funded. Each manufacturer has opposed a system whose funding would put them at a competitive disadvantage with respect to their competitors. As a result, each possible system is opposed by one or more powerful manufacturers and the result is no system. The proposed act would do little to solve this fundamental problem. We recommend that the research supported under the act include research into possible funding models and how to reduce or eliminate competitive inequities that prevent forward motion.

BIOGRAPHY FOR JEFF OMELCHUCK

I received a BS in Industrial Engineering from Montana State in 1982.

Moved to the Silicon Valley where I worked in high-tech engineering.

Received an MS from Stanford in 1987 on an Honors Fellowship from my employer.

Moved to Oregon and worked for a computer company from 1990–1992.

Started a consulting practice in Oregon that evolved to focus on sustainability management systems in 1992.

Founded the GEC in 2005.

GEC was selected to manage EPEAT in late 2005.

We launched EPEAT in 2006.

Chair GORDON. Thank you, Mr. Omelchuck. Just collaterally, you had mentioned water in the process, and another major legislative effort by this committee is going to be on water, and one of the elements of that will be research to how to use in closed systems, and how to use water and reuse water more efficiently.

Now Mr. Cade, you are recognized.

[3] Rifer et al. (2009), "Closing the Loop: Electronics Design to Enhance Re-use/Recycling Value." (See *Appendix 2: Additional Material for the Record.*)

STATEMENT OF MR. WILLIE CADE, FOUNDER AND CHIEF EXECUTIVE OFFICER, PC REBUILDERS AND RECYCLERS, HOME OF THE COMPUTERS FOR SCHOOLS PROGRAM

Mr. CADE. Thank you, Mr. Chair. It is an honor to be here today and I particularly want to echo my fellows at the table here in terms of their testimony, so I am going to skip kind of quickly on to the recommendations that I would have in the legislation.

First of all, in the definitions, I would suggest that there be very specific references to reuse, refurbishment, repair, remanufacturing, material recovery, and proper disposal. I think the current draft lacks some definition on that, and my experience has been when it is enacted into law, if those definitions are not clear, it becomes very problematic.

I would also suggest the definition of "hazardous" and "potentially hazardous." I think that is one of the issues that really is hard for us to deal with in this particular situation, and I do want to let people know that using their computers in the home is not hazardous. There just is potential for hazard later on.

In terms of section 4, the research and development, in terms of part 1—one of the things that we have been doing—I have run the collection facility for the city of Chicago on Goose Island and over the last year we cataloged over 7,000 items that people have brought to us as computer waste, and of those, 3,000 different model numbers exist with 425 different brands that those are made up of. The average age of that equipment is 10.2 years old so that is a very important number there to understand, and while we may want to design better products that are going to be coming down the road later, we have a large backload, large volume of equipment that we are going to need to deal with for many years to come. Our data suggests that the equipment is actually being stored longer and longer now that people are putting more and more of their valued data on that equipment. The other thing that I think is very important in this particular process is that we understand that this is not equipment that is not functional. It is just a perception that it doesn't work as well as the new equipment, and one of the things that we are very excited about is using these older Pentium 3, Pentium 4 systems to help homes monitor their energy use in the new smart grid environment. We are currently working with the Centers for Neighborhood Technology on creating a product that will measure your home energy use—and therefore be able to reduce your consumption.

One of the things that we anticipate is, by the mere savings on energy usage in a home, we will be able to finance the purchase of a PC for low-income families. Today there is still 25 percent of the households that do not have a computer in them. If we can provide them with a computer that can help them reduce their energy consumption, we believe we can finance not only the computer, a working model that has all the bells and whistles, but also the Internet connection and still save them dollars and energy on their home plans.

And I believe that this remaking of the products, the remanufacturing, the reuse, the refurbishment of these products will actually give us the ability to bring home the electronics industry. If you are competing merely on cost per hour for production, we probably can't compete with foreign competitors but if we are competing on a whole system of collection and use and knowledge and understanding of these systems and to bring product out, I believe we will be able to do a very, very good job with it. We are currently working on a pilot project in the city of Chicago where 100,000 homes will have smart meters, will be able to connect to these smart meters and be able to bring back information to the home user. Reports show—studies show—right now that the home user who has that kind of information is saving anywhere from 15 to 30 percent of their home energy costs. Average home energy costs right now are about $1,200 a year. That is a significant savings.

Thank you very much, and I will be happy to entertain any questions.

[The prepared statement of Mr. Cade follows:]

PREPARED STATEMENT OF WILLIE CADE

Mr. Chairman, Members of Congress, thank you for the opportunity to be before you today and testify on the issue of *Electronic Waste: Investing in Research and Innovation to Reuse, Reduce, and Recycle.* I would especially like to thank Congresswoman Biggert for her support of my work. I have submitted my full written testimony to the Committee and I will only summarize my statement at this time.

Fifteen years ago I began working with discarded computer equipment to help bridge the digital divide for at risk students in high school. I was attending a board meeting of LINK Unlimited a not-for-profit organization that supplies mentors and financial aid for capable students to attend the best schools in the City of Chicago. During the meeting I was arguing that each student needed a personal computer in their home so they could prepare adequately for college. The then Chief Financial Officer of Waste Management offered four conference rooms full of equipment that they were storing because they didn't know how to throw it away. So began my adventure of computer refurbishment and electronics recycling. When I walked into the conference rooms on that cold February morning I saw opportunity not a pile of waste. For me this is e-opportunity not e-waste. With the Chairman's indulgence I will continue to use my term e-opportunity not e-waste.

We quickly discovered that the single most complicated part of computer refurbishment was installing a fresh, reliable, and legal operating system across a broad spectrum of hardware. We worked with Microsoft for seven years and in 2000 the Microsoft Authorized Refurbisher (MAR) Program was launched. My company was one of the first five organizations that Microsoft authorized to reinstall their Windows operating system on refurbished computers in the U.S. Since then we have refurbished over 40,000 computers for schools, not-for-profits, and in homes of children at risk. We provide a complete system (CPU, monitor, keyboard, mouse and speakers) with an instruction booklet, free U.S. bases telephone support and a three year hardware warranty for a starting price of $150.00. Our fist year failure rates are less than new equipments first year failure rates.

We reluctantly became involved with equipment that we could not use for our refurbishing because of the demands of our donors. If we wanted the good stuff we had to take the whole lot. While this has significantly complicated our business model it has also provided us with enormous opportunities. Early in 2000 the extra equipment was relatively easy to deal with but as more and more equipment was brought out of closets and store rooms the task became more challenging. Today a significant majority of equipment is not refurbishable for general personal computer usage. Recently a stakeholder group supported by the U.S. Environmental Protection Agency has published *"Responsible Recycling (R2) Best Management Practices for the Electronics Industry."* This document is attached at the end of this testimony. These practices specify the philosophy and practice that high quality organizations should employ. I whole heartily support the implementation of these practices in certification programs like. There is some controversy that these practices do not hold organizations like mine to a high enough standard. As a practitioner of the art of e-opportunity I believe that significant research and development must be carried out before we can practically implement higher standards. This legislation is well suited to accomplish those goals.

Comments on the draft legislation:

Section 3: Definitions.

1) I would suggest that the legislation include a specific definition of "recycling" that includes reuse, refurbishment, repair, remanufacturing, material recovery, and proper disposal. I have attached to my testimony a brief concept document on "Strategies for Improving the Sustainability of E-Waste Management Systems" that may be useful in defining the above terms.

2) I would suggest that the legislation include a definition of "hazardous" and "potentially hazardous" materials. I believe that it is important to assure consumers they are not overly exposed to environmental hazards while using a computer. It is however important to educate people that improper handling may be harmful to themselves and the environment.

Section 4: Electronic Waste Engineering Research, Development, and Demonstration Projects.

Part 1) I believe that Radio Frequency Identification (RFID) should be the major way that efficiency of recycling (in all of its forms) be studied. For over a year my organization has cataloged over 7,000 items at the Computer Collections facility that we operate for the City of Chicago on Goose Island. We keep detailed data on each item over one pound that is delivered to this permanent collection facility. There are roughly 3,000 different model numbers from over 425 different Brands. The average age of the equipment is 10.2 years old. People travel on average six miles to drop off their equipment. TVs average 15.5 years old while Apple Computers are two to three years older than other brands of computers. CPUs average 25 pounds and monitors average 35 pounds while TVs average 45 pounds. Automated triage with the support of RFID must be developed that fully utilize both the carbon investment of the products and increase the recovered value. (Note: over 80 percent of the energy used in the life cycle of a computer is used in the making of the product.)

Part 2) Casual reading of the Discussion Draft in this section might lead one to believe that research should only be done on "e-opportunity" only after it has been destroyed and separated into different commodities. While I concur that much work still needs to be done on that issue there is a broader area of research that should be identified. A significant majority of the equipment being turned in by consumers and organizations is still functioning. Newer models may have come on to the markets that perform the desired tasks faster and better: *triggering the false impression that the older equipment is waste.* For instance most of the working CPUs that we receive could be cost effectively remanufactured into home energy monitoring and control devices, thus allowing consumers simple and efficient ways to take advantage of Smart Grid technology in their homes. I believe that the refurbishing and remanufacturing of e-opportunity will bring the electronics manufacturing industry back home.

Part 3) The university setting is well suited for this kind of basic materials research. I applaud the Committee for it's inclusion in this legislation.

Part 4) I believe that it will be at least 15 years before all of the potentially hazardous materials will be removed from our electronic devices. In the mean time we need to develop safe methods of removing those materials both in developed and underdeveloped countries. Many well intentioned environmentalists have suggested that unwanted electronic devices that come from the US and go to developing countries should be shipped back to us for end-of-life processing. I would rather see safe portable processes that are applicable in many different environments.

Part 5) Product design is one of the most important issues in transforming e-opportunity into value. To that end I currently teach a graduate/undergraduate "e-opportunity" course at the University of Illinois at Urbana/Champaign. The course is housed in its industrial design department, the oldest such program in the country. This semester we are conducting a contest, open to all students on campus, for the most creative and the most "geeky" use of e-opportunity. I would like to invite each and every Member of this committee to be a judge for this contest on April 21st of this year.

Part 6) We need scientifically sound tools that aid us in assessing the environmental impact of e-opportunity and manufacturing in order to make informed decisions about the quality of our processing and balance it against the needs to be cost effective. I am not suggesting that we diminish our goal of 100 percent environmental safety but rather that we use these new tools to expedite reaching those goals. Again I applaud the Committee on the inclusion of this section of the legislation.

Part 7) We have not come close to exhausting our electronic devices. All too often our perception of obsolescence prematurely retires our electronics. Product design that can incorporate repairs, upgrades, etc., need to be encouraged and real business cases need to be found to support them.

Part 8) I believe that the single biggest issue confronting consumers and business in recycling their equipment is the concern about data security. People are not educated nor can they readily identify a device that has its data erased. Given that the systems turned in at our facility in Chicago are on average 10.2 years old and preliminary research has shown that people use their computers for about six years they must be storing them for four plus years. RFID can allow a complete and reliable chain of custody that can generate better consumer acceptance and therefore quicker equipment turn around. This would be a better utilization of the carbon investment made in our devices.

I also applaud the inclusion of sections 5, 6, and 7.

Please let me reiterate the following point . . . this legislation will significantly contribute to bringing home the electronics manufacturing industry.

Biography for Willie Cade

Willie Cade is the founder and CEO of PC Rebuilders & Recyclers (PCRR). He started the company in 2000 to help underprivileged students get cost effective computers. PCRR has placed over 40,000 refurbished computers in schools, not-for-profit organizations and in homes of at risk children. Mr. Cade has been at the for front of the computer reuse industry for the past 15 years. In the early years he worked closely with Microsoft to help create what is today's successful Community Microsoft Authorized Refurbisher (Community MAR) program. He founded the first ever refurbisher conference and continues to organize them today. He is active nationally and internationally creating best management practices that help reduce the possible harm of e-waste. Now Mr. Cade's expertise is being shared with graduate and under graduate students at the University of Illinois Urbana/Champaign. Along with Wal-Mart and Microsoft he is co-sponsoring an e-waste "new products" competition this spring at the University.

Discussion

Chair GORDON. Thank you, Mr. Cade. And we would appreciate your specific recommendations on definitions and we would recommend again the panel any other recommendations they might have on our draft as well as anyone in the audience or watching or listening to us on a website now. This has been a collaborative effort to get to the point we are now, but I am sure that as we have more people thinking and giving input, we can make it even better.

So at this point we will now have the first round of questions, and the Chair recognizes himself for five minutes.

Mr. Bond, you raised the issue earlier of the collaboration with the private sector and the universities and how that is going on now. I know that as this takes place, there is going to be some proprietary research, so is there going to be any kind of special provisions that we need in this bill that will provide incentives for the public sector and private sector to work together?

Mr. BOND. I think that as a general rule, the Federal Government's role in doing a lot of the basic research, fundamental research and very often through a grant structure where you have a lead investigator, a lead at the university who then invites private-sector participation at a pretty fundamental level is very good and it allows for the proprietary innovations that might be built on top of that, but I think you will find a ready and willing partner in the private sector to do some of that fundamental research, new materials that could be incorporated into design, better uses or testing and research into uses of new materials that we haven't thought of before, technologies to recover materials. I think the industry has shown that it is on the edge of its seat and willing to——

Chair GORDON. So you don't think any kind of special provisions need to be made for proprietary issues?

Mr. BOND. Well, we have some vehicles in the government already for cooperative research and development agreements and so forth that take that into account to protect intellectual property, but I think there is a great agreement that there is a first step where the government should lead and the private sector is more than willing to participate.

Chair GORDON. On that topic, I think one of the biggest obstacles to national e-waste R&D initiative, like many things, is tech transfer and getting it from the academic research area into industry, so I will just ask Mr. Bond if you want to, or anybody else wants to, have any comments on how we can make that transfer better.

Mr. BOND. Just in some very general terms, I want to observe that I think the tech transfer laws in this country have been one of the great, great global competitive advantages we have had. As we try to maintain our global edge competitively, I think we have to constantly look at that because others—it is a competitive market and other universities based in other countries are trying to attract investment from some of the multinational companies that do significant research. So I think we want to continue to look at that and would certainly welcome thoughts from those in the more academic side of the equation, but I think we need to have a balance in this as we do in so many things to make sure that as we divide the intellectual property, that it doesn't result in a stalemate but it instead results in the tech transfer.

Chair GORDON. Well, let us ask anybody else on the panel. Mr. Cade.

Mr. CADE. Thank you, Chair. I do teach at the University of Illinois, Champaign Urbana, an e-waste sustainable class, and one of the—we are working on those. Also, the University has an international component to it. They have research centers outside the United States. We are finding that their cooperation with us has been extraordinarily wonderful, and we are actually using students to take this pile of equipment and bring it back to life. We have already discovered just through a few trials some major issues that we need to input to our friends over here at EPEAT (Electronic Product Environmental Assessment Tool) in terms of making this product more accessible for reuse and refurbishment.

Chair GORDON. Anyone else want to comment?

Dr. ANASTAS. I would just suggest that there are existing models that have been used in various agencies to address this exact type of question. When you look at the Technology for Sustainable Environment out of the Environmental Protection Agency (EPA), that has not only brought about excellent industry-university partnerships but also sprouted quite a number of new businesses. If you look at some of the National Science Foundation (NSF) models, the industry-university cooperative research centers, the engineering research centers, and science and technology centers, these questions of tech transfer and intellectual property have been dealt with well.

Chair GORDON. Mr. Bond, I know you would like to speak. I would like to get on to one other question before my time runs out, and maybe you want to help us with that one. The E.U. has taken more of a regulatory position across the board than we have in this country, although some states have. This bill really is in the research area. But are there any lessons to be learned from what the E.U. has done that would be pertinent to our bill in terms of not regulations, but rather research? Is anyone familiar with what they are doing over there or have anything they want to suggest? Yes, sir.

Mr. OMELCHUCK. Mr. Chair, the E.U. has completed twice now, I believe, comprehensive performance reviews of the e-waste system implemented in Europe. They recently completed, I think very recently in the last few weeks, completed a second kind of comprehensive review of the system so that is available to be researched. I recommend that we look closely at that. The other striking thing about the E.U. system, the two things that I would observe, are that even though it is a regulatorily required comprehensive system, the actual rate of recovery of electronics is surprisingly low, in the 35 percent range, which means still 65 percent, even though it is a regulatorily required system, still 65 percent of the e-waste is leaving the system inappropriately, is escaping the system, which is a surprising number, I think, for many of us.

Chair GORDON. Well, that is why Mr. Baird is very interested in how do we—the psychology aspect of getting folks to work with the system. My time is running out here, so anybody else want to comment on the lessons from the E.U. Yes, Dr. Thomas.

Dr. THOMAS. One lesson from the E.U. is that there is some kind of goal set forward by the government, and to move things forward in the United States, it might not have to be an E.U.-style program but some guidance to push forward recycling and remanufacturing to let—because industry—it won't just be one industry that needs to work on this. Somehow there needs to be integration between the manufacturers and the retailers and the recyclers and university researchers and EPA or some other government agency could provide some forum for making these organizations work together productively. That won't happen in a vacuum.

Chair GORDON. It needs to be good, Mr. Bond, because——

Mr. BOND. It is going to be short. I don't know about good. Just that there are a full range of stakeholders that should be a part of that discussion and part of that research, the government and its procurement rules, just to name one quickly.

Chair GORDON. Thank you.

Dr. Ehlers is recognized.

Mr. EHLERS. Thank you, Mr. Chair, and first of all, thank you for holding the hearing. This is a very important topic. I was watching 60 Minutes a few weeks or months ago and wrote a note to myself that I had to check into this. They were talking about how they had followed a container of used computers, waste computers, some of them post recycling, supposedly, and followed it all the way to China where it was simply burned on a trash heap after they had extracted some things. Everyone along the line specifically violated the law because they are not allowed to do this. So whatever we do, it has to have teeth and it has to have enforcement.

Secondly, let me say the Minority regards this as a very serious issue and would be very happy to work with you on developing a really good and strong bill.

I looked at some of the options and you have mentioned some of the options. I don't see any reason we can't do it. We just have to make sure we do it right and we have to make sure we do it fairly, and any specific suggestions you have along that line would be useful. But before I go to you and ask for your comments on that, let me just ask a question, a generic question. What does the U.S. House of Representatives do with its used computers? When I was involved in computerizing the House for the first time in 1994 and 1995, we decided that any used computers from the House would be available for purchase by the employees, who loved that and many of them didn't have good computers at the time and it got them in the home computer business and we thought it was beneficial to the House too. Later on we were told we were not allowed to do this because that was somehow giving a bonus to the employees. I didn't particularly worry about that but it turns out I don't know whether it was GSA (General Services Administration) or what stopped us from doing it. But it has gotten steadily worse. We then proceeded in our district office, when we changed computers, and donated them to nonprofit organizations. That lasted two years and then we were told we couldn't do that either. I think we have to broaden our discussion to the GSA and what they are doing about this problem because they have responsibility for a huge number of computers nationwide, and if we can set up a program that works for the GSA, it most likely will work for the Nation. Plus, I don't think it hurts for the government to be first and find out what the burdens are on this so that we are not imposing unusual burdens on the private sector. We can answer their questions and say well, we are doing it and this is how we are doing it and it works.

Mr. BAIRD. Will the gentleman yield for one second, Mr. Ehlers?

Mr. EHLERS. Yes.

Mr. BAIRD. I faced the same problem in my office this year, would like to donate my computers to the local schools, and have been prohibited. Jose Serrano, our colleague, has a bill to allow us to do just that, and I would encourage all my colleagues to co-sponsor that bill. It is ludicrous that we can't give our replaced computers to local education, and I applaud the gentleman for his initiative.

Mr. EHLERS. And I would even broaden it to other nonprofit organizations. There are a lot of social organizations that could easily pass these on to poor individuals who can't afford one. That is my basic point. I hope we can answer the questions internally about what the U.S. House does, what the GSA does, and change that.

Back to—oh, I should mention, by the way, my wife would be very happy if we adopt a good program because I cannot in good conscience throw out a computer now. We have seven or eight of them in the basement and the basement is starting to overflow with that and my other junk.

I appreciate any comments you would like to make. Mr. Cade.

Mr. CADE. Thank you. Just—we do—we have worked over the last number of years to try to get Executive Order 12999 changed so that refurbishers like myself can take the equipment from government agencies and distribute them. The issue really is around software and about the issue. In order to securely give the equipment to us, it needs to be—the hard drive needs to be wiped. It is tantamount to taking an engine out of a car and delivering the car to someone's driveway and saying here, you have got a great product, have fun with it. So we actually have in the last three Congresses had legislation to change Executive Order 12999 to allow refurbishers to get the equipment and then pass it on to the not-for-profits, et cetera, and I will be happy to take the equipment from your home.

Mr. EHLERS. Yes, Dr. Anastas.

Dr. ANASTAS. I would just like to comment on your remark that we need to do this right and comment on why it is so important to have sustainable design frameworks that allow us to do the right things right and not the right things wrong. What I mean by that is, so often we see good intentions for environmental and sustainability issues get it wrong, looking at our solar photovoltaics that are using toxic scarce metals, our biofuels that may not be compatible with our land-use policies, our efficient lighting that may introduce toxins into the environment. So how do you ensure that you are not going to be doing the so-called right things wrong? And it is these design frameworks of understanding that the intrinsic nature is of the materials and energy flows that we are using in our electronics, not only what we make but how we make it, and so that is why I come back to the compass being more important than the speedometer and knowing that when you are trying to make something green and sustainable that you are actually heading in the right direction.

Mr. EHLERS. A very good comment, and just a quick comment in response. Individuals generally do not look to the future as much as they should and analyze what can and should be done, and yet you save money by doing it. I was struck this morning when I heard the news once again there is a lot of talk about the lead in the water in Washington, D.C., and the damage it has done to the children. Every few years this appears and the problem never gets solved. Kids continue to drink water with lead in it. And if you just analyze the cost of what that is compared to fixing the problem in the first place, I am sure fixing it is infinitesimal and I think you will find the same thing with the computer situation. If you do it right, it is going to cost less in the long run than whatever we are doing now or whatever might happen if we don't do things right.

With that, I yield back.

Chair GORDON. Thank you, Dr. Ehlers. My daughter has been drinking that water. I am terrified. And we do need to get some answers.

If I could real quickly—as usual, you know, you raised some very good questions, some of which aren't particularly in our jurisdiction but let me try to respond. It is my understanding that Mike Thompson on the House side and Barbara Boxer on the Senate side are organizing a recycling effort and that there will be a time where we can do that. The second thing is, as the former Chairman of the House Administration Committee, why don't you and I collaborate and write a joint letter to the Speaker and to Minority Leader Boehner about those things that it may not be—you know, what we can do administratively, maybe not legislatively but administratively and make those recommendations and challenge them to do that? So we will work together on that.

Mr. EHLERS. Thank you very much, and if anyone wants an original Mac SE, I have one in my basement.

Chair GORDON. Okay. Ms. Johnson, you have been very patient. You are recognized for questions.

Ms. JOHNSON. Thank you very much, Mr. Chair.

I would like to pose a question to the panel. We have in some of our schools a program where computers are rebuilt by students and they are teaching them to do that. Do you see any danger in that? Does that have to do with anything about restricting where they are circulated?

Mr. CADE. The actual process of the refurbishment is typically swapping out whole parts so there is typically no danger associated with that. That is one of the reasons I recommended earlier that we put in the legislation a definition of "hazardous" and "potentially hazardous." We don't see any, and we have been audited with environmental experts on those issues when we are refurbishing computers. We are typically undoing screws or unplugging things. We are not taking and grinding up the material to that end, and I am certain that that is not happening in the schools. So with a high degree of confidence I would say that there is not any increased exposure risk to the students in that kind of a program.

Mr. BOND. Congresswoman, if I could add too, the upside of that is, a number of programs around the country have shown that it serves to demystify the computer to the kids and make them that much more willing to pursue a career in that field.

Ms. JOHNSON. Yes. How can we leverage existing R&D that may be beneficial to solving the challenge of the e-waste?

Dr. ANASTAS. If I may, there is a tremendous portfolio of research going on currently in green nanotechnology, some of the leading groups out of the University of Oregon. There is wonderful work going on in biomimetic materials. There is wonderful work going on on new types of batteries, energy storage, energy scavenging. That type of broad research is being done for a wide range of purposes but is directly relevant to the up-front design of next-generation electronics. By leveraging that existing research, there could be a real multiplier effect on the purposes of this legislation.

Ms. JOHNSON. What is the rationale for exporting it? Is it for disposal or——

Mr. OMELCHUCK. If I may, the rationale is really not—you know, it is not illegal or intentional activity by and large, so it is being exported to these places that you saw in the 60 Minutes documentary. It is at the edge of legality. It is neither legal in China nor is it really legal in the United States so I think it is hard to describe the rationale. It is being done because it is mildly profitable.

Ms. JOHNSON. Thank you very much.

Mr. BOND. If I could, Congresswoman, I would add that at least theoretically, and I believe in practice, there are examples too where someone would refurbish and then export what had been considered e-scrap or e-waste to maybe a developing nation or someplace where it would really be of use, and so you want to make sure as you think of an international regime that you don't somehow make that illegal because it was considered scrap but it has been refurbished and could be put to use in some other setting.

Mr. OMELCHUCK. And I would add to that that the reality is that all electronics today, or almost all, are built in Asia, and if this is where they end up, there are very legitimate reasons to want to send the materials from which they were built back to Asia because that is where they can be used by and large and so there are legitimate reasons to do it. The challenge is to do it appropriately.

Ms. JOHNSON. Thank you very much.

Chair GORDON. Thank you, Ms. Johnson.

Ranking Member Hall, do you have any questions?

Mr. HALL. Thank you, Mr. Chair. I was called away to an emergency meeting and I don't know what questions have been asked. I had looked forward to hearing their testimony, and I will read it at a later time, and I thank you. I won't waste your time with repetition of questions.

Chair GORDON. Thank you, sir. We will move on then to Mr. Bilbray.

Mr. BILBRAY. Thank you, Mr. Chair. I think it is important that we come back to certain terminologies that could be very, very damaging to this. Your reference to the term hazardous, we have thrown that around and we like to say that, and the argument, especially coming from California, is you always want to go to the extreme of safety to avoid any possibility of exposure on a lot of this stuff, and in California we have seen what has happened with that. You can't walk into any store or any hotel without a big warning sign, "The carpeting may cause cancer," you know, that basically people just turn off and don't read it. But the definition of "hazardous"—you know, I served ten years on hazardous reviews boards and on environmental health agencies, and the definition does matter, doesn't it? It really draws a defined there yet.

Mr. CADE. Yes, and I think it is important to make the distinction between hazardous material and potentially hazardous, and much of the problems that you see in informal recycling is the issues that they bring up using things like cyanide, et cetera, so it is in the processing that those are the real hazards that are coming up or the inappropriate burnings and those kinds of things. So I think that is exactly right, and I would defer to your experience in terms of writing the legislation in terms of making those kinds of points. Thank you very much.

Mr. BILBRAY. Mr. Chair, I just want to point that out because it triggers certain processes and we have to be careful, and I just— not to belabor but to give you an example. We had a great system where there was an entrepreneur who went around to all the shipyards and all the industrial places and took the sandblasting sand

and used that sandblasting sand in an asphalt mix, in other words, recycled it, put it into a product, avoided having to go out into the back land and mine sand from riverbeds and stuff, and it was going into an asphalt or concrete where it was stabilized, but because the item was a waste product, it triggered a whole environmental oversight that outlawed his ability to recycle it and it ended up having to go to facilities to be thrown away rather than reused. Nobody meant that kind of thing to happen so we have got to be careful with our trigger going down. You have a comment?

Dr. ANASTAS. I would just say that this speaks directly to the provisions in the bill for the physical, chemical property database, that when you are looking at the substances in this determination of hazardous or potentially hazardous, you are looking at what are the intrinsic physical properties, chemical properties that allow something to be hazardous, allow it to be bioavailable, and those intrinsic properties are so essential in this database because separating the intrinsic nature of these substances from the circumstances, those about whether or not people are going to be exposed, is the difference between hazardous and potentially hazardous. So I think the provisions for physical-chemical property database is well founded.

Mr. BOND. Just real quickly, underscoring the Chair saying we have to get this right, it is further complicated by needing to weigh other societal benefits, so originally in laptops we went to fluorescent lamps because it was going to decrease the amount of energy used, but then there are problems with fluorescent lamps because they have mercury, so would you have not wanted that societal goal met for this one? Now, thankfully, we are moving to LED technologies, which are going to be the next innovation and we will avoid a problem. As the design for environment improves, the need for regulation hopefully will go down.

Mr. BILBRAY. And the issue of exportation, exporting the material, the waste product, it is universal in recycling and maybe one of the things we need to talk about is why we don't make it legal to do more reprocessing within the boundaries of the United States because I don't care if it is cardboard or if it is e-waste, the rule is ship it thousands of miles away, they will recycle it, come back out, increase the carbon footprint and it becomes a real problem there. I think one of the answers, and I am glad to see that Member Baird is interested in this too, is this issue of the Federal Government looking at purchases of materials and designing the e-material from the beginning to be recyclable so that you not only eliminate the waste problem but you provide a long-term source of material for the next generation so that now you have engineered something to where you build it with materials that then can be taken and used as a natural resource or a recycled resource for the next generation. There is a sustainable economic base, and I think I am very excited with that, and that is, Mr. Chair, where we get into an issue that in the air strategy we always call the technology forcing regulation, and one way to do that would be for us within our own purchasing and procurement, and as Ranking Member on Procurement and Government Oversight, I would like to work with this committee at moving that item one step further and setting an example for the next generation of e-recycling and that is basically using it as the mainstream, not as a subsidiary of the source for material. Thank you very much, Mr. Chair.

Chair GORDON. Thank you, Mr. Bilbray.

Mr. Smith, I apologize to you for jumping over you. Promptness should be rewarded, and we will get to you right after Mr. Baird.

Mr. BAIRD. Thank you, Mr. Chair. First, I want to applaud you, Mr. Chair, for taking the initiative that Mr. Ehlers raised. It is tremendously frustrating, we are mandated to replace our computers because they fall out of currency with the current operating systems and then we see local schools in our district and we can't give our computers to them. Instead, we have to transfer them and get them scrubbed. It is crazy. And anything you can do to fix that would benefit our kids and make a lot more sense.

I want to ask a few questions. My district has made a real effort on e-waste recycling but I would like to know something about what are the best practices and what do we know actually works. Let me—I do a lot of work on my own computers at home, and just uninstalling a single program is frankly a pain oftentimes. Are there industries—so what are my obstacles, and I am a pretty environmentally responsible person. What are my obstacles? One is, it is fairly complicated to uninstall. Secondly, you just don't know what to do with the waste. You sit there with batteries or an old cell phone, or I don't know how many old chargers I have sitting around that I don't even know what they go to. There is copper in there and that is useful and a valuable material but I don't know what to do with it. So we have seen in other areas that the computer industry has done things to establish standardization. The USB port is an example. I mean, there are hundreds. They have these whole networks of people that work together. Are they doing anything to come up with standard procedures or mechanisms to facilitate this? For example, a well-hidden complete delete button that deletes every—you know, that auto-scrubs your entire computer for when the time comes to put it away, standard mechanisms by which you could extract transformers or copper, et cetera. What is being done in that realm and what are the best practices to help public citizens respond?

Mr. CADE. Mr. Baird, we actually have built into our refurbished computers the ability to do exactly what you are talking about, a one-button, well-hidden erase. We did it because we provide our equipment across the United States and we provide 800-number support based in the United States for that equipment, and what we found is, approximately 80 percent of our errors that our users have are software related, not hardware. They will call me up and say my computer doesn't work and so after a few minutes I will go through and I go, if you are willing to lose everything on your computer, then fine, I will reset that back to factory settings for you, and so you are absolutely right. We need to develop those. And our process takes about 20 minutes in order to completely reset the data. Unfortunately, what it doesn't do, it doesn't—because of the nature of the way software has been designed, it doesn't erase the information, it just loses the ability to find it. And so I agree with you totally that we need to have or some way encourage, particularly hard disc manufacturers or any storage devices a one-button, let us erase it all and know that that is done.

I looked into my drawer before I came today and I have approximately 17 different USB drives with storage. I have no idea what is on any of them. I took a magnet and tried to degauss them. They don't degauss. I also, by the way, put it through a washing machine because it was left in my pants. The thing still works. So we have gotten lots of equipment out there, and if you look at the NIST [National Institute of Standards and Technology] special report 80088 on erasing information, it is a much bigger problem and especially since—I mean, I am personally concerned about it because I do my tax returns myself on my computer. I don't want to change them out. And I understand. I think, by the way, that is the fundamental problem with e-waste right now is people just don't have confidence in understanding how to get rid of the—and they need to rely on people like me.

Mr. BAIRD. And you don't want to take the time. I have got several old Mac laptops sitting around. I don't know what is on them but I don't want somebody else to find out what is on them.

Mr. CADE. Well, and that is why it is so important, the work that we are doing with Dr. Thomas on RFID (radio frequency identification), individual identification of product, because that will give us a verifiable custody history that we can work on, and it is the kind of thing that we need to develop, and just back to Representative Johnson's point about the nature of this legislation. It has requirements in it that it is multi-departmental in terms of working on these research centers. That is an absolute must in my mind, everywhere from the art and design and industrial design product all the way through to the chemist and all the products that they are working with.

Mr. OMELCHUCK. I would like to respond also. I think, Representative Baird, your first premise was that the House needs to obsolete our computers at a pretty rapid rate because they are no longer compatible with the new operating systems, and I think that is an assumption that we as the society need to look at pretty closely.

Mr. BAIRD. I agree. I didn't want to do this. The former computer worked just fine. It now crashes with regularity. So I paid more money to get a system that works less well and then I can't recycle or reuse my prior system. That is pretty stupid.

Mr. OMELCHUCK. Right. So I think that is really a fundamental issue that—and it was part of my testimony to encourage research in the amount of e-waste, hardware waste caused actually by software obsolescence and of course I think we all recognize that that is a very challenging problem to address with the hardware-software industry. That scares the bejeebers out of them to have us looking at that, but I think it is something that needs to be looked at in the light of day and thought about.

The other comment I wanted to make is, you talked about design for end-of-life and how we design these products for end-of-life, and I just wanted to return to the point that e-waste doesn't do that. However, there are developing research programs around design for end-of-life on electronic products. In fact, EPEAT, the system we operate, has probably the best criteria of any eco label around designed for end-of-life and to be candid, it needs more research. We don't really quite yet understand how design affects end-of-life scenarios and the challenge in the United States is that the actual process used to recycle electronics is all over the map, from a room full of guys with hammers to very sophisticated processes and so what—how do you design a product to be recovered efficiently in each of these scenarios. That is an area for further research that I think this bill could support.

Chair GORDON. Thank you, Dr. Baird. As usual, you hit a hot button, and Mr. Smith, you are recognized.

Mr. SMITH. Thank you, Mr. Chair.

First, a couple questions for Dr. Thomas. In light of the fact that I think many recycling efforts are cost effective both long-term and short-term, both directly and indirectly, and when you mentioned that approximately 18 percent of electronics are being recycled right now, does that mean the first user is not the last user or does that mean like the second user might be the last user as well?

Dr. THOMAS. That 18 percent is an estimate made by the U.S. EPA and that includes in that number both reuse and recycling.

Mr. SMITH. Okay, so——

Dr. THOMAS. It is kind of an upper limit number. The actual number is less.

Mr. SMITH. In that 18 percent, that might also——

Dr. THOMAS. That includes reuse.

Mr. SMITH. Okay. Thank you very much. And then furthermore, we know that there are certainly energy costs associated with some recycling efforts and reusing and refurbishing as well. Are there any organizations that collect the data on the energy consumption so that consumers might be more familiar with what might be a best practice?

Dr. THOMAS. Yes. University researchers do that kind of analysis. The energy use of products can also be directly measured, and I believe that in EPEAT's ratings for green electronics, energy use is included.

Mr. SMITH. All right. Thank you very much.

And Mr. Bond, one of the things that I don't believe your testimony addressed is the rather patchwork nature of State laws and various approaches, and being a former State legislator I advocate, you know, flexibility. I think that we want states to be innovative and by no means do we want to see a boilerplate approach to this. But what lines of research would you say are most helpful for your members to be able to comply with so many different laws and what kind of approach might you suggest?

Mr. BOND. In terms of the infamous patchwork, I would have to think a little bit about whether that question lends itself much to research although you could certainly research the added cost, and perhaps cost to competitiveness of some of that. We confront this as an industry in multiple arenas where you do have this infamous patchwork across the states so at the same time, we are a federal system and you need to respect that, so the industry has tried to engage where they can. It is one of the reasons why we as an association have most of the State leading tech associations affiliated with us so that we really can work on that basis. So I think that is an ongoing challenge for us. I think the best solution is to look forward to look for design for environment solutions so that you stay a step ahead of the regulators because ultimately—in this case, that patchwork, if you are reducing the need because you have really designed for the environment, then you don't have as much regulation. I think that ultimately we do want to make sure as a country we keep our innovation advantage. I think that is critically important in so many ways. If the Chair would bear a short analogy, it is kind of like Mr. Gordon is famously, I think, the fastest Member of the House when it comes to the annual three-mile race here, but at some point if we put enough weight on him, it would have to be in the form of a vest because he is not putting it on naturally, but at some point enough weight would allow somebody else to win that race. So we want to keep Mr. Gordon winning, we want to keep America winning.

Mr. SMITH. Thank you. I appreciate your comments, and I guess I would reiterate the fact that, you know, many of these efforts I think can be very profitable and I think that is good, especially in light of certain conditions facing our economy today, and having also served at the local level where a small town in Nebraska rarely has a landfill, I did learn a lot in terms of what we can and should do and we did do to extend the useful life of a landfill in a good, sustainable manner as well.

So thank you, Mr. Chair.

Chair GORDON. Thank you, Mr. Smith, and really let me just say, I think the thrust and the basis of this legislation is to make recycling a profitable, you know, business model for either the companies that Mr. Bond represents or others that want to do it, so that is what we want to do. We want to make this profitable so it is not a burden. And the other thing I will just quickly, a side note, you talk about as a State legislator, there is sort of a life cycle that I have seen here in Congress, and that is that industry starts off by saying, you know, no regulation, no regulation, and then some entrepreneurial state will—you know, they will do something here, another one will do something there, and then industry says oh, please regulate us, please regulate us because they need to have that continuity. That is something you will see over and over here.

Mr. Luján, a new Member of our committee, is recognized.

Mr. LUJÁN. Thank you, Mr. Chair, and thank you to everyone that took the time to be with us today. I would like to get back to some of the discussion that took place with the concern of exporting some of the toxic materials and the number of people that are sometimes exposed to these, especially because most of them are low-paid workers that are sometimes exposed to these, and I appreciate the fact that we have been talking about sustainable design frameworks. The challenge is to do it appropriately and the recognition of the physical-chemical property database. I would just like to hear your thoughts on other accountability measures or standards that could be implemented within the e-recycling community to prevent this from happening.

Dr. THOMAS. I would like to point out that there are actually laws governing the export of used cathode ray tubes (CRTs). Those are the big monitors for TVs and CRTs. And there was a GAO (Government Accounting Office) report last year that concluded that those laws need to be enforced. So some of the legislation already exists. You might look at the CRT rule and it may need to cover some other electronic devices as well.

Dr. ANASTAS. I completely agree with the perspective that we have a large problem that needs to be dealt with today in e-waste. I guess the only point that I make is, the reason that the research, the innovations, and design for disassembly and new materials and new energy storage is so important is so that we know that two steps forward in our current problem is going to be two steps forward and not one step back, that we don't keep on creating. As we all know, the rate of production of these electronics is not slowing down and so that is why the design is so important in addition to the problem that you are focusing on.

Mr. BOND. And I would add, Mr. Luján, just very quickly, that you will find our industry very much in support of strong international safeguards and a regime here to protect workers and the environment here and around the world. These things do get tied up in other international agreements whether it is trade or others and so again affirming the Chair's call for getting it right. There are some facets to the question but you are going to find the industry supportive of your core goals.

Mr. CADE. Towards that end, the U.S. EPA just concluded back in October last year standards called Responsible Recycling. I was part of that stakeholder process. It took about three years to work through it. I think a lot of the issues are addressed there. There are some people who would suggest that they are not high enough standards. I suggest that what we need to do is implement swiftly those responsible recycling standards, or the R2 standards, and then continue the research to see what is next in those steps. What has been presented and what is now public documentation is really, really quite good, and I believe the Institute for Scrap Recycling Industries is going to be the first body to have certification available for electronics recyclers, and quite frankly, we are excited about doing that. Hopefully that will come about by the end of the year.

Mr. LUJÁN. Thank you. And Mr. Cade, specifically in your testimony you also addressed, and we heard from you today, about how we could be utilizing some of the technology to support a smart grid application, and just to hear your thoughts again just to expand that on a large-scale application of what kind of benefits we could see as a result of that?

Mr. CADE. Well, the smart grid by the utilities will bring—will allow utilities to control the grid to the home. In order to really take advantage of that smart grid and differential pricing, you are going to need the user in the home, the homeowner, or the person in the apartment, to take advantage of that differential pricing or that deferred usage, and technology is an obvious answer to those issues. Also too is when this equipment is rebuilt and refurbished, it is U.S. jobs, and frankly, I am worried about that right now.

And I believe a perfect example of what we can do in terms of refurbished equipment is the coming 2010 decennial census. It is a relatively short-term project as projects go on a government basis. It will have relatively large volume. I think that if we made sure in the census that refurbished equipment was part of the equation, I think we can really see it as a demonstration project that would be very bold by the Federal Government to bring some real awareness that reuse is a viable option.

Mr. LUJÁN. Thank you, Mr. Chair.

Chair GORDON. Thank you, Mr. Luján.

I see no one to my right other than my friend, Mr. Hall, who has passed. Dr. Griffith, would you like to be recognized?

Mr. GRIFFITH. Thank you, Mr. Chair. I think this is a very, very important discussion that we are having, and the manufacturer of consumer products with known carcinogens is an interesting concept, and we recognize that this is not only a great part of our economy but we also recognize the danger that we see here, and even though we may ship them off to be incinerated in some other country, once they are in the air we know they are on the way back here. And so small, trace amounts, whether it be antimony, arsenic, or brominated hydrocarbons, we recognize that 200-plus years ago the first malignancy that we related to hydrocarbon exposure were the chimney sweeps in London with testicular cancer. We know that this is going to occur as these electronic products become more imminent, closer to our skin, our bodies, and even implanted into us. So I compliment the Chair on this subject because I believe that it has great ramifications for us because we are not going to decrease the amount of these products in our environment but we are going to increase them, and I think the safety of it is not just in recycling, et cetera. I think it has a health care ramification. Thank you, Mr. Chair.

Chair GORDON. Thank you, Dr. Griffith.

Now the gentlelady from Pennsylvania.

Ms. DAHLKEMPER. Thank you, Mr. Chair. I apologize. I was at another meeting and missed most of your testimony, so my question is fairly basic, but are there any existing e-waste programs either domestically or in some other foreign nation that we can actually look at for its merit to further study, possibly to replicate at this point?

Mr. CADE. I would defer back to the Responsible Recycling standards that were set up by the U.S. EPA and really look to those as the standard that we have today, but again, I want to reiterate that we need more research and that is why I applaud the Chair in this draft legislation that we really do need to research and make sure that we do it right in the process. I mean, just kind of an interesting aside, my carbon offset or mitigation for traveling to this meeting is refurbishing a computer. You refurbish two computers, it is the equivalent of taking a car off the road for a year.

Ms. DAHLKEMPER. Yes?

Mr. OMELCHUCK. It is the case that, deferring to Mr. Bond's numbers, that approximately 18 states now have electronics e-waste bills in place today. In addition, the best-known international example is the E.U. has a program. China is in the process of emulating that largely, not entirely. So there are a lot of models that can be researched and I think it would be very fruitful to research the environmental and economic aspects of all those and there is enough to research.

Mr. CADE. If I can just add to that, one of the things that is really interesting, of those State models, there is only one, the State of Illinois, where reuse is actually included in the legislation and there is actually concepts on that. I think one of the things that is the advantage of all of the states is, we have a number of different experiments going on about e-waste and the research is very important. I think when we talk to people, for example, in Oregon, about their law and we talk to them about reuse and how it was included in Illinois, they kind of went oh, yeah, we forgot that. So I think there is real fertile ground by the States' entrepreneurship, as the Chairman represented, coming out with the legislation and I suspect in a couple of years that we will be back here with the question of national legislation, and if we do our research right, we will have some very good answers and some very good understanding.

Ms. DAHLKEMPER. Thank you.

Chair GORDON. Just a quick comment. I think you are correct, and that is what we are trying to do—is get in front of that to have the research so when that inevitable likelihood of legislation comes up or regulation, that we can try to do it right.

Ms. Biggert, you would like to close us out?

Ms. BIGGERT. Yes. I probably could use a lifeline because I missed all the questions. I am sorry if I ask something that has already been asked and I am sorry. I had two Committee hearings and one markup all at the same time and I need a clone. Do you do cloning too or just computers? I think what is important, you know, is the recycling and maybe, Mr. Cade, you can just tell us—you probably told us—just tell us one more time about how important the reuse is and is there anything that would be better in what to do with our e-waste?

Mr. CADE. Well, again, thank you Congresswoman, for your question. I think reuse really is the fundamental issue. The analogy I like to use is, currently without electronics it is the equivalent of taking a loaf of bread and taking three slices out of it and then putting it in the cupboard and two years later coming back and wondering why it is moldy and no longer good to use. We need to be able to make sure that people feel safe about getting rid of their equipment, that we have that standard set and that it is clear and it is transparent to individuals, and once that happens, then they will start to bring their equipment out and then we need to be able to have the database necessary to understand what is in that product so that we can figure out how to reuse it. So we need to build a complete infrastructure from scratch that includes reuse, that includes processing and includes understanding of what chemicals, et cetera, are in there. That was quite frankly in the stakeholder negotiations on R2. It was incredibly difficult to try to parse out all of those different steps with the lack of data.

So, you know, Mr. Chair, I encourage you. The blanks that I saw in the draft legislation were basically around the dollar amounts. I know it is a tough request but I think money spent here will go a long way to helping our environment and helping not only individuals but also all of what we do here. So thank you very much.

Dr. ANASTAS. If I could just add to that, I completely support what has been said about the recycle, reuse, and the imperative of that. We want to also keep an eye on design so that we make sure that we are not cycling materials through our society and our economy that are toxic, that are hazardous. The point that I would like to make is that there is nothing about the performance of these materials, whether it is in a display, in a housing, in battery storage, that requires them to be toxic. There is nothing about the manufacturer of an electronic that requires it to use literally thousands of times more material than actually winds up in the product. These are design challenges, and by taking on the basic research with the sustainability frameworks, we can change this equation.

Ms. BIGGERT. Mr. Omelchuck.

Mr. OMELCHUCK. Thank you. I would like to kind of add to Dr. Anastas's point and remind us that because the dramatic share of the impacts of electronics happen during their manufacture and their indirect materials, my point is, it is a pleasant concept to think about closing the material loop on electronics, and if we could only recover them at the end, we could make new electronics out of the old electronics and we would be—you know, that would be a nice closed loop. And the reality is that if we were to do that 100 percent, recover 100 percent of electronics, we would be recovering perhaps a tenth of one percent of the environmental impact that was invested in manufacturing electronics. So I think it is important for us to keep that in mind, that closing the material loop is really not the goal, the overall goal.

Ms. BIGGERT. Do you have any figures about how much goes into the landfill versus how much is recovered and reused?

Mr. CADE. There are some figures, Dr. Thomas has a few, but quite frankly, those numbers I don't trust. We did a two-week study at one of the four waste collection centers of the city of Chicago and asked them to pull all computers that came through their garbage trucks, in other words, someone literally put it in their garbage. We asked them to pull all the PCs out of there, and there were only 37 that came in a two-week period for about a quarter of a million households. So it just doesn't seem like the numbers work on that. By the way, we did take one of the hard drives that had gone through the compression——

Ms. BIGGERT. That had been squished?

Mr. CADE. That had been squished, and we were able to read the information and who owned it. We looked up on the Internet and we found the guy's address. So we were able to actually backtrack with that. So again, it is important stuff that we need to work on.

Mr. BOND. Congresswoman, if I could, I just wanted to underscore that many of the leading companies, I will give the example of HP, for instance, that have recycling programs, they do not send materials to landfills. So I don't want you to assume that everything automatically is headed——

Ms. BIGGERT. No, I was thinking more of the consumer probably is the one that doesn't know what to do with it.

Chair GORDON. I think the doctor might have a rebuttal.

Ms. BIGGERT. Okay, Dr. Thomas.

Dr. THOMAS. No, I actually want to agree that we don't really know where electronics are going and how much is recycled. EPA tried to estimate this. They just pretty much have to sit down in a room with a piece of paper and make some estimates. We don't know where they are. We don't know how many are in people's basements, how long they keep them there. We don't know how many are sent to other countries. There is just nothing. We know very well what goes through the manufacturing system, what is retailed, what is sold and after that it is just dark.

Ms. BIGGERT. I have a couple in my attic that are really old and they are the old Macs with the little screen and my kids used to use and I keep worrying about them being there. They are too old to be reusable, but what do I do with them? Just take them to the recycling centers that we have for electronics?

Mr. CADE. Congresswoman, I will pick it up next week. I will be in town.

Ms. BIGGERT. Well, I am going to have to dig them out. I have got a lot in the attic. Thank you.

Chair GORDON. Thank you, Ms. Biggert. Let me thank our panel for a very interesting hearing, and let me once again suggest that we are welcome to your specific suggestions. This is only a draft. Mr. Hall raised some very good questions in his earlier comments. We want to try to address those so we can get the very best bill we can. This is an important topic.

And so now the record will remain open for additional statements from the Members and for answers to any of the follow-up questions the Committee may ask of the witnesses. The hearing is now is adjourned.

[Whereupon, at 11:45 a.m., the Committee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Valerie Thomas, Anderson Interface Associate Professor of Natural Systems, School of Industrial and Systems Engineering, and School of Public Policy, Georgia Institute of Technology

Questions submitted by Representative Ralph M. Hall

Q1. The discussion draft includes a section that would make funding available for joint public/private research projects.

Q1a. How would the program in the draft legislation differ from existing programs at the federal level?

A1a. Currently, there are no programs funding e-waste research at the federal level. Researchers proposing e-waste research can submit proposals to broad National Science Foundation programs related to reducing the environmental impacts of manufacturing; in this case the proposals compete against all other manufacturing and sustainability research topics.

Q1b. How would this funding effort integrate into the existing overall e-waste strategy?

A1b. The U.S. EPA has been promoting e-waste recycling; this funding could support that effort.

Q2. Many of you discuss what we should do for electronic waste that will result from products that are currently being sold or are on the drawing board. What do we do with all the orphan waste and products people still have stored in their attics? How will research assist us in properly disposing of this type of electronic waste?

A2. Immediate e-waste problems should be addressed by action, not research. Enforcement of the CRT rule, more comprehensive regulation of electronic waste exports, and legislation for end-of-life management of electronics would provide a basis for development of appropriate electronics recycling capability for existing products.

Q3. What lessons can be learned from the "Mercury-Containing and Rechargeable Battery Recycling Act" *about federal efforts to encourage recycling?*

A3. The *Mercury-Containing and Rechargeable Battery Recycling Act* does not require battery recycling. It requires that rechargeable batteries have a recycling label and that they be easily removable, that EPA establish a public education program, and it loosens the hazardous waste restrictions on handling and transport of batteries. Despite significant voluntary efforts to promote recycling, the battery recycling rate remains below 20 percent. The lesson is that these measures are not sufficient to ensure high recycling rates.

Q3a. Why do you believe that consumers will not recycle e-waste instead of disposing of it?

A3a. Currently, it is generally not easy for consumers to recycle e-waste.

Q3b. Car batteries are one of the few products that are recycled with regularity. This reality has to do, in part, with the fact that auto repair shops collect old batteries when they are replaced. How could this type of success be replicated in the e-waste field?

A3b. Most states have strong lead-acid battery recycling laws that prohibit lead-acid battery land disposal or incineration and require recycling, that require battery sellers to take back batteries for recycling, that require battery sellers to charge a deposit for sale of batteries in some cases, and that specify fines for noncompliance.

This model of recycling could be replicated for e-waste.

Q4. You suggest that a standardized label is needed for identifying and tracking various models of electronic equipment, and further suggest that manufacturers and recyclers would derive benefits from this system.

Q4a. Can you expand on how labeling, be it electronic or printed, would improve upon visual identification and sorting of these pieces of equipment?

A4a. Visual identification and hand-sorting by trained workers can indeed be quite effective for some tasks.

Automation does, however, have many advantages. Labels can be read automatically, either by a bar code reader (for bar code labels) or by an RFID reader (for

RFID tags), and the information would be automatically recorded in a computerized database, which can link to information about that product, such as the value of components, the identification of hazardous components, instructions for dismantlement, and so on.

Specifically, labeling could allow for better identification of re-usable parts; reusable parts are a key component of the profitability of many electronics recyclers. In addition, labeling can significantly reduce costs for reporting to regulatory agencies and to large customers; recyclers report that these reporting costs are significant.

The benefits of automation for recycling are the same as the benefits of automation for recycling. Initial benefits of automation include some cost reduction due to efficiency and some cost reduction due to reduced labor costs. As automation becomes more integrated into the industrial process, it allows for the development of new processes and innovations.

Q4b. To optimize these efficiencies, is labeling needed for overall units, or should labeling also include components?

A4b. Discussions with recycling industry representatives generally indicate that labeling of key components as well as the overall unit would be most effective.

Q5. There is a numbering system associated with the recycling of plastics. However, it has been suggested that this system does not work well due to lack of public knowledge. How would you propose to prevent similar difficulties with electronic labeling for recycling?

A5. The plastics labeling system was developed to help consumers sort plastics. Plastic recycling technology has changed over time so that the numbers are no longer relevant to the recycling technologies used in many locations.

The technology for e-waste recycling can also be expected to change over time. For this reason, the label should simply identify the make and model of the product; the information about the recycling of that product would be kept in databases that can be changed without needing to change the label.

Q6. What are the energy costs of recycling, reusing, or refurbishing electronics? What organizations collect data of this sort?

A6. No organizations are collecting and reporting data on the direct energy costs of recycling, reusing, and refurbishing electronics. The environmental impacts of recycling and refurbishing operations are generally assumed to be small compared to the environmental benefits of recycling. Life cycle assessments indicate electronics manufacturing is highly energy intensive and that, therefore, reuse of electronics can save energy by reducing manufacturing energy needs.[1]

[1] E. Williams, Energy Intensity of Computer Manufacturing: Hybrid Assessment Combining Process and Economic Input-Output Methods, *Envir. Sci. Technol.* 38 (22):6166–6174.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Paul T. Anastas, Teresa and H. John Heinz III Professor in the Practice of Chemistry for the Environment, School of Forestry and Environmental Studies; Director, Center for Green Chemistry and Green Engineering, Yale University

Questions submitted by Chair Bart Gordon

Q1. How would a database containing the chemical and physical properties of materials used, or potentially used, in electronics be used? Does such a database currently exist?

A1. I am not aware of a database that duplicates the purpose of the proposed database. The proposed database would be used by electronics designers in assessing the physical/chemical properties which are directly related to both the performance as well as the impact of the electronic on human health and the environment. By having this information, those wishing to ensure that our high performance computers have a reduced impact on the environment can use it to identify substitute chemicals and alternative substances in the electronics components.

Questions submitted by Representative Ralph M. Hall

Q1. The discussion draft includes a section that would make funding available for joint public/private research projects.

Q1a. How would the program in the draft legislation differ from existing programs at the federal level?

A1a. I am not aware of any programs that are focused on the issue of the impacts of electronics on human health and the environment throughout their life cycle. The research that would be the basis of this draft legislation would provide new design tools to ensure that our current electronics waste programs are more effective and, as importantly, make sure that our future electronics don't cause the same issues as our current and historic approaches to designing electronics.

Q1b. How would this funding effort integrate into the existing overall e-waste strategy?

A1b. While there is currently good work being conducted on electronics recycling and reuse, there is little research focusing on the basis of how to make all life cycle stages of electronics less harmful to humans and the environment. While the electronic waste programs currently are making a bad situation less bad, there is research needed to understand how we design our electronics to be genuinely good for humans and the environment. This means ensuring that they have increased performance and reduced adverse impact on the environment. Rather than simply dealing with only the waste at the end-of-life stage, these sustainability frameworks allow practitioners to be able to design such that economic and environmental goals are mutually reinforcing.

Q2. Many of you discuss what we should do for electronic waste that will result from products that are currently being sold or are on the drawing board. What do we do with all the orphan waste and products people still have stored in their attics? How will research assist us in properly disposing of this type of electronic waste?

A2. The research that will be done under this legislation can help deal with the existing waste in many ways. The research can allow us to better understand how to separate the wide range of substances that make up most electronics that include plastics, polymers, metals, glass, and much more. By being able to separate these substances, we begin to be able to extract the value from this waste and use it productively. The research will also involve new sensors to be built into new disassembly facilities. It will involve new process and reactor technologies to be able to transform these mixed materials. This research will need many disciplines involved including electrochemists, mechanical engineers, product designers, analytical chemists, and others. While I am only scratching the surface of the various ways that this research can impact existing orphan electronics, it is only because the potential is enormous and there may be approaches in the research community that people have not even considered as yet.

Q3. You point out that electronic production is increasing exponentially, so that even with steady improvements in each generation of devices, the overall negative en-

vironmental impact may still increase. What level of improvement over time is needed to begin to reduce the negative consequences of e-waste?

A3. The good news about the approaches that I have outlined in the testimony about sustainable design through the 12 Principles of Green Chemistry and Green Engineering is that it is not merely reducing material and energy (which it is), it is also addressing the intrinsic nature of the energy and the materials used in the electronics and throughout their life cycle. This means that even if some level of "waste" were continue to be produced, the inherent nature of that waste would be of reduced concern for humans and the environment because it would be less toxic, less depleting, more degradable, less persistent, etc. These improvements would be coupled with the innovations in performance that have marked the history of the electronics industry and make the environmental and economic performances work hand-in-hand. This has been achieved in a number of other industry sectors and the potential in the electronics sector is tremendous.

Q4. You quote a 1999 study that suggests the average lifespan for a PC is two years.

Q4a. Is this driven mostly by businesses that regularly replace the inventory while home consumers hang onto their equipment longer?

A4a. I am not aware of the exact data on the breakdown of business electronics lifetime versus home electronics lifetime.

Q4b. Has there been no change in the life-spans of personal computers in the last 10 years since this study was published?

A4b. The issue is very often not the functional lifetime of a computer or other electronics. Many of the electronics that are "waste" work fine and their life-spans are very long. These electronics are discarded because they are viewed as not having the latest capabilities or are stylistically not as appealing. Making the electronics simply more durable is not going to address these issues. Making their functionality and upgradability more modular may be one way to address the issue.

Q4c. Do consumers and businesses have similar patterns of use and disposal of electronic devices?

A4c. I am not aware of data on the use and disposal patterns of business and consumers.

Q5. What is your definition of "toxic" and "hazardous material?"? Is the goal of complete elimination of these materials realistic?

A5. The definition of hazard is the ability to cause adverse consequence. There is nothing about the chemicals and substances used in electronics and the functions we wish them to serve that REQUIRES them to be toxic. That being the case, it is simply a scientific and design challenge to address this issue through the research this bill supports. This reduction and elimination of hazardous substances through green chemistry has been done by many companies in many sectors and it can certainly be done by the electronics sector. The research that will allow it to happen will simultaneously benefit the performance and economics of the electronics industry.

Q6. Does better design necessarily mean less toxic, more efficient and easily recyclable? Would it also include more focused designing for difference consumer groups? How would that alter the environmental impact of electronic products?

A6. Hazard is a design flaw. Unless a particular hazard is intended, such as in the case of pesticides, then unintended hazard—unintended adverse consequence—is something that can and should be addressed.

Q7. You describe a lack of quality data on the stocks and flows of various materials crucial to the electronics industry. What mechanisms currently exist to estimate the amount of precious metals available on the market and the reserves of those materials?

A7. The best work in this area that I am aware of is being conducted by Prof. Thomas Graedel of Yale University on the stocks and flows of metals in commerce. I am aware that his research requires working with national agencies in the U.S. and around the world as well as with private data sources. There is very little research funding in this area for the development of data sources. This is important of course strategically both for economic and national security reasons.

Q8. In your testimony, you define frameworks of sustainable design and illustrate your point with the example of closing the material loop, or working towards achieving a zero waste scenario.

Q8a. In order for this approach to work, particularly with material synergies outside the electronics industries, how would you propose fostering communication and information exchange between parties?

A8a. The sustainability design frameworks outlined in the testimony view closed loops as merely one aspect of sustainable design. It is essential to incorporate design into the inherent nature of the substances and energy sources to ensure they are benign and sustainable as well. Closed loops can be achieved at many scales; in the process, within a factory, within an industrial park, or within a city. Each of these scales will require different levels of communication and coordination. Transparency on what materials are flowing through a system is essential. This requires companies and other organizations to be willing or required to both know what materials are coming into and being released by their operations as well be willing to share this information. This communication and information exchange will allow for the boldest opportunities to be realized. Even in the absence of this level of communication, individual companies and industry sectors can still achieve closed loops very effectively within themselves.

Q8b. Would the green database outlined in the draft legislation sufficient? Or would it be necessary to incorporate a clearinghouse such as the pollution prevention resource exchange?

A8b. The database suggested in the legislation would be an essential element that would enable closed loops to happen but it would not be sufficient on its own. It would inform designers what is possible in closed loop systems but not necessarily provide enough detail on where those materials are used geographically and industrially. A resource exchange database would be valuable but should be more robust than the current EPA database.

Q9. How would you suggest adapting the IGERT program, which currently focuses on interdisciplinary research and education, to include partnerships with industry?

A9. The IGERT program is regarded as one of the crown jewels of the research programs from NSF. Partnership research programs with industry could be achieved through the development of a parallel program or an option within the IGERT program However, it may be easier to look at programs such as the NSF's Industry University Cooperative Research Centers (IUCRC) and instead extend those to include educational aspects to them especially for graduate students. The IUCRC has already dealt well with many of the problematic issues that arise in academic-industry partnerships and this approach would ensure that the IGERT program is not unintentionally disrupted.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Phillip J. Bond, President, TechAmerica

Questions submitted by Representative Ralph M. Hall

Q1. The discussion draft includes a section that would make funding available for join public/private research projects.

Q1a. How would the program in the draft legislation differ from existing programs at the federal level?

A1a. There are currently no programs at the federal level that would establish public/private research projects into the issue of green electronics design. The program, therefore, would establish a new program with a new focus.

Q1b. How would this funding effort integrate into the existing overall e-waste strategy?

A1b. Currently, there is no federal strategy for providing direction or prioritization on the issue of e-waste. The U.S. Environmental Protection Agency regulates the management of hazardous wastes, which may include some (not all) electronic products. This funding effort would help prioritize environmental risks from electronic products and provide overall direction to a federal strategy.

Q2. Many of you discuss what we should do for electronic waste that will result from products that are currently being sold or are on the drawing board. What do we do with all the orphan waste and products people still have stored in their attics? How will research assist us in properly disposing of this electronic waste?

A2. It is correct that design incentives or guideline or standards will not address historic electronic waste, which will require proper management. The research that will be generated through this legislation will help us determine which types of historic waste will require hazardous waste management and which may be discarded in conventional waste management facilities due to its low-risk status. Currently, that very basic information is missing.

Q3. In your support for a National Academies study of e-waste, you suggest that an authoritative baseline of e-waste impacts is needed. What impacts of e-waste are currently in dispute?

A3. There has never been a science-based assessment conducted of the environmental risks posed by electronic products—as a result, this central issue, remains in dispute. Also, the best ways to manage the different types of e-waste—some products have high reuse potential, some products can be managed in municipal solid waste facilities and some will require treatment as hazardous waste—the categorization and requirements for each have never been fully researched and addressed.

Q4. How are EPEAT's criteria affecting producers' design decisions?

A4. EPEAT, as a federal and institutional purchaser procurement requirement, operates as a significant driver of green design principles for electronics. The move to LED lighting for computer monitors (over mercury-containing lamps) is an example of an EPEAT environmental design success story.

Q5. One of the things I noticed you did not address in your testimony was the patchwork of State laws dealing with electronic waste. If this framework continues for the next decade, what lines of research would be most helpful for your members to be able to comply with so many disparate laws?

A5. The State laws establish requirements for end-of-life management of certain electronic products—mainly, computers and televisions. Currently, they are operating as State experiments into which financing models work the most efficiently and cost effectively. There may be a time when the industry works with Congress and other stakeholders to establish a national model. Until that time, the information gathered at the State level regarding the costs and economies of scale associated with e-waste management will help inform this issue going forward.

Q6. Industry often partners with academia to conduct research. Given the current level of interest in moving the electronics industry in a "green" direction, why do you feel that this type of legislation is needed? Is it just a matter of funding basic research?

A6. The issue is larger than the simple issue of funding basic research. Electronic products are the engine of our economy and the need to design them for environmentally appropriate and more cost-of-life end-of-life management is a societal issue in which all stakeholders must participate—the product designers, federal, State and local environmental agencies, the science community, environmental stakeholders, and recyclers—all stakeholders have a role to play in constructing sustainable solutions to this issue. It is critical that we fund the basic science that is at the core of the issue and we need to the Federal Government to play a central role for credibility and accountability purposes. Only then will all stakeholders accept the results and move forward in a balanced and meaningful way.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jeff Omelchuck, Executive Director, Green Electronics Council, Electronic Product Environmental Assessment Tool (EPEAT)

Questions submitted by Representative Ralph M. Hall

Q1. The discussion draft includes a section that would make funding available for joint public/private research projects.

Q1a. How would the program in the draft legislation differ from existing programs at the federal level?

A1a. I am not aware of other federal programs that would create centers to research issues related to e-waste and it does not appear to me that e-waste is a focus of much federal research. Perhaps existing programs could be directed to research the issues identified in the draft bill.

Q1b. How would this funding effort integrate into the existing overall e-waste strategy?

A1b. I am not aware of an "existing overall e-waste strategy." In fact, that is a very large part of the problem! I don't believe the Federal Government has developed a national program or approach to e-waste recycling. Many municipalities and local agencies that manage solid waste have banned electronics of various types from their landfills or incinerators. Thus, in large parts of the U.S. there is no organized and regulated way for citizens to safely dispose of e-waste. As a result, our e-waste stays in our closets and basements, is disposed in municipal systems that are not designed to handle this material, or is dumped illegally. Several leading electronics manufacturers and retailers have implemented recycling programs but they are usually quite limited, at a cost, and collectively they recover only a few percent of total e-waste. Private sector "recyclers" have emerged and some are very good, but much of that material is exported to countries where it is "recycled" using the worst possible practices.

This absence of a federal program, refusal of municipalities to handle e-waste, the growing ocean of e-waste in closets and basements, and the resulting private sector has caused a growing number of states to develop and implement their own e-waste recycling programs. These programs are often quite different from each other, and each impacts producers, municipalities, recyclers, retailers, and consumers differently. Because of federal inaction we are on a path to create 50 different State-specific programs.

Q2. Many of you discussed what we should do for electronic waste that will result from products that are currently being sold or are on the drawing boards. What do we do with all the orphan waste and products people still have stored in their attics? How will research assist us in properly disposing of this type of waste?

A2. You are quite right to focus on the ocean of e-waste the public has in our homes, and that problem will not be solved by changing product design practices. We simply must develop and implement an effective e-waste recycling program and we must do it fast—it is the only way to deal with the growing ocean of legacy e-waste and should be the highest priority. While certain research may be helpful in implementing an effective e-waste solution, the lack of scientific research is not preventing a solution. What is preventing a solution is lack of political will. That is why I proposed including economic and policy research in the scope of research included in the bill.

Electronics are fundamentally different from other products, and certainly from the ones that come to mind when we think about recycling, like bottles, cans, and newspaper. Whereas the primary environmental reason to recycle bottles and cans is to reduce the volume of material in landfills, reduce litter, and recover the material for re-use, the primary environmental problem with e-waste is its toxicity. We need to collect e-waste in order to keep it out of standard municipal landfills and other inappropriate disposal methods because they contain many toxic materials. The electronics industry has done a good job over the last several years of reducing the overall toxicity of electronic products in general, but as you observe, that doesn't help us much with the ocean of legacy e-waste that was designed and manufactured before this recent revolution.

The key is collecting e-waste from the public. Once collected there exists, or can be quickly created, sufficient infrastructure to recycle it properly. By the way, e-waste recycling can be a relatively labor intensive process and could be a key source of jobs.

If we develop and implement an effective national e-waste recycling system we will have solved the clear and present danger of toxics presented by legacy e-waste, but we will forever be dealing with toxic e-waste unless we can find a way to change the nature of the product itself. This is particularly important when we realize that it is impossible to mine and create toxic materials, manufacture products with them, use those products in our homes, businesses, and schools, and collect and recycle them, without putting miners, manufacturers, users, recyclers and the environment at risk. It is a far better long-term solution to find a way to change the design of these products over time so that perhaps, in time, they are not toxic. We will still likely want to recycle them for other reasons, but we will not be putting every person in the process at risk.

Q3. How does the co-mingling of different producer's products in the waste stream impact recycling operations? How can improvements in one producer's products adversely affect the overall waste stream?

A3. First, let me clarify that there are very good environmental and economic reasons to co-mingle products from different manufacturers in the waste stream. It would be very inefficient to create separate collection and recycling systems for each manufacturer, you'd have to create parallel systems everywhere, and you'd have the problem of orphan products. Even if one were to create consortia of producers who banded together to share a recycling infrastructure, the existence of multiple consortia is less efficient than one infrastructure, and if the consortia combined over time we have effectively created one co-mingled system.

Even though a co-mingled collection system is much more environmentally and economically efficient, it has its challenges:

1) It presents recyclers with a very wide variety of products to deal with. Many electronic products contain components that must be removed from the product in order to be treated appropriately and it is difficult for recyclers to know the best way to do that for every product. Even if a producer created a special button that, when pressed, would release all the hazardous components, the button would do recyclers little good if they didn't know it existed or where it was on each product.
2) The co-mingling of different producer's products makes it difficult for individual manufacturers to benefit from advances in design or manufacturing processes they might make that would make their products more easily, cost effectively, or environmentally soundly recycled. Thus, the co-mingled nature of e-waste collection removes the incentive any manufacturer would have to improve their product.

These challenges are not insurmountable. For example, as part of my written testimony I provided the report from an EPA-funded research project that GEC recently completed in which we conceptualize a common database where producers could put information that recyclers need in order to effectively recycle their products.

The second issue of creating an incentive for producers to make their products more recyclable over time could be addressed by creating a way to evaluate specific products for "recyclability" and creating a differential fee to cover their recycling, so the recycling fee would be less for products that were designed to be more easily recycled. As in most current e-waste recycling systems, this fee could be levied at the time the product is sold when its identity is known and the fee can be easily collected, either visibly from the consumer, invisibly from the consumer, or from the manufacturer or retailer, or some combination. This would provide a mechanism to optimize design of the product and its recycling system over time.

To answer your last question, there are several examples of how one producer making what appear to be improvements can actually adversely affect the overall waste stream, and several examples of how apparent advances simply make no difference:

- The use of bio-based and biodegradable plastics would appear to reduce petroleum use and reduce waste at end-of-life. However, bio-based plastics are generally not compatible with recycling practices used for petro plastics and actually contaminate those recyclate streams. So unless bio-based plastics can be effectively identified and separated during recycling, and there is an industrial compost facility available, they inhibit plastics recycling. The same situation exists for wood or bamboo electronics enclosures.
- A few manufacturers have employed novel disassembly methods, particularly to allow removal of hazardous materials like batteries or lamps. However, unless recyclers know about them, how to use them, and have the tools (if any),

they usually end up dismantling the product with a hammer, often breaking the parts that the manufacturer intended to protect, for instance, CFL lamps that contain mercury.

- Different plastic resins must be recycled in different processes and plastics are difficult to separate by type, so it would be very helpful to reduce the number of different plastics that are used in electronics. However, one or a few manufacturers doing that wouldn't help much. It would need to be industry-wide.
- Most producers mark plastic parts with codes that identify which type of plastic resin the part is made from to facilitate separation and recycling. However, some of the most sophisticated e-waste recycling systems sort plastics by other characteristics (specific gravity, etc.) in automated systems so the marks are useless (though not harmful).

Q4. How does the EPEAT program compare to the Energy Star program in consumer awareness and purchasing decisions?

A4. ENERGY STAR has perhaps the highest consumer awareness of any eco-label, exceeding 75 percent awareness in the U.S. public. ENERGY STAR has come to be trusted by millions of consumers as a reliable way to identify energy efficient products that reduce greenhouse gas emissions and save money.

EPEAT was designed primarily for use by institutional purchasers, organizations that buy products on purchase contracts. EPEAT was launched in 2006 and is now required by more than $60 billion worth of purchase contracts, including those of the Federal Government. EPEAT covers a full range of product environmental characteristics, including energy efficiency (in fact, ENERGY STAR is EPEAT's primary energy criterion). We do not track consumer awareness of EPEAT but it is certainly very low. We are beginning to make plans to increase EPEAT's consumer awareness.

EPEAT and ENERGY STAR have a long history of cooperation and are currently exploring ways to work together to help consumers identify electronics that meet a broad range of "green" criteria.

Q5. In your testimony you mention a Design for Environment, End-of-Life registry that is a critical source of recycling information for many electronic products. Would the Pollution Prevention Resource Exchange be an appropriate place to warehouse this information?

A5. Perhaps. We would welcome the opportunity to explore that idea further.

Q6. How can changes in software design reduce e-waste?

A6. Many believe that software "advances" are one of the leading causes of PC hardware obsolescence. Think of your last several computers. How many met their end-of-life because they physically broke? I'll bet that most became obsolete because they would no longer run the applications software and operating systems that were the only options available, or succumbed to a virus or other software problem that became too maddening to fix, or "got too slow." Of course, the hardware doesn't actually slow down over time. These performance degradations are caused by software changes. It seems likely that the majority of PC obsolescence is caused by software. However, it appears that relatively little research has been done on this question.

We would like to study this issue further and would welcome the participation of government, industry, academic, ENGO, and other interested parties who can contribute.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Willie Cade, Founder and Chief Executive Officer, PC Rebuilders and Recyclers, Home of the Computers for Schools Program

Questions submitted by Representative Ralph M. Hall

Q1. The discussion draft includes a section that would make funding available for joint public/private research projects.

Q1a. How would the program in the draft legislation differ from existing programs at the federal level?

A1a. The program described in the draft legislation would be managed using sound data collection and management systems. Research, education, and technical assistance priorities would be developed through careful examination and consideration of the data collected through this program. This approach would ensure that resources are allocated such that maximum benefits are derived from the monetary resources invested.

Current methods for tracking the origin, use and management of e-waste are extremely limited. EPA currently estimates the amount of electronic products sold, stored, recycled, disposed of, and exported in the U.S. using a series of assumptions and estimates based on market research data for sales and data from electronics collection programs along with some government statistics for sales. These data are usually not complete or current and are developed only for purposes of deriving national estimates. Additionally, the information is woefully inadequate for making strategic decisions regarding feedstock, market and system management. Current EPA e-waste management efforts focus on:

1. number and weight of products that become obsolete
2. amount of electronic products that are recycled or disposed of
3. amount of electronic equipment that is stock-piled
4. collection rates of current electronics recycling programs, and
5. export of electronic material

The development of a more sustainable e-waste management system is contingent on the quality of data available for decision-making purposes. Consequently, development of a more complete, accurate and useful data collection and management system is paramount to establishing a more sustainable e-waste management system. Examples of additional data needed to support an effective system include the following:

1. Where the waste originated/how far it traveled
2. User information (personal, commercial, industrial, etc.)
3. Manufacturer name
4. Model numbers
5. Serial numbers
6. Product type (TV, monitor, CPU, etc.)
7. Product age
8. Product service life
9. Reason for discarding (e.g., obsolete, damaged, software issues, etc.)

This information could be combined with other pertinent databases associated with product information (e.g., model numbers could be cross-referenced with specific parts lists) and demographic information (e.g., census, Thomas Registry, etc.) to create a comprehensive database that would be extremely valuable for users interested both in the quality of the products they produce, availability of reusable components, and methods for remanufacturing, reusing and recycling them.

Q1b. How would this funding effort integrate into the existing overall e-waste strategy?

A1b. U.S. EPA has already performed cursory analysis of the problems and opportunities associated with electronic wastes. They have also developed some very basic assistance materials for helping individuals and organizations better manage electronic waste. This program would build on these efforts by providing the data collection, research, education, and technical assistance means necessary to fully develop and implement a more sustainable system for producing and managing electronic devices. It is envisioned that such a system would minimize waste, pollution, and safety hazards while maximizing opportunities for remanufacturing and recycling.

Q2. Many of you discussed what we should do for electronic waste that will result from products that are currently being sold or are on the drawing board. What do we do with all the orphan waste and products people still have stored in their attics? How will research assist us in properly disposing of this type of electronic waste?

A2. People are keeping these systems in their attics or basements for an estimated three to four years. This is a waste of the resources invested in this equipment. Research will help us to understand the reasons that people store this equipment so long. Our current guess is that people are afraid to get rid of this equipment for fear of their personal information being misused or that they would be contributing to a growing environmental problem. Understanding these problems and addressing the needs will help use get equipment sooner and allow us greater reuse opportunities. Better identification of the items and materials that comprise the current waste stream will better enable us too safely and cost effectively process this equipment.

Q3. What components are best suited for reuse? Do enough of these components exist to create a stable supply of sufficient quantity? Would high reuse and recycling greater standardization of component circuitry? What effects would the use of reclaimed components have on industry warrantees and hardware support?

A3. Solid state components are best suited for reuse. They also happen to be the items that require the most resources for their initial production. I have been working around computers for the last 15 years and last month was the first time I ever saw a solid state component physically fail. Yes there is more than enough equipment to create a stable supply. Component circuitry is highly standardized by generation, but the generational turn over is very rapid. While there may be 1,000 different computer model on the market at any give moment there may be only 100 different components. I believe that reuse of reclaimed components would have no effect on industry warrantees and hardware support. My program offers a three year hardware warranty on our three- to four-year-old refurbished computers.

Q4. How can changes in software design reduce e-waste?

A4. To date most software design has been about increasing functionality. As software design matures more emphasis will be placed on efficiency. More efficient software will require less powerful hardware and allow people to keep using their hardware longer. This can be seen in the beta testing of the new Microsoft Windows 7 operating system.

Q5. Some computers are too old to be refurbished for general computing task. Are there customers for components from these computers? What is the quality of the hardware in these very old systems and what uses can they be put to?

A5. The quality of these "very old" systems is very good. Proper quality control testing can identify week parts and eliminate them from production. We are just now learning the different ways to use this equipment. My company is investigating ways that homeowners and businesses can use e-waste to help reduce their energy consumption. The smart grid will provide a vast amount of opportunities to monitor and control energy use that our current "dumb" electrical grid does not.

Refurbishing computers educates, creates local jobs, is cost effective and helps the environment. I believe that we could provide refurbished computers for the upcoming census at a significantly reduced cost per unit with out sacrificing any needed capabilities or quality. In fact using refurbished computers would more effectively stimulate the U.S. economy because all of the money spent on refurbishment is for U.S. jobs where as 80 percent to 90 percent of the money spent on new equipment is for overseas manufacturing jobs.

Q6. What is your definition of "toxic" and "hazardous materials"? Is the goal of complete elimination of these materials realistic?

A6. My definitions of "toxic" and "hazardous materials" are materials that can cause harm to people and the environment. I think it is important to distinguish between equipment that contain toxic or hazardous materials but do not pose any risk of exposure during the use of the equipment. The most concerning issue around electronic equipment is its manufacturing and disposal. Modern methods of major manufactures are fundamentally safe. Real concern occurs when informal process such as burning are used. I believe that we need to research safely processing this equipment rather than eliminating substances of concern from the equipment because I believe it is unrealistic to eliminate them.

Q7. Your testimony mentions that computers from one manufacture are older that the stream as a whole. Have other recyclers seen the same phenomena and if so are there specific lessons to be drawn from this manufacture's designs? Additionally, this manufacturer has been criticized for creating products that are particularly difficult to disassemble and recycle. Are there trade-offs between longer use and recyclability?

A7. I know of no other Refurbisher/Recycler that has quantitative data on this issue. There are very valuable lessons to be learned from these differences. I believe one of the major benefits to this kind of research is that it will increase the product quality for the industry as a whole. I do not believe that there are inherent trade-offs between longer use and recyclability rather I think they go hand-in-hand.

Appendix 2:

Additional Material for the Record

STATEMENT OF REPRESENTATIVE MIKE THOMPSON (D–CA)

Thank you for the opportunity to comment briefly on electronic waste, or "e-waste." I appreciate Chairman Gordon and Ranking Member Ralph Hall allowing me to be a part of this hearing on e-waste, a subject I've been involved with since I was first elected to Congress. I also applaud the Chairman and the Committee's continued work and interest on this critical issue of our age.

As you know already, electronic products are becoming smaller and lighter, but they also are creating an ever-growing environmental and waste disposal problem. That's because it's often cheaper and more convenient to buy a new PC or cell phone than to upgrade an old one. Today, the average lifespan of a computer is only two years and Americans are disposing of 3,000 tons of computers each day. These discarded items, more often than not, wind up in the landfills of developing countries, where the waste becomes not just an environmental issue but a moral one as well. A recent GAO report, *"E-Waste: EPA Needs to Better Control Harmful U.S. Exports through Stronger Enforcement and More Comprehensive Regulation,"* found that most e-waste exported from the U.S. is dismantled under unsafe conditions, using methods like open-air incineration and acid baths to extract component metals.

The legislative language you consider today, including grant programs to spur studies into making electronic equipment easier to recycle on the front end and training our nation's engineers in "green design," will lay a critical piece of the foundation for comprehensive e-waste legislation in the future. Truly an ounce of prevention is worth a pound of cure; if obsolete computers and other such items can be diverted from the waste stream at the outset, half the battle will have already been won.

Thank you again for bringing much needed attention to this issue and to allow us to gather expert testimony on the problem of e-waste. I look forward to working with you further to enact a comprehensive plan to reduce e-waste.

Closing the Loop
Electronics Design to Enhance Reuse/Recycling Value
Final Report

January 2009

Conducted by the Green Electronics Council
in collaboration with the National Center for Electronics Recycling
and Resource Recycling, Inc.

GREEN ELECTRONICS COUNCIL

NCER
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1.0 Introduction

The end-of-life (EOL) management of electronic products has traditionally been an externality for those who design and sell the products. However, customers requiring that products meet an environmental design standard can provide an effective incentive to improve design for EOL. And that is the intent, and strength, of the Electronic Product Environmental Assessment Tool (EPEAT)[1]. To achieve that potential fully, the EPEAT Standard[2] must reflect the best and most effective design features that speak to the real world of electronics refurbishers and recyclers.

This project, Closing the Product Design – End-of-Life Loop ("Closing the Loop"), conducted by the Green Electronics Council (GEC), in collaboration with the National Center for Electronics Recycling (NCER) and Resource Recycling, Inc., explores the following questions:

1. What are the greatest challenges and obstacles facing electronics refurbishers and recyclers that are caused by the design of consumer electronic products?
2. How could the design of these products be changed to enhance the EOL value proposition?
3. What kind of information from manufacturers, and in what form, would expedite the most efficient management of electronics at EOL?

To address questions #1 and #2 above, the research team sought out a diverse set of North American EOL managers and talked to them in depth, both in individual interviews and at larger symposium events. EOL managers across the electronics EOL industry spectrum were interviewed: recyclers, for-profit and non-profit reuse operations, asset recovery businesses, resellers of both whole units and components, shredding recyclers, smelters, plastics reclaimers, and industry specialists. We asked for input on needed changes in electronic product design elements, focusing primarily, but not exclusively, on computers (both desktop and notebook) and monitors, that could enhance the value at EOL – and received thoughtful insights and ideas. EOL managers told us a number of product design element changes that could:

- Increase EOL process efficiency, and/or
- Enhance the market value or resource conservation value of commodities within each category of activity.

Because purchasing power drives the marketplace for product design, the research team will seek to have findings incorporated into purchasing and related programs intended to promote design for end-of-life (DfEOL), including EPEAT.

EOL managers were also asked about question #3 above – opportunities for information exchange between manufacturers and EOL managers. Manufacturers are required to provide information on product design features of EPEAT-registered products that are relevant to end-of-life managers. Because a tool to make this information easily accessible for recyclers does not exist, manufacturers are meeting this requirement of EPEAT on their own, in an uncoordinated

[1] For background on EPEAT see www.epeat.net.
[2] The ANSI-accredited IEEE 1680-2006 Standard.

fashion. This is likely of marginal utility to EOL managers. Additionally, states (such as Washington) and provinces are beginning to include information requirements of manufacturers in their takeback laws. Given this need, this project examines frameworks for an information resource, and develops a prototype and conceptual business plan for its sustainability on a long-term basis.

2.0 Processing Activities Used in the North American Electronics EOL Industry

The electronics EOL management industry is comprised of many different activities, which include practices and technologies ranging from very simple to very high-tech. The categories of activities below were defined because they identify processing steps that can be enhanced by either product design elements or the availability of information about the product and its components. With this project's specific focus on computers and monitors, the following nine categories of activities are explored:

1. Triage
2. Data Destruction
3. Refurbishment, Reuse and Resale
4. Demanufacturing into Subassemblies and Components (including resale of these items)
5. Depollution
6. Materials Separation
7. Mechanical Processing of Similar Materials
8. Mechanical Processing of Mixed Materials
9. Refining/Smelting of metals

These categories include both activities geared towards recycling (material sales) and those geared toward redeployment, refurbishment and resale of both whole units and working parts. Note that these activities are generally consistent with the categories used in research by *E-Scrap News* and in the International Association of Electronics Recyclers' report.[3]

Individual EOL businesses will likely perform more than one of these activities. There is a wide range of business models within the electronics EOL management industry, utilizing an array of different combinations of these activities. Some organizations focus on a single activity such as refurbishment and resale (e.g., an asset recovery business model) or mechanical processing (shredding – e.g., a recycling business model), whereas other organizations engage in many of these activities in their business. This is germane to this research because the various business models respond better to differing design-for-EOL imperatives.

Each of these activities is described briefly in the sections below.

[3] IAER Electronics Recycling Industry Report, International Association of Electronics Recyclers, 2006, Albany, NY

2.1 Triage

Triage is the inventorying, sorting and, as appropriate, the testing, of incoming material in order to route into the selected business activities. Triage may include:

- Intake and inventory
- Visual inspection for identification of specific items (based on business model)
- Sorting and/or testing for working versus non-working
- Sorting equipment/component by age, functionality, or type, and less frequently, by brand
- Sorting by disassembly strategy (e.g., into equipment type for manual deep disassembly prior to resale of components versus into equipment type for manual and/or automated disassembly prior to preparation of similar materials to flow into recycle markets)
- Sorting and/or testing for whole units for resale and/or refurbishment

Each organization or company has a different set of criteria that used in triage and sorting based on business model, customer requirements, expertise, equipment and outlets or markets. Organizations prioritize different kinds of products and components that are then selected for the appropriate type of processing.

Virtually all EOL management organizations conduct some type of triage unless they are collection-only entities, simply collecting, packaging, and transporting material to another EOL management organization for necessary triage.

Performing in-depth and accurate triage allows product to be sorted into the highest value activity and enhances both the process efficiency and value of EOL electronics.

2.2 Data Destruction

Data destruction has become an increasingly important step in the EOL management of electronics, driven by an array of privacy and security laws and policies at both the national and corporate level. Many EOL operations offer data destruction services, either via hard drive wipes or physical destruction of the hard drives. However, Information Technology Asset Disposition (ITAD) companies usually offer the highest level of service such as locked and monitored transport and storage areas, and/or real-time video or in-person monitoring of customers' equipment moving through secure data and/or product destruction.

Data destruction is also conducted by refurbishment organizations whose intention is primarily to make memory devices reusable, while meeting customer data destruction requirements. Both these aims can be met in one organization however.

The demand for data destruction services continues to grow in the EOL electronics management industry.

2.3 Refurbishment and Resale (whole units)

Refurbishment and resale of consumer electronics comprises a significant portion of the EOL electronics management industry. ITAD companies service large businesses and institutions, typically with access to newer equipment to refurbish, if needed, and resell. Non-profits and other smaller scale recyclers generally refurbish equipment from residential and small business returns.

Reuse of electronic products is vital and substantially more resource efficient than recycling. A majority (estimated to be approximately 80% in Computers and the Environment by Ruediger Kuehr and Eric Williams, UN University[4]) of the life cycle energy for computers is used in the manufacturing phase. Thus, extension of the reuse cycle yields greater environmental benefits than recycling earlier in a product's life.

Based on conversations with a variety of EOL managers, the percent of e-scrap coming from businesses versus residents that has resale value varies considerably. Generally, large ITAD businesses reported that about 90% of the commercially generated equipment they received had resale value. One EOL manager noted that although 90% had resale value, they refurbished and resold less than 50% due to customer requirements that equipment be destroyed. The same manager indicated that the amount resold (less than 50%) generated 90% of its revenue.

Residential e-scrap is typically much older and more heterogeneous than commercial e-scrap and consequently has a much lower percentage of units with resale value. EOL managers indicated only about 10 to 15% of residential e-scrap has resale value.

Interestingly, research during this project revealed small, but growing, skill sets for the repair and refurbishment of smaller IT products – laptops, PDAs, and other small devices. These skill sets are being added to a variety of EOL businesses – asset managers, recyclers adding a resale outlet, and expansion of skills in reuse operations. Several years ago small products were not considered viable for repair; in late 2008, growing skills and economic realities have made sale of refurbished laptops – along with other IT products – a growing segment of the computer industry, much like the mature used-car aftermarket that accompanies the new car industry. However, the volume of these products can be captured by this niche repair and refurbishment sector is not clear.

The refurbishment process can include:

- Testing to verify working status of both entire units and components therein
- Upgrade of processor, memory or other components
- Repairs as necessary
- Cosmetic treatments

One of the critical components of resale for desktops and laptops is an operating system – a unit can be resold having no system, using an open-source operating system, or using a Microsoft system[5].

[4] Computers and the Environment: Understanding and Managing their Impacts, Ruediger Kuehr and Eric Williams (Eds.), Lkuwer Academic Publishers, United Nations University, 2003.

[5] Microsoft has two Microsoft Authorized Refurbisher (MAR) programs to provide Microsoft operating system software to refurbishers:

1. The Community MAR program, a partnership between Microsoft and TechSoup, provides software to non-profit refurbishers. This program was created to increase the number of usable PCs available to nonprofits,

2.4 Demanufacturing into Subassemblies and Components

Many EOL management organizations recover value from working and/or non-working components/sub-assemblies.

In order to separate products into subassemblies and components, a manual disassembly process must be used. Usually this is a workbench-style operation, with pneumatic or sometimes simple hand tools to expedite the unscrewing, etc. that is central to this activity. The worker will sort into various subassemblies (e.g. a CPU) or components (e.g. motherboards, graphic cards, hard drives, PCBs by grade, etc.). This separation is by subassembly/component function, rather than material type, as in Section 2.6. Typically there will be bins or gaylords for circuit boards, hard drives, video cards, etc., as well as for other items that are not components such as the plastic or metal housings, cabling/wiring, etc.

At facilities where component reuse is part of the business model, working status of components can only be determined after disassembly. Special equipment is needed for testing of printed circuit boards, and consequently, there is little testing of circuit boards. They are typically separated and sometimes baled and sold for metals value.

2.5 Depollution

"Depollution" is a term used in Europe to mean the removal and the separate and appropriate handling of substances of concern that have been identified in the WEEE directive. This can be difficult to contain or control in certain EOL processes, such as whole-unit shredding. If depollution is not done, or done improperly, human health and the environment can be adversely impacted. Some examples include:

- Button cell batteries are removed from circuit boards prior to shredding, and are sent to a specialized battery processor
- Mercury-containing fluorescent lamps are separated from display devices and sent to a specialized processor
- CRTs containing phosphors are sent to specialized CRT processors after removal of the housing, copper yoke, and low-grade circuit boards.
- Removal of plastics embedded with brominated flame retardants (BFR) from the plastic recycle stream (common in Europe but not in North America)

All organizations that are involved in deep disassembly and/or mechanical processing should engage in depollution.

This necessary activity takes additional time in the recycling process, thereby reducing the efficiency of processing.

It is unclear how widespread the practice of depollution is in the EOL management industry in

schools, and low-income families across the globe by reducing the cost of software to refurbishers.

2. A commercial MAR program tailored to the needs of large refurbishers (who supply at least 5,000 refurbished PCs per month, on average) who want to deliver preinstalled Windows software licenses on refurbished PCs to be sold in the commercial market.

the U.S.; though virtually all the EOL managers we interviewed indicated that they were aware of the importance of depollution. In Europe it is driven by requirements of the WEEE Directive. In future years, with the development of recycler certification programs, depollution (and attendant worker protection) should become a universal best practice within the industry.

2.6 Materials Separation

A majority of EOL management organizations conduct some level of disassembly to separate materials and recover value from those material streams. These organizations may include manual disassembly operations, secondary recyclers, non-profits, some ITAD operations, etc. Generally, manual material separation generates a higher-grade commodity (cleaner fractions) than mechanical systems.

Materials separation involves manually separating and preparing materials for further processing. Disassembled equipment is sorted into material categories such as:

- Plastic housings/stands
- Ferrous/non-ferrous metal cases, strips
- Printed circuit boards of several grades
- CRTs
- Copper-rich components and subassemblies
- Other precious metal categories
- Cabling and wiring
- Batteries
- LCD panels/mercury lamps, or other mercury-containing devices
- Small peripherals (keyboards, mice)
- Sound/video cards
- Wood (from old console televisions)
- Miscellaneous packaging including Styrofoam, cardboard, etc.

One processor that was interviewed indicated that they manually separate into 55 discrete material streams; however, most processors manually separate into far fewer material streams.

2.7 Mechanical Processing of Similar Materials

This activity involves mechanical processing together of similar materials (such as compatible plastic resins, metals or CRT glass) by laser or wire cutting, shredding, grinding, pelletizing, and/or refining to generate market-grade commodities. Some examples include:

- A recycler has a relatively small metal shredder – all hard drives are shredded in it before being shipped to a metals recycler paying for the materials on a price–per-pound basis
- A recycler sorts the plastic housing from televisions, monitors, CPUs, and laptops into white versus black streams, and crushes and bales them before sending to a plastics recycler
- A plastics recycler uses optical sorting to separate grades of plastics into fairly pure grades of specific plastics, which are then put through a re-melt process that produces pellets of specific-grade plastics for the feedstock market
- A recycler bales all the cardboard and paper grades it receives (packaging for incoming e-

scrap), and sells to a paper recycler

- A recycler's automated CRT shredder (after the housing and copper yoke is removed) uses hot-wire, laser, or mechanical processing to separate face from funnel glass (these have different lead contents); it then crushes each stream to be sold into different markets
- A recycler shreds printed circuit boards for size reduction before shipment to a refiner
- A refiner receives loads of printed circuit boards and assays a small core sample of the PCBs; it then pays the e-cycler who shipped to the refiner. It then refines in a small furnace to remove some impurities, and sends materials to a larger smelter for final chemical reduction and metals separation.
- A smelter receives shipments of printed circuit boards and shreds them, conducts spot assays to determine potential value and pays the customer who shipped the load based on assay; the smelter then uses chemical reduction processes (electrolytic reduction involving use of flux such as limestone, for example) to extract the metals from the printed circuit boards, and sells the metals in the global metals markets

2.8 Mechanical Processing of Mixed Materials

Typically, mechanical processing of mixed materials, such as whole units (after depollution), is conducted by larger EOL management companies that have made significant capital investments in large-scale equipment.

This activity involves mechanical processing of mixed materials for recycling – usually by shredding followed by a series of separation technologies. For some mixed materials, a complex series of steps are needed to separate material into commodity-grade streams.

It is critical that adequate and compliant depollution occurs prior to this processing activity; however, it is not always done.

Mechanical processing, without any disassembly, is often driven by customer demand. Institutional/commercial/industrial (ICI) customers of processors frequently require product destruction for security or proprietary reasons. This can include product from electronics manufacturers.

These mechanical processing systems, if they handle large quantities, can be cost effective. Even though they forego revenue opportunities from recovered systems and components, they also avoid substantial labor costs involved with manual disassembly. They also may generate lower-value materials from a resource recovery perspective. They can effectively handle large quantities of old or lower-valued products or products that are not designed well for disassembly.

2.9 Refining/Smelting of Metals

After materials have been sorted into components (e.g., high-grade and low-grade circuit boards from demanufacturing) or into shredded streams (e.g., mostly copper, ferrous, or non-ferrous streams from mechanical processing), if being managed responsibly, they are sent to smelters or refiners. These final destination operations use sophisticated thermal and chemical management processes to extract metals of many types, which are then resold into the global metals markets.

Front-end processing to remove materials of concern is typically done. For example, at Boliden's smelter in Sweden, a separate metals management company, Kuusakoski, removes all batteries and certain other items from circuit boards before they are fed to Boliden's smelter. This results in a higher quality product and safe capture of hazardous substances.

3.0 Design for End-of-Life

There are two aspects of design for EOL: first the actual design elements, and secondly communication of those elements to the EOL industry. This section provides a summary of our findings on the challenges and recommendations on design elements themselves, based on what we heard is needed from EOL managers. A following section, Section 5.0, discusses how information about those design elements could be communicated to EOL management organizations.

As described in Section 1.0, the research for this project included interviewing EOL managers engaged in a range of different EOL activities both through individual interviews and at larger symposium events. The interviews sought to obtain insight and input on needed changes in electronic product design elements that could enhance the value at end-of-life.

The following sections (3.1 through 3.10) summarize the key design for EOL challenges and recommendations within each of the nine EOL activities addressed in this project. Please note that these findings are based on input from interviewees. It is recognized that some of the recommended product design changes may be extremely challenging, if not impossible, to achieve in the near term. The purpose of researching product design element changes from the EOL management industry perspective is to begin the dialogue with electronic product designers and close the communication loop.

3.1 DfEOL for Triage

We received much input in the area of inventorying and sorting of EOL electronics, particularly from reuse and asset recovery organizations, on both the information that would enhance process efficiency and methodologies for communicating the information.

Triage is a critical element in the EOL process. Products are often divided into different groups for different processing strategies.

For most operations, it is critical that this activity occur as quickly and accurately as possible. Challenges to streamlining this operation include getting adequate data, correctly identifying every aspect of incoming equipment – from make and model to component types - and accurately determining level of functionality.

Product Design Recommendations

Inventorying and Sorting

- EOL managers need products to be designed to improve access to key information for enhancing inventorying and sorting activities, such as:
  - Serial number
  - Manufacturer
  - Type of equipment (e.g., inkjet or laser printer; if it is a multi-function device

- (MFD) – information on what type)
  - Model
  - Date of manufacture
  - Component inventory (age, type, RoHS compliant, etc.)
  - Accurately identifying the customer's required security level with regard to data destruction and equipment disposition
  - Type and location of hazardous materials (such as mercury lamps)
  - Type and location of new materials
  - Other information suggestions included:
    - Distribution and sales history of unit
    - Data that would assist states with return share allocation for producer responsibility takeback programs
- The suggested methodologies for communicating the above information, that should be incorporated in the product design include:
  - Markings and/or labeling on product, for example:
    - Identify products, their performance features and all internal components clearly on the outside of the unit, or
    - Print a uniform schematic format on the inside of product cases showing internal components and product information
    - See Section 3.4 for suggestions for items containing hazardous substances
  - Bar code identification to get component performance specifications
  - Consistency in serial numbers – so that the string of numbers and letters can provide information about the product to an EOL manager
  - RFID technology, particularly down to the component level to dramatically improve efficiency of the inventory process
  - Manufacturers providing "Bills of Materials" (BOM) which would identify key parts, sub-assemblies, and components, as well as those containing hazardous substances. These could be made available online, much as the automotive industry provides for automotive repair and body shops. As well, these BOMs should also identify any industrial hygiene or special treatment information related to how the items should be handled to protect worker health and safety.

For any of these communication methods, several interviewees emphasized the importance of creating a uniform and internationally readable format and information set.

More discussion on communication is provided in Section 5.0.

Testing for Working/Non-Working Units and/or Components

The following was also suggested:

- Mechanism for ease of testing for components (work/don't work)
- Development of an "indicator" on components showing amount of useful life remaining, like battery "charge indicators"
- Manufacturers provide test procedures for functionality online, for access by EOL managers

3.2 DfEOL for Data Destruction

Interviewees indicated that data destruction is gaining importance in the industry. Currently, different tools are required to wipe different types of memory devices. Some interviewees expressed a desire for developing industry harmonization, but it was also noted that the industry may be headed towards a change anyway with solid state drives and encryption of data. There are industry associations (including those for IT professionals, and the National Association for Information Destruction) addressing this, as well as the National Institute for Standards and Testing (NIST). As well, some OEMs are producing computers with Secure Erase features on the hard drives (allowing HDs to meet DOD security clearance levels) – EOL managers need to be able to identify and work to capture the maximum value from computers equipped with these features

Product Design Recommendations

- Information for consumers on how to erase and save data, including in operating manual or even links to such data directly on the product
- Hardware design that lends itself to thorough data destruction and reporting; etc. For example, personal computers with a Secure Erase feature (see above) may or may not be identifiable – use of pre-loaded features for data destruction can save EOL managers time using purchased data destruction products. Or, data storage device uniformity can lend itself to faster data destruction and thus faster re-deployment of storage media – thus enhancing the positive environmental impact by lengthening product life.
- A standard way to clear memory for smaller products, especially the handheld category. Clearing memory is different for each maker's products. Need standard way to plug in and reprogram.
- Need industry standards for drive formatting to ease data eraser (wiping hard drive).

3.3 DfEOL for Refurbishment and Resale

Critical for reuse and asset recovery organizations' efficiency is the quick and accurate (a) identification of product information (see Section 3.1); (b) differentiation between working and non-working units and components; and (c) efficient and safe disassembly (see Section 3.5).

Product Design Recommendations

Ease of Disassembly/Assembly

- Snap in/snap out components
- Use of consistent, limited and uniform set of screws and fasteners.
  - One recycler suggested that manufacturers use many different and uncommon screws to protect against customers disassembling products and voiding the warranties. This recycler suggested that manufacturers could put a simple seal in place saying "warranty void if seal is broken".
- Consistent placement of commonly used assembly features – e.g., how video displays are attached to stands; if it was always the same screw or attachment feature, damaged parts

could be quickly replaced

Longevity and Reparability

- Design for longer life span of components, including greater durability of components
- Eliminate or reduce painted plastics and proliferation of colors which precipitates cosmetic damages and unique models making it more challenging to refurbish
- Standardized test procedures for functionality of whole units and for components
- Manufacturers provide repair manuals within two years after first selling a product, in order to promote reuse and refurbishment of the products
- More easily transferable licenses for operating system licenses – e.g., some type of transferable certificate of authenticity that would survive a hard drive wipe of data, but leave core operating system software intact

Power Supplies

- Standardize power supplies, particularly for portable equipment. There is tremendous variation in voltage, amps, and plugs. Several interviewees noted that power supplies should be as universal as USB plugs. Uniformity of cords would enable much, much more reuse (cords and units often get separated in the multi-stop journey from use to an EOL facility).

Using RFID to Assess Reuse and Refurbishment Value

A particularly interesting concept that was brought up by a few EOL managers, and is being explored in academic circles, is the idea of a Radio-Frequency Identification (RFID) "blackbox" for each computer – essentially a chip that records operational data and can transmit it via RFID – which would periodically record the functionality of different subsystems. Essentially, the RFID would track data that could be used to estimate whether subsystems work or not, the remaining useful life of each component, whether a hard drive has been wiped correctly, or other pertinent information.

An RFID scan could extract the lifetime consumption data and provide an indicator of reuse and refurbishment potential. This information would be accessed off a unit by RFID and would simultaneously reference a central database, which could possibly also include real-time data on component resale prices or other information. When the data is combined with a component inventory of the unit, a highly valuable projection of the quality and value of the system for reuse and refurbishment could be rapidly secured upon the product's entry to a processing facility.

Research in this arena is being conducted at the University of Limerick[6], Arizona State University[7] as well as in another EPA-funded project[8] which includes assessing the use of RFID tags in electronic products and the environmental benefits at EOL.

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[6] "RFID Signaling to Stimulate Reuse of Personal Computers" by Eanna Cronin, Steward Hickey, and Colin Fitzpatrick, ISEE 2008

[7] Eric Williams, Department of Civil and Environmental Engineering & School of Sustainability, Arizona State University

[8] The PURE Project; managed by Elliot Maxwell emaxwell@emaxwell.net

3.4 DfEOL for Depollution

The primary challenges associated with depollution are 1) identification of the location of components containing hazardous materials, and 2) removal of components containing hazardous materials. Depollution is an essential activity for products that will be mechanically processed, if they contain hazardous substances, and involves shallow disassembly that is generally done before products are shredded. It may be a more natural and integrated part of a deep disassembly process.

Interviewees indicated that better identification mechanisms are needed for mercury lamps, batteries and toner cartridges – both on the specific component containing a hazardous material and on the exterior of a whole product. Manual removal of these items is necessary in large-scale shredding operations and it slows down processing considerably.

Many EOL managers expressed frustration at the difficulty of removing mercury lamps intact. One interviewee described a situation where the lamp in a laptop screen was "literally embedded into the screen with glues" and was "absolutely impossible to remove without breaking." Another EOL manager of a large reputable company said that they had stockpiled laptop screens for a year because they were such a challenge to handle responsibly.

Interviewees indicated that large batteries were generally easy to locate and remove. However, small batteries, such as those affixed to circuit boards can be a challenge to identify and in some cases, are soldered onto the boards or embedded in clocks making them very difficult to remove.

Toner cartridges were recognized as universally easy to remove; however there was a concern that sometimes large imaging devices can have multiple toner cartridges and it can be hard to know whether all of the cartridges had been located and removed.

One interviewee discussed EOL worker health and safety issues associated with beryllium. This interviewee described how beryllium, when melted or shredded at EOL, can release a fine particulate into the air which can cause a disease called berylliosis, a chronic allergic-type lung response and chronic lung disease caused by exposure to beryllium and its compounds.

Interviewees did not provide much input on management of liquid crystals in flat panel devices. One interview said that liquid crystals are adhered to the metal, can therefore just be shredded. Given that more and more flat panel devices will be entering the recycling stream in the years to come, more research should be conducted on DfEOL product design elements of flat panels.

This section deserves mention of the importance of upstream design that eliminates hazardous substances from electronic devices altogether. Under the influence of RoHS and REACH, this is an important and growing trend in the consumer electronics and IT industries; however, there needs to be continual improvement in this area – especially in finding safe alternatives to items such as intentionally-added mercury in light sources, brominated flame retardants in plastics, etc.

Product Design Recommendations

Identification of Components Containing Hazardous Materials

- External marking indicating the presence and location of components containing hazardous materials (mercury lamps, batteries, toner, brominated flame retardants, perhaps beryllium, etc.)

- Identification of components containing hazardous substances, through use of technology such as RFID tags or other tags.

  For example, an RFID, or other tags, could be affixed to a component requiring special handling, such as a battery. A mechanical processing system would be equipped with an RFID reader or other sensor that would sound an alert when a battery, or other components containing substances of concern, is detected. This would protect against crushing mercury lamps, explosions from crushing batteries, etc. It was noted it could be the equivalent of a radioactive detector used in scrap yards.

- Color coding all components containing hazardous materials, in particular small batteries. It was noted that many small batteries are hard to identify, and can easily inadvertently end up going through a shredder.
- Components containing hazardous materials located within "line-of-sight" spotting when external housing is removed.

Ease of Removal of Hazardous Substances/Components

- Design these components to be extremely easy to pull out, using cartridge-style housing that snaps, pulls or slides in and out readily.
  - For example, a mercury-containing lamp could be removed as easily as a battery from a laptop to protect from release of the hazardous material in handling. Interviewees indicated that it is currently an enormous challenge to get mercury lamps out intact – they are tiny and often deeply embedded.
  - Another example is batteries on circuit boards and embedded in clocks; it was suggested that these be affixed in a manner that allows for easy snap-off or pull-off.
- Use of consistent, limited and uniform methods of affixing components containing hazardous substances. This would greatly ease removal of these components.
- Manufacturer BOMs should be provided that identify new and hazardous substances, and any related industrial hygiene or special treatment information related to how items containing hazardous substances should be handled to protect worker health and safety during the entire recycling/reclamation process. An example is liquid crystal displays, where knowledge of handling requirements, exposure risks, and impact of various treatment methods is unknown by the EOL industry.

Elimination of Substances of Concern

- Elimination of intentionally added mercury used in light sources (this is already an optional EPEAT criterion, but is noted here because of the number of times this was mentioned by interviewees)
- Batteries free of lead, cadmium, mercury, and lithium
- Elimination of intentionally added cadmium in wires and cables

- Elimination of beryllium (often alloyed with copper) in connectors
- Elimination of brominated flame retardants, halogens, and polyvinyl chloride in plastics, due to concerns regarding dioxin formation if reclaimed plastics are subject to high-temperature treatments (see Section 3.9 for additional discussion)

3.5 DfEOL for Demanufacturing into Subassemblies and Components

The greatest challenge in demanufacturing or disassembly was universally identified as the number, diversity and variable locations of screws and fasteners. There was a strong desire amongst interviewees to enhance ease of disassembly and develop consistency in connection mechanisms.

Product Design Recommendations

- Use a consistent, limited and uniform set of screws and fasteners. One recycler suggested that manufacturer's use many different and uncommon screws to protect against customers disassembling products and voiding the warranties. This recycler suggested that manufacturers could put a simple seal in place saying "warranty void if seal is broken".
- Do not use hidden screws; if hidden screws must be used, have arrows showing location
- Metal fasteners should not be molded into injection molded parts
- Use press-fit, not screw-fit connection mechanisms
- Snap, pull, slide-in/slide-out, or cartridge-style housing for components for ready removal
- The cartridge or slide-in/slide-out housing should protect items containing hazardous materials and the cartridge itself should be easy to disassemble (e.g., LCD mercury bulbs are fragile and the cartridge must keep them rigid so that they don't get broken on removal from a device)
- Manufacturer guide to quickest and safest disassembly

3.6 DfEOL for Materials Separation

Interviewees indicated that plastics are their greatest challenge with regard to materials separation: the proliferation of so many different plastic resins, flame retardant plastics, laminated plastics, plastics with paints or coatings, and lack of consistency in labeling plastics. A couple EOL managers expressed skepticism about the reliability of plastic markings, noting it is costly to change plastic molds.

Many EOL managers noted that an inability to effectively separate plastic resins prior to processing greatly decreases the value of the material. However, some plastics processors indicated that it is not a problem to process mixed plastic resins. One interviewee indicated that even facilities designed to separate plastics generate high percentages of waste. Another noted that the plastics regrinders have to remove trace contaminants from plastics such as stickers and labels (pervasive on certain electronic product categories). Currently the regrinders have to peel or "buff" them off.

The value of plastic resins and the downstream markets was also brought up as a concern. Some plastic resins have little secondary value, such as HIPS which, according to one interviewee, is only down-cycled currently. It should be noted, however, that plastic markets can evolve over time.

Molded–together, dissimilar materials, or bonded in some manner, was also mentioned as a barrier to materials separation.

Product Design Recommendations

- Develop a consistent and limited set of resins to be used, or at least a limited number of different resins per product category
- Consistent labeling of plastic resins (note that this is already an EPEAT criterion)
- Labeling to indicate the presence and type of flame retardant in the resin
- Eliminate laminated, bonded, glued, and/or molded-together dissimilar materials, including stickers and labels
- Inform the EOL industry when new materials or metals are being designed into products to enable better recovery of those materials
- Circuit boards, and/or other precious metal-containing components, should be easily removable using manual separation methods both from the product as a whole and from specific components (such as drives) that contain such boards to enhance recovery of high value material.
- Larger ferrous and aluminum parts should be easily separable from the precious metal-containing components.

3.7 DfEOL for Mechanical Processing of Similar Materials

Research findings for mechanical processing of similar materials centered on plastics. Specifically noted were the separation of plastic resins prior to processing greatly increasing the value of the material and elimination of laminated and affixed together materials. Some plastics processors indicated that it is not a problem to process mixed plastic resins. However, many of the EOL managers who are not solely processing plastics expressed that mixed plastics were of much lower value than separated plastics.

Separation of plastic resin types is discussed above in Section 3.6. Other product design recommendations for mechanical processing of similar materials are below.

Product Design Recommendations

- Ease of separation of affixed foams, glues, and metals
- Eliminate lamination of dissimilar materials, even two slightly different resins
- Reduce of number of resin types used

3.8 DfEOL Mechanical Processing of Mixed Materials

The mechanical processing of mixed materials, generally the shredding of whole units, involves some of the same challenges described above for other EOL activities. Most critical for this activity is depollution, described in Section 3.4.

The cleaner the material streams, the higher the value of the material. Barriers to separation into clean material streams include design elements such as materials laminated together that are incompatible for recycling. Interviewees also expressed a desire for ease of access and removal of high value materials cables and wires containing copper.

Product Design Recommendations

- All depollution recommendations in Section 3.4
- Minimize the variety of materials in any given product
- Ensure that items containing precious metals such as cables and wires containing copper can be removed easily (i.e. snap out)
- Eliminate lamination of dissimilar materials, even two slightly different resins, to maximize valuable materials recovery

3.9 Refining/Smelting of Metals

Refining and smelting of metals is an old and mature industry, often referenced as both a bedrock and bellwether of the global economy. Its role as an economic driver of the EOL industry should not be underestimated – therefore design to enhance value recovery from metals at the refining and smelting level should not be overlooked.

One large smelter contacted for this research noted that when OEMs add new metals, the EOL extractors of metals (i.e., refiners and smelters) need to be apprised of this. For example, ruthenium (Ru) is used in hard disks, but there are few Ru-recovery operations in the world. Once refiners and smelters are aware of the use of new metals, they can design assaying and extraction processes to recover valuable metals, such as Ru and improve recovery rates (thus keeping metals prices down).

This smelter called for easier removal of circuit boards: it reported that it now may take in two tons of "circuit board shred mix" (from a shredder of mixed materials; this mix includes plastics and metals from other items beyond circuit boards) to extract 200 grams of gold (Au). If the circuit boards were more easily and quickly separated from other materials then one ton of circuit boards alone would be enough to extract the same quantity of gold, using much less energy. etc.

Further, this smelter noted that smaller products, such as hand held devices, can contain "the whole periodic table of elements" – in tiny, closely interconnected bits and pieces. The valuable materials can be trapped between fiber layers, contained in tiny metallic pieces (e.g. pins or coated on copper in contacts), embedded in a ceramic matrix or plastic found in chips, and/or embedded in layers of the circuit board itself. Pyrometallurgical processes (smelting) can more effectively extract precious metals or other valuable materials from such complex, interconnected materials.

Product Design Recommendations

- Manufacturers provide notification to recyclers – but especially to market players such as refiners and smelters who recover precious metals – of addition of new metals and materials to enhance metals recovery
- Ease of disassembly (see Sections 3.3 and 3.5)

3.10 Other Findings

As discussed above in Section 3.4, interviewees did not provide much input on management of liquid crystals in flat panel devices. However, given that more and more flat panel devices will be entering the EOL stream in the years to come, research should be conducted on DfEOL product design elements of flat panel devices.

Another important DfEOL concept, encountered during this project, is the issue of "closed loop" recycling – addressing whether the materials selected in manufacturing can be recycled back into new products in the same product category. Because end-of-life managers are not driving materials selection at the manufacturing level (as OEMs are), our interviewees did not have informed opinions about how to ensure that materials used in making electronics can be re-used again. They just think it is a good idea. For example, glass from LCD TVs and LCD monitors is not commercially viable to recycle at this time. If OEMs could design this glass to be reused or recycled back into the same material type, it would reduce the overall environmental footprint of display devices, thus providing an environmental benefit.

4.0 Suggested End-of-Life Management Concept – Two DfEOL Scenarios

It became clear to the research team as we discussed processing approaches with EOL managers that different electronic products, based on their inherent design, have greatly different potentials at EOL. This is especially notable given the evolution of increasingly smaller and lighter weight products, and products that are designed for particular functions or markets such that they are increasingly difficult to disassemble at EOL.

The intent of the two-scenario approach is to define design standards relative to the product's management at EOL for different types of products. These design standards are intended to maximize the environmental benefits relative to resource use and conservation and environmentally safe EOL management. The key distinguishing design issue is whether the products can be readily and effectively disassembled through non-destructive processing at EOL. If so, systems and components can be recovered and reused, and pure streams of recyclable materials can be readily generated. The other scenario suggests design strategies for extended product life, dematerialization and smart material selection.

The Challenges

The interviewees described some of the trends in product design and resulting challenges that are facing the EOL management sector, and in particular in the reuse and asset recovery arena. They include:

- Product distinctiveness and uniqueness is increasing as OEMs seek to distinguish their products in a market flooded with high technology. This results in:
    - Diminished adaptability of spare parts for repair or refurbishment
    - Increasing expense in sourcing spare parts for repair and/or refurbishment
    - A period of a steep learning curve while refurbishers learn how to repair product variants
- The race for faster and smaller processing power shows no sign of letting up. Moore's Law states that processing power of high technology products doubles every two years. This exponential growth in computing capability has held true for more than half a century and is expected to do so for some time to come. The result is not only smaller and smaller products, but also rapid obsolescence and short-lived generations of equipment.
- Increasingly unique external case designs, resulting in:
    - Increased difficulty in stacking and transporting equipment, particularly LCD monitors and televisions
    - Housings that damage easily in transport and are increasingly difficult to cosmetically repair (e.g., materials that do not allow for painting, a great variety of colors, etc.)
    - Increased product returns for cosmetic reasons; returned but functional products are often directed by retailers into recycle streams
    - Difficulty in opening external cases without irreparably damaging internal components
- Incoming EOL equipment increasingly is arriving at recyclers' docks without data storage devices (due to data security concerns), while it is getting more difficult to source affordable compatible replacement drives.
- Incompatible power supplies across product and category types further hinders ease of reuse.
- The trend toward more notebooks and fewer desktops exacerbates these problems since notebooks, especially as they are minimized in size, are more challenging to dismantle than the more generic desktop or tower computers.[9]

Most electronic product environmental standards that address design for EOL assume that the top environmental objective is deep disassembly for refurbishment and recycling. However, based on these technology trends, and the increasing efficiency and pervasiveness of automated

[9] Note that there may be an environmental benefit through dematerialization in the trend towards smaller products, unless the smaller weight of materials used is offset by the use of more resource-intensive materials. An environmental life cycle assessment would be needed to assess those benefits.

recycling systems[10] as well as new pyrometallurgical extraction processes tailored for EOL electronics, it may be that in the future only a portion of the electronics waste stream will be compatible with deep disassembly for refurbishment and recycling. If this turns out to be the case, the question, then, is what types of design standards can promote environmental improvement for products that are not suitable for deep disassembly?

Design Solution

We propose a potential concept of two scenarios, both of which can optimize product design and integrate EOL management methods. This two-scenario approach recognizes the realities of the marketplace and technology evolution and the need to maximize both reuse/refurbishment and the recovery of valuable resources at EOL through management systems that are tailored to the product design.

The ***two scenarios*** are:

	Scenario #1	**Scenario #2**
Environmental Design Paradigm	***Products designed for disassembly*** including refurbishment, component and system reuse and recovery, removal of hazardous materials, and separation of materials into relatively pure streams for commodity recycle markets. Some mechanical processing may recover materials following disassembly. For example, a desktop or notebook computer with features that promote upgrading, disassembly and component recovery fits in this scenario.	***Products designed for whole unit processing for materials recovery*** – these products are built with highly recoverable materials and the absence or easy removal of hazardous materials. This scenario may include some targeted shallow disassembly for necessary depollution. Ideally these products would be designed for longer life. For example, a compact fashionable notebook may present inherently difficult access to internal components and therefore is a better candidate for automated or pyrometallurgical processing.
Product Characteristics	Products without inherent and substantial constraints on design for disassembly.	Products designed for uses or markets that posses substantial constraints on size, weight or other design factors that present significant challenges for disassembly at EOL.

[10] This trend toward automated, mass-processing systems, based on product shredding, is evidenced in Europe under various countries' producer responsibility systems. These producer-subsidized systems increase the flow of products substantially, and they increasingly draw products from the consumers. They appear to change the economics of EOL management in such a way that the efficiencies of mass, automated processing is favored.

	Scenario #1	**Scenario #2**
Environmental Design Objectives	Optimize the recovery and reuse of the system, its components or pure material streams through non-destructive disassembly.	Optimize long life, dematerialization and effective recovery of materials at EOL through smart design and material selection.
EOL Handling	***EOL management with a focus on demanufacturing*** and an end goal of maximum reuse and asset recovery	***Recycling with a focus on whole unit materials recovery*** and an end goal of depollution and efficient material recovery
Design for EOL Objectives	• Maximize hardware service life across software generations, perhaps with cascading functionality to enhance reuse • Increase demanufacturing process efficiency • Enhance the market value of the resulting material streams • Eliminate/minimize worker health and environmental impacts at EOL	• Maximize product longevity (including design features which enhance whole product reuse) • Enhance dematerialization (minimize material usage) • Increase the generation of high-value material streams and materials recycling • Provide readily identifiable and removable hazardous components • Eliminate/minimize worker health and environmental impacts at EOL

	Scenario #1	Scenario #2
Key Design Features	• Ease of identifying and removing components containing hazardous materials • Use of consistent, limited and uniform set of screws and fasteners; elimination of hidden screws; increased use of press/snap fit connection mechanisms • Snap, pull or slide in and out components • Ease of plastics identification and separation • Increased standardization of components, such as power supplies, particularly for portable equipment • Easy access to product and component information to assess the resale value and refurbishment potential	• Ease of identifying and removing components containing hazardous materials • Elimination of adhered-together (laminated, bonded, glued, etc.) materials that are not recyclable or compatible in recycling • Minimize the variety of materials in any given product, especially those that cannot be easily separated through mechanical systems such as different plastic resins • Ensure that items containing precious metals such as cables and wires containing copper can be removed easily (i.e., snap out) • Use of durable materials and robust power supplies/batteries that further product longevity • Offer warranties and training services for repair and refurbishment of products

As the electronics recycling industry matures, and more U.S. states and Canadian provinces adopt producer responsibility laws, there is likely to be increased use of mechanical processing. There are differing opinions on the merits and drawbacks of shredding versus demanufacturing as a primary processing approach from an environmental perspective. These opinions have been expressed in technical papers that take different stances, and are one of the major points of contention as the European WEEE system is under review. The question has also been posed to EPEAT as to whether products should be designed for disassembly or efficient shredding. This research is not to address the question of the merits and drawbacks of shredding versus demanufacturing, but to assess how best to design products for EOL, given that both processes are used, and mechanical processing may increase in the future.

One critical question is that of reuse – is there a place for design elements geared towards whole product reuse in the mechanical processing scenario? Reuse is much more environmentally beneficial than recycling, and for EOL scenarios to be fully environmentally responsible – whether driven by EPEAT ratings, manufacturer take-back programs, purchasing specifications, state and provincial policies, or marketplace realities such as precious metals prices – they must include reuse. We suggest that for the Scenario #2 concept to maximize environmental benefit, it must include design elements for longevity and some shallow disassembly for whole-unit reuse.

5.0 Information Communication

The second important aspect of design for EOL is communication; communication of design elements from OEMs to EOL managers, as well as feedback from EOL managers to OEMs. As one EOL manager said, "what good is a magic button to release all connectors (screws, snap fits, etc.) if you don't know that it exists on the unit and/or where it is located?"

This section provides:

- A summary of our interview findings on communication methods
- A description of a web-based information resource prototype for communicating design elements critical for EOL management
- A conceptual business plan for its continuation on a long-term basis

5.1 Interview Findings

Interviews with EOL managers included exploring communication needs and preferred methods. Interviewees were asked what information from manufacturers would enhance EOL process efficiency and/or material/commodity values, and how should that information be communicated to EOL managers. The findings of the interviewees were used to inform the development of the web-based information resource prototype described in Section 5.2.

Three primary categories of information were identified:

1) Product information for inventory and sorting purposes (see Section 3.1)
2) Identification, location and removal instructions of components containing hazardous substances (see Section 3.4)
3) Identification of plastic resins for separation for processing (see Sections 3.6 and 3.7)

The two communication methodologies that were highlighted as preferable by interviewees included:

1) Exterior labeling or marking on product
2) A web-based tool that could eventually be accessed in a semi-automatic fashion using technology such as RFID tags or bar codes

Many EOL managers were enthusiastic about RFID tags. It was pointed out that eventually an RFID tag could be affixed to every major component. This would enormously enhance inventory efficiency and identification of components containing hazardous substances. One interviewee indicated that from a shredding perspective, it was not a problem to have an RFID tag attached to the material at EOL. Another EPA project[11] is currently assessing the use of RFID tags in electronic products and the environmental benefits at EOL.

[11] The PURE Project; managed by Elliot Maxwell emaxwell@emaxwell.net

Recent announcements in the electronics industry indicate that the ability to print RFID tags (as printed integrated circuits, as opposed to conventional silicon integrated circuits) is nearly market-ready – and can print at sizes ranging from 10 to 150 µm on initial test RFID tags, with prices expected to reach below $.01/tag in high volumes in the foreseeable future.[12]

The research indicated that in the context of managing electronics at end of life, the cost of reading barcodes could be prohibitive. Additionally, barcodes must be in line-of-sight to be read, and therefore cannot be used at the component level.

5.2 Web-Based Information Resource Prototype

Following on the data gathered from EOL managers, the NCER led the development and launch of a prototype design for recycling web application, the "CTL Registry", to house key information on product attributes that are useful for recycling purposes. The web application, known as the CTL Registry, will be a resource for EOL managers searching for information about a particular product (such as location of hazardous materials). The goal is to assist these EOL managers with proper breakdown and recycling by providing pertinent information on an array of electronic products. Users of this web application will be able to search products by the following categories: manufacturer, product type, model, date of manufacture, serial number, materials of concern and brand. Search results will net the user information such as the location of hazardous substances, information on identification and separation of plastics, and disassembly instructions, if available.

Manufactirers providing such information is a requirement of EPEAT and of the Washington state electronics recycling law, but a place to make this information easily accessible for recyclers does not exist. Thus manufacturers are meeting this requirement of EPEAT on their own, in an uncoordinated fashion. This will be of marginal utility to recyclers. Moreover, the one-stop information source will be designed to house information for all products organized under easily recognizable categories, not only EPEAT-declared products. The conceptual business plan noted in Section 5.3 below proposes options for a sustainable funding model for the activity.

One of the major challenges in developing this web-based resource was to ensure that manufacturers can easily provide information on their products in a format they would be familiar with. After examining several options, the project team decided that integration with the back-end EPEAT data would be the most appropriate and logical method. Although this limits the data collection to EPEAT-covered products, it also allows manufacturers providing data on their products an easy method for including this additional information. EPEAT manufacturers can use their existing login information without duplication and input data in a format similar to data gathered for EPEAT registration purposes.

5.3 Conceptual Business Plan

Introduction and Background

[12] "Kovio Demonstrates RFID Tags Using Printed Electronics," David Lammers, Semiconductor International, October 16, 2008. Accessed 10/16/08 at www.semiconductor.net/article/CA6605965.html?nid=3572&rid=418790434.

The CTL Registry prototype allows manufacturers who are already registered with EPEAT to use their existing registration to enter key data such as year of manufacture, number and location of materials of concern, and disassembly instructions. Previously, this type of information was not easily accessible for recyclers, and not centrally located. Recyclers desire this information to prevent operational accidents or pollutant releases and to make their disassembly, reuse or shredding operations more efficient. Manufacturers are incentivized to provide this information due to high environmental awareness among consumers, requirements of EPEAT, and requirements in a growing list of state statutes on electronics recycling. Instead of providing this information to recyclers in an uncoordinated fashion or on an as-requested basis, the registry aims to create a one-stop clearinghouse that allows manufacturers to satisfy their obligations and recyclers to obtain reliable data.

However, the prototype will not be able to fulfill its main goal without a sustainable source of funding. Therefore, this conceptual business plan described below offers several avenues for expanding and sustaining the work under the Closing the Loop project to date. While there are a few barriers to ensuring the registry develops into a robust information resource, the conceptual business plan articulates steps to overcome those barriers, target key potential customers, and market the registry to sustain its development over the long term.

Market for CTL Registry Services

There are two primary markets for the CTL Registry service. The first market is the recyclers and other end-of-life managers seeking information for their processes. This market is currently not served with the type of service offering of direct manufacturer data described below. The second primary market is manufacturers seeking compliance assistance in achieving additional EPEAT points and meeting state mandated requirements. Individual companies may be providing this information currently on an as-needed basis to individual recyclers, or on their corporate environmental websites, but there is currently no central information clearinghouse for these data. Other potential markets include consumers wanting info on potential materials in their products, and policy makers wanting to target key materials that could be in the waste stream.

CTL Service Offering

The CTL Registry offers an easily accessible database of key product attributes that are valuable for end-of-life management. By incorporating the database into the widely used EPEAT database, the CTL Registry provides information directly from the primary source – the manufacturer. The database provides custom reports and is searchable based on any of the criteria the user selects. For example, users desiring information about which products contain batteries and where they are located can search the battery field. The CTL Registry will serve as a "one-stop shop" for recyclers seeking these data points, and for manufacturers looking to provide this information once rather than in several locations.

Near-Term CTL Registry Services

During the next six months to one year, the CTL Registry will focus on populating the database by reaching out to the manufacturer market, initially for EPEAT registered products. The key messages to encourage the initial group of manufacturers to utilize the CTL Registry include:

- If you participate in EPEAT, you are already registered! By signing in to the CTL Registry, your basic contact information as well as all EPEAT-registered models will automatically be transferred without duplicative data entry.
- By supplying additional information on your currently registered EPEAT products, you are satisfying the following EPEAT Criterion:
    - 4.3.1.1 Identification of materials with special handling needs

      For all covered products manufacturer shall provide ***treatment information*** to reuse and recycling facilities that identifies materials with special handling needs. This requirement addresses non-standard or new substances and technologies that would not be expected to be well-known to reuse and recycling operators.
- By utilizing the CTL Registry, your company is also responding to a requirement in the Washington Electronics Recycling law[13] regarding communication of design for recycling information to recyclers:
    - **"Design for recycling**: A description of how the plan participants will communicate and work with processors used by the plan to promote and encourage the design of electronic products that are less toxic and contain components that are more recyclable.[14]"
- Use of the CTL Registry also demonstrates your commitment to proper end of life reuse and recycling, as well as your company's willingness to go beyond compliance in providing information about the environmental attributes of your products.

A key group of manufacturers will be recruited to pilot the data entry system of the prototype, recommendation improvements, and be highlighted as the early adopters. Once a critical mass of manufacturers has entered data in the CTL Registry, it can be marketed to recyclers and other EOL managers.

Longer-Term CTL Registry Services

Over the long term, the CTL Registry can be expanded to include more product categories and other data elements of interest. Initially, product scope will only expand as EPEAT adds categories to its list. Other product categories could be added in the future separately from incorporation into EPEAT, but this will involve restructuring the database to allow product model input. As explained below, the CTL Registry will be managed by an active stakeholder group that may provide suggestions on additional product categories and data elements.

[13] http://apps.leg.wa.gov/RCW/default.aspx?cite=70.95N&full=true
[14] Language on requirement for "plan participants," or covered manufacturers under the Washingont law, taken from final version of regulations found at: http://www.ecy.wa.gov/pubs/0707042.pdf

As became clear in interviews with EOL managers for the Closing the Loop project, many see the use of RFID as a key information communication tool in the future. RFID tags at the product, or even component, level would greatly enhance the ability to efficiently identify materials of concern and prevent inadvertent mishandling. Instead of relying on line-of-sight barcode identification, RFID tags could allow a recycling operation to scan all equipment in a Gaylord, for example, and determine if a hazardous substance is present. However, as RFID tags do not contain information embedded within the tag, they must point or refer to an external database. The utility of the RFID tags for design for recycling purposes will depend upon the quality of the database. The CTL Registry offers the opportunity to build a robust database of direct manufacturer information that can later be incorporated into larger RFID databases when this technology is incorporated at the product or component level.

Management Strategy

The core management team will consist of the NCER and GEC, and their respective staffs. The two organizations have experience in managing similar web-based databases and a manufacturer registration process. The two organizations will work cooperatively to develop a management strategy utilizing initially one primary IT services provider support database development and improvements.

Two potential scenarios exist for the future management of the CTL Registry. First, the CTL Registry could be made an official, but voluntary, extension of the EPEAT database. GEC would notify EPEAT manufacturers of its availability and purpose, and let manufacturers input data to fulfill one of their EPEAT requirements. Manufacturers would access the CTL Registry data input screen from the main EPEAT website without logging in to a separate site. An alternative second option is to keep the database separate from EPEAT, but functionally integrated at the back end. That is, the CTL Registry would be hosted on its own web page, and manufacturers would need to separately log in to input their data. Product information from the EPEAT database would be transferred to the CTL Registry to prevent duplicative data entry. NCER and GEC would work to engage stakeholders on the content and functionality of this database separately from the EPEAT standards development process.

Organizational Strategy

The CTL Registry will be managed cooperatively by two existing organizations, NCER and GEC.

Pricing Strategy

Customers of the CTL Registry would initially be manufacturers and EOL managers. The most likely source of revenue in the short term would be manufacturers looking for a compliance service for EPEAT and state requirements. As manufacturers are already paying annual subscription fees for EPEAT, the initial pricing strategy will be to charge manufacturers a separate, voluntary add-on fee for access to the CTL Registry service.

Over time, EOL managers could also be added as a potential source of revenue with a unique pricing structure. The CTL Registry will always have a component of data that is publicly available, but a specific service of customized reports could be offered to recyclers and other EOL managers. Some flexibility may need to be incorporated as some EOL managers might want to customize this service such that they can interface with their own proprietary in-house software.

Communications Strategy

The initial communications will be targeted towards individual manufacturer participants in EPEAT. It is critical that the CTL Registry gain their acceptance and participation first before marketing the Registry to other stakeholder groups. Once a critical mass of data has been provided by manufacturers, communications in the form of press releases and earned media news articles in trade publications will announce the availability of the CTL Registry to recyclers and other members of the public.

Timeline

- *1st Quarter 2009:* Identify and recruit 5-10 manufacturers for testing, improvements, and input of data into CTL Registry
- *2nd Quarter 2009:* Announce availability CTL Registry to all EPEAT-registered manufacturers, incorporate pricing for service
- *3rd Quarter 2009:* Implement communications strategy to EOL managers, enlist EOL manager input on potential services/reports to be derived from CTL Registry
- *4th Quarter 2009:* Evaluate feedback and usage of CTL Registry, plan for improvements in 2010, and changes to pricing structure

Financing

The initial rollout of the CTL Registry will require seed funding. Much of the work for the development of the prototype database has been funded by the CTL Project grant. The grant has enabled the creation of the database structure to incorporate feedback based on findings from the CTL research.

Financing will be required to support the maintenance and improvements to the database structure via an IT services vendor, and administrative support for outreach to the initial group of manufacturers. The seed funding is estimated to be $50,000 for 2009. Options for the seed funding include additional government grants or "founding member" fees for the initial group of participating manufacturers.

Major Issues/Uncertainties and Planned Response

Issue: The data for EPEAT registered products will be of marginal utility to recyclers since it only applies to products placed on the market today.

> *Response: It is difficult obtain data directly from manufacturers on the location of these materials for current products, but nearly impossible for historic products coming into the recycling stream today. Since the initial focus is on IT products registered in the EPEAT database, and IT products have relatively shorter lifespans than consumer electronic products, this will be a temporary issue. Over time, recyclers will see more products from the CTL Registry entering their facilities.*

Issue: Manufacturers provide extremely basic information, such as a boilerplate listing of mercury lamps in all LCD products.

> *Response: While the input of all the data fields in the CTL Registry is voluntary, manufacturers who wish to use the CTL for compliance with EPEAT or state laws will need to prove that they are satisfying the requirements. Managers of the CTL Registry will be in contact with state and EPEAT officials regarding submissions that are incomplete or do not meet the intent of the CTL Registry mission.*

6.0 Summary of Findings and Recommendations

6.1 Overview of Product Design-for-EOL Recommendations

This study yielded a great amount of information about product design from the perspectives of EOL managers. The research team will provide the product design findings and recommendations to upcoming EPEAT standard development working groups for their consideration in developing EPEAT criteria for new and revised standards.

The findings are applicable to EPEAT criteria in two primary environmental performance categories: 1) design for EOL; and 2) product longevity and life cycle extension. The product design recommendations could be incorporated in EPEAT in two ways; either developed into new criteria or used to improve existing criteria.

Based on the input of EOL managers, several product design recommendations were identified as most important for EOL management. These product design recommendations include:

- To make triage more efficient: Communications mechanisms that yield data "at the dock" for EOL managers to quickly identify key information about products such as age, power and functionality performance features, and internal components. The tools for accomplishing this should keep pace with advancing communications technology. In the near term, there could be systematic number sequences on product ID codes providing useful information based on pre-determined characters in each position. Bar code identification, or in the future RFID technology, can provide the same data more efficiently, using hand-held or other devices to read useful information directly into "at the dock" intake databases.
- To ease disassembly/assembly, refurbishment and resale, and demanufacturing into subassemblies and components: Use of a consistent, limited and uniform set of screws and fasteners, no hidden screws and fasteners, no injection-molded fasteners. Note that this recommendation may require harmonization of design, and is therefore included in Section 6.2 below on initiating working groups to develop workable and agreeable voluntary harmonization.
- To enhance reuse, refurbishment and resale: Design for longer life span of components through more durable and interchangeable parts and other strategies.
- To enhance reuse, refurbishment and resale: Standardize power supplies, particularly for portable equipment; despite variation in voltage and amps, have consistent plugs and jacks; uniform cords would enable much more reuse. Note that this recommendation may

also require harmonization of design, and is therefore included in Section 6.2 below on initiating working groups to develop workable and agreeable voluntary harmonization.

- To reduce hazardous material impacts: Depollution was by far and away the highest priority product design area identified during this study. Specific design recommendations were highlighted in both identification and ease of removal of components containing hazardous materials, as well as elimination of hazardous substances including:
    - External marking indicating the presence and location of components containing hazardous materials
    - Color coding all components containing hazardous materials, in particular small batteries
    - Design these components to be extremely easy to pull out, using cartridge-style housing that snaps, pulls or slides in and out readily
    - Components containing hazardous materials located within "line-of-sight" spotting when external housing is removed
    - Elimination of intentionally added mercury used in light sources, beryllium in connectors, and BFRs and other halogenated substances

  This recommendation is also included in Section 6.2 below; a working group could develop workable and agreeable voluntary harmonization design strategies and solutions in this area.

- To enhance materials separation: Develop a consistent and limited set of resins to be used, or at least a limited number of different resins per product category. Managing plastics was identified as EOL manager's greatest challenge with regard to materials separation. Using a limited number of different resins per product category and/or adhering to a limited set of resins would enhance EOL managers' ability to separate and market plastic materials.
- To enhance materials separation: Eliminate laminated, bonded, glued, and/or molded-together dissimilar materials, including stickers and labels (materials separation).
- To enhance materials recovery and system efficiency: The study found that the case could be made for two different fundamental design/EOL management scenarios (discussed in detail in Section 4.0). The overall structure of EPEAT 1680 DfEOL criteria could be reconsidered in light of this two-scenario EOL paradigm, such that products could be designed to optimize EOL value through the two recovery scenarios, each with a corresponding set of EPEAT criteria.

6.2 Recommendations for Future Research

The Close the Loop Project has found very fertile ground in exploring the issue of how electronic product design, and the communication of design for EOL features, can enhance the economic viability and environmental sustainability of the EOL management of electronics. During the research, three areas have surfaced for further work that have substantial potential to increase the life-cycle environmental profile of electronics by enhancing business opportunities for end-of-life managers.

- **Recommendation #1 – Refinement of Performance Measurement Parameters for Existing Eco-Label and EPEAT Criteria.** Several of the design-for-EOL recommendations developed in this project, and including criteria in existing eco-labels such as EPEAT, need to be refined and, in some cases quantified. The necessary refinement includes agreement on specific definitions and measurements that are critical in assuring that certain environmental criteria are meaningfully met.
- **Recommendation #2 – Development of Standards for Environmental Design Elements that could be Harmonized Across Products, Brands, and Even Generations**. This includes the development of technical industry standards that define, for electronics manufacturers, methods to harmonize specific design features of their products. The goal is to harmonize – across a broad range of products, brands and generations – design features that are especially critical for the environmental performance of the EOL system, including product life extension, refurbishment and reuse, and recycling. Once developed, stakeholders in future EPEAT work groups could choose to include criteria referencing these technical industry standards.
- **Recommendation #3 – CtL Registry Implementation and Expansion.** A web-based information resource that was designed and developed at a prototype level as part of this Close the Loop project. This tool needs to be expanded and implemented into a fully functioning information exchange system.

Recommendation #1 – Refinement of Performance Measurement Parameters for Existing Eco-Label and EPEAT Criteria

Several of the design-for-EOL recommendations developed in this project need to be further refined and, in some cases quantified for inclusion in design standards. It will require a small but diverse stakeholder group, with broader input from others, to develop some of these definitions/measurements. These differ from Recommendation #2, in that the necessary refinement includes agreement on definitions and measurements, as opposed to harmonization of design elements – and thus can likely be accomplished though a much more streamlined process.

Examples may include:

- Eco-label criteria often prescribe that certain items be "easily identifiable" (for hazardous items), "easily removable," or "easily separable". The important principle of "easily" needs to be quantified into a time measure, a disassembly step measure, a use of tool measure, or some other measurable and verifiable criterion.
- Eco-label criteria often prescribe that reference items that are above, or below, a certain size or mass have certain characteristics, such as removability, recyclability, marking of material type, made of a single resin, etc. The thresholds for each of these needs to be quantified into a mass or size measure that is both practical and environmentally responsible from a recycler's perspective.

- Eco-label criteria often prescribe a reduced number of plastic resins. This is a highly subjective measure and it is essential to define "reduced" for both advice to designers and for eco-label verification.
- Eco-label criteria often prescribe a percent "recyclability". It will be important to quantify and further define all the measurable parameters of "recyclability" that can be used in eco-label criteria.

Recommendation #2 – Development of Standards for Environmental Design Elements that Could be Harmonized across Products, Brands, and even Generations

Whereas Recommendation #1 requires engagement of a fully diverse set of stakeholders, this project is more focused on design technicalities and would thus be more focused on industry representatives including product designers and stewards, while soliciting, of course, input from other key stakeholders especially EOL managers. Working groups would be convened, either directly by the team, or, more likely, through interested industry organizations and organizations. These groups would develop workable and technically sophisticated design standards to accomplish at least two of the four key challenges identified below. Some elements of this project may build on definitions and metrics established in Recommendation #1:

1) Harmonization of Power Supplies for Computers and Possibly Other Electronics

The customization of power supplies is a huge challenge for refurbishment and reuse organizations. Power cords often get separated from units and finding the correct power supply is often a time-consuming or costly effort, due to lack or harmonization and variation in voltage, amps, and plugs. The purpose of this working group would be to establish more uniformity, interchangeability, and/or adaptability in power supplies.

2) Enhancement of Cross-Brand and Cross-Generational Component Compatibility

The reuse and asset recovery sector is significantly hampered by the difficulty of obtaining replacement parts and the lack of component compatibility. Product uniqueness is increasing as OEMs seek to distinguish their products in a market flooded with high technology. This results in reduced availability of replacement parts, diminished adaptability of spare parts for repair or refurbishment, and increased cost to source spare parts for repair or refurbishment. A workgroup would explore the options for developing guidelines for components that could be used both cross-generationally and cross-brand.

3) Clearer Identification and Removal of Components and Parts containing Hazardous Substances

In all EOL management scenarios, it is critical to be able to safely but quickly identify and remove parts and components that contain hazardous substances, such as batteries, mercury-containing lamps, plastics with brominated flame retardants or polyvinyl chloride, and toners. Because RoHS allows exemptions for certain items, the need for depollution will continue. The first challenge facing an EOL manager is to identify components containing hazardous substances, which are often hidden or otherwise not obvious when the housing is removed. Color coding of items in highly visible colors, markings to indicate presence of hazardous substances, and other strategies should be developed to ensure enhanced protection of human health and the environment during the EOL stage. Further, rapid and easy methods to remove such parts, without causing dispersion of the hazardous substances, are critical. The purpose of this working group would be to establish some basic principles and methods for how parts containing hazardous substances can be identified and removed from electronic products before intensive processing.

4) Harmonization of Connection Mechanisms

One of the most common complaints heard from EOL managers during this research is the use of an unnecessarily large variety of different types of screws and fasteners which greatly impacts the efficiency of EOL management. EOL managers expressed a strong desire for use of a consistent, limited and uniform set of screws and fasteners. The purpose of this working group would be to explore agreement on a consistent, limited and uniform set of screws and fasteners.

Recommendation #3 – CTL Registry Implementation and Expansion

The development of the prototype information system into a fully functioning information exchange would focus on implementation and expansion of the prototype web-based resource. Specifically:

1) **Begin first phase of business plan by forming manufacturer committee for input, testing, and final integration into EPEAT**

   As the CTL Registry is currently in prototype form, there is still a need for manufacturers and others to test and modify the functionality before it is fully integrated as an extension of the EPEAT database. NCER will identify and recruit 5-10 manufacturers for testing, improvements, and input of data into CTL Registry.

2) **Announce availability of CTL Registry to all EPEAT-registered manufacturers, populating database with manufacturer input, and then announcing availability of data to EOL managers**

   The next step after final integration is to populate the database with a critical mass of data points from manufacturers. The Registry can then be marketed as a useful tool to EOL managers.

3) **Incorporate ability for direct communications between EOL managers and product designers**

   This activity will incorporate into the system a website for EOL managers to provide targeted feedback on design challenges can be directed to individual manufacturers anonymously.

6.3 Ideas for Future Research from StEP - for Discussion Purposes

Solving the E-Waste Problem (StEP) is an initiative of various United Nations organizations with the overall aim to solve the e-waste problem. Together with members from industry, governments, international organizations, NGOs and the science sector actively participating, StEP is working to initiate and facilitate approaches towards the sustainable handling of e-waste.

Following a review of the discussion draft of this report, StEP submitted the following ideas for future research:

1) Conduct a parallel study within the European Union. The composition of the EU EOL infrastructure is somewhat different from the infrastructure within U.S. The U.S. system may be headed more towards that of the EU, though it is much unknown. However, given that possibility, it would be beneficial to gain the insight of EU EOL managers. This effort could be conducted directly with the European StEP members.
2) Conduct a similar research project on DfEOL, focusing on the informal electronics recycling sector in geographies such as China, India and/or Africa. This research would assess how design could reduce impacts to human health and the environment during informal recycling.
3) Work with EOL managers to develop photo documentation on "Bad Design - Good Design". This would guide product developers on how to improve DfEOL. This effort could be expanded to a training for electronic product designers.
4) Engage with, or track, a soon to launch research project (ZeroWIN) in the EU with the University of Limerick, HP and others to investigate DfEoL criteria for LCD products.

[DISCUSSION DRAFT]

111TH CONGRESS
1ST SESSION

H. R. ____

To authorize the Administrator of the Environmental Protection Agency to award grants for electronic waste reduction research, development, and demonstration projects, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

Mr. introduced the following bill; which was referred to the Committee on

A BILL

To authorize the Administrator of the Environmental Protection Agency to award grants for electronic waste reduction research, development, and demonstration projects, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Electronic Waste Research and Development Act".

SEC. 2. FINDINGS.

Congress finds the following:

(1) The volume of obsolete, broken, stored, or discarded electronic devices, known as electronic waste, is substantial and will continue to grow. The Environmental Protection Agency estimates that over 2 billion computers, televisions, cell phones, printers, gaming systems, and other devices have been sold since 1980, generating 2 million tons of unwanted electronic devices in 2005 alone.

(2) Electronic waste can be refurbished or recycled to recover and conserve valuable materials, such as gold, copper, and platinum. However, according to the Environmental Protection Agency, only 15 to 20 percent of household generated electronic waste reaches recyclers.

(3) The electronic waste recycling industry in the United States is growing; however, challenges remain for the recycling of electronic waste generated by households and other small generators. Collection of the electronic waste is expensive, and separation and proper disposal of some of the materials recovered, like lead from cathode-ray tube televisions, is costly.

(4) The export of electronic waste to developing countries also presents a serious challenge. The crude methods of many of the recycling operations

these challenges and help reduce the burden of electronic waste on the environment.

(5) The public currently does not take full advantage of existing electronic waste recycling opportunities. Studying factors that influence behavior and educating consumers about electronic waste could help communities and private industry develop recycling programs that draw more participation.

(6) The development of tools and technologies to increase the lifespan of electronic devices and promote their safe re-use would decrease the impact of electronics production and disposal on the environment.

(7) Accurately assessing the environmental impacts of electronics production and electronic waste recycling is a complex task. Data and tools to better quantify these impacts would help policymakers and others determine the best end-of-life management option.

SEC. 3. DEFINITIONS.

For the purposes of this Act:

(1) ADMINISTRATOR.—The term "Administrator" means the Administrator of the Environmental Protection Agency.

(2) CONSORTIUM.—The term "consortium" means a grant recipient under section 4(a) that includes—

(A) at least one institution of higher education, non-profit research institution, or government laboratory; and

(B) at least one for-profit entity, including a manufacturer, designer, refurbisher, or recycler of electronic devices or the components of such devices.

(3) DIRECTOR.—The term "Director" means the Director of the National Institute of Standards and Technology.

(4) ELECTRONIC WASTE.—The term "electronic waste" means obsolete, broken, or discarded electronic devices, including computers, computer monitors, televisions, laptops, printers, cellular phones, copiers, fax machines, stereos, video gaming systems, and the components of such devices.

(5) INSTITUTION OF HIGHER EDUCATION.—The term "institution of higher education" has the meaning given such term in section 101(a) of the Higher Education Act of 1965 (20 U.S.C. 1001(a)).

SEC. 4. ELECTRONIC WASTE ENGINEERING RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROJECTS.

(a) IN GENERAL.—The Administrator shall award multiyear grants to consortia to conduct research to create innovative and practical approaches to reduce and manage electronic waste and, through the conduct of this research, to contribute to the professional development of scientists, engineers, and technicians in the fields of electronic device manufacturing, design, refurbishing, and recycling. The research areas supported under this section shall include—

(1) technology to increase the efficiency of electronic waste recycling;

(2) expanded uses for materials recycled from electronic waste;

(3) development and demonstration of green alternatives to the use of hazardous materials in electronic devices and the production of such devices;

(4) development of methods to separate and remove hazardous materials from electronic waste and to recycle or dispose of such materials in a safe manner;

(5) product design and construction to facilitate disassembly and recycling of electronic waste;

(6) tools and methods to aid in assessing the environmental impacts of the production of electronic devices and electronic waste recycling and disposal;

(7) product design and construction and other tools and techniques to extend the lifecycle of electronic devices, including methods to promote their safe re-use; and

(8) strategies to increase consumer acceptance and practice of recycling of electronic waste.

(b) MERIT REVIEW; COMPETITION.—Grants shall be awarded under this section on a merit-reviewed, competitive basis. [The reviewing body shall be composed of subject matter experts and related industry representatives.]

(c) APPLICATIONS.—Applications shall be submitted by a consortium to the Administrator at such time, in such manner, and containing such information and assurances as the Administrator may require. The application shall include a description of—

(1) the research project that will be undertaken by the consortium and the contributions of each of the participating entities, including the for-profit entity;

(3) the applicability of the project to reduce electronic waste in the electronic device design, man-

ufacturing, refurbishing, or recycling industries and the potential for and feasibility of incorporating the research results into industry practice; and

(2) how the project will promote collaboration among scientists and engineers from different disciplines, such as electrical engineering, materials science, and social science.

(d) DISSEMINATION OF RESEARCH RESULTS.—Research results shall be made publicly available through—

(1) development of best practices or training materials for use in the electronics manufacturing, design, refurbishing, or recycling industries;

(2) dissemination at industry conferences;

(3) demonstration projects; and

(4) educational materials for the public produced in conjunction with State and local governments or non-profit organizations on the problems and solutions related to electronic waste.

(e) FUNDING CONTRIBUTION FROM FOR-PROFIT MEMBER OF CONSORTIUM.—The for-profit entity participating in the consortium shall contribute at least 10 percent of the total research project cost, either directly or with in-kind contributions.

(f) AUTHORIZATION OF APPROPRIATIONS.—There are authorized to be appropriated to the Administrator to carry out this section:

(1) $ [______] for fiscal year 2010.

(2) $ [______] for fiscal year 2011.

(3) $ [______] for fiscal year 2012.

(4) $ [______] for fiscal year 2013.

(g) BIANNUAL REPORT.—Within 2 years after the date of enactment of this Act, and every 2 years thereafter, the Administrator shall provide a list of the grants awarded under this section, the entities participating in each consortium receiving a grant, and a description of the research project and results funded by such grant.

SEC. 5. NATIONAL ACADEMY OF SCIENCES REPORT ON ELECTRONIC WASTE.

(a) IN GENERAL.—The Administrator shall enter into an arrangement with the National Academy of Sciences for a report, to be transmitted to the Congress not later than 1 year after the date of the enactment of this Act, on opportunities and barriers to reducing electronic waste, reducing the use of hazardous materials in the manufacture of electronic devices, and designing electronic devices to facilitate re-use and recycling.

(b) SPECIFIC REQUIREMENTS.—The Administrator shall ensure that the report described in subsection (a) addresses—

(1) the opportunities for and barriers to—

(A) recycling or safe disposal of electronic waste;

(B) reducing the use of hazardous materials in electronic devices;

(C) the sale and re-use of electronic devices; and

(D) the recycling of electronic devices or components; and

(2) the current status of research and training programs to promote the environmental design of electronic devices to reduce electronic waste.

SEC. 6. ENGINEERING CURRICULUM DEVELOPMENT GRANTS.

(a) GRANT PROGRAM.—The Administrator shall award grants to reduce electronic waste to—

(1) institutions of higher education to develop curricula in environmental design that will be used for the training of electrical, mechanical, industrial, manufacturing, materials, and software engineers and other students at the undergraduate and graduate level; and

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(2) [community colleges] to support the continuing education of professionals in the electronic device manufacturing, design, refurbishing, or recycling industries about the environmental design of electronic devices.

(b) MERIT REVIEW; COMPETITION.—Grants shall be awarded under this section on a merit-reviewed, competitive basis.

(c) USE OF FUNDS.—Grants awarded under this section shall be used for activities that enhance the ability of an [institution of higher education] to broaden undergraduate and graduate-level engineering curriculum to include green engineering design principles and consideration of product life cycles. Activities may include—

(1) developing and revising curriculum to include multi-disciplinary elements;

(2) creating research and internship opportunities for students through partnerships with industry, non-profit organizations, or government agencies;

(3) creating and establishing certificate programs; and

(4) developing curricula for short-courses and continuing education for professionals in the environmental design of electronic devices.

(d) APPLICATION.—[An institution of higher education] seeking a grant under this section shall submit an application to the Administrator at such time, in such a manner, and with such information and assurances as the Administrator may require.

(e) AUTHORIZATION OF APPROPRIATIONS.—There are authorized to be appropriated to the Administrator to carry out this section:

(1) $__________ for fiscal year 2010.

(2) $__________ for fiscal year 2011.

(3) $__________ for fiscal year 2012.

(4) $__________ for fiscal year 2013.

SEC. 7. "GREEN" ALTERNATIVE MATERIALS PHYSICAL PROPERTY DATABASE.

(a) IN GENERAL.—The Director shall establish an initiative to develop a comprehensive physical property database for "green" alternative materials for use in electronic products.

(b) PRIORITIES.—The Director, working with the [private sector/industry], shall develop a [roadmap] to establish priorities and the physical property characterization requirements for the "green" database.