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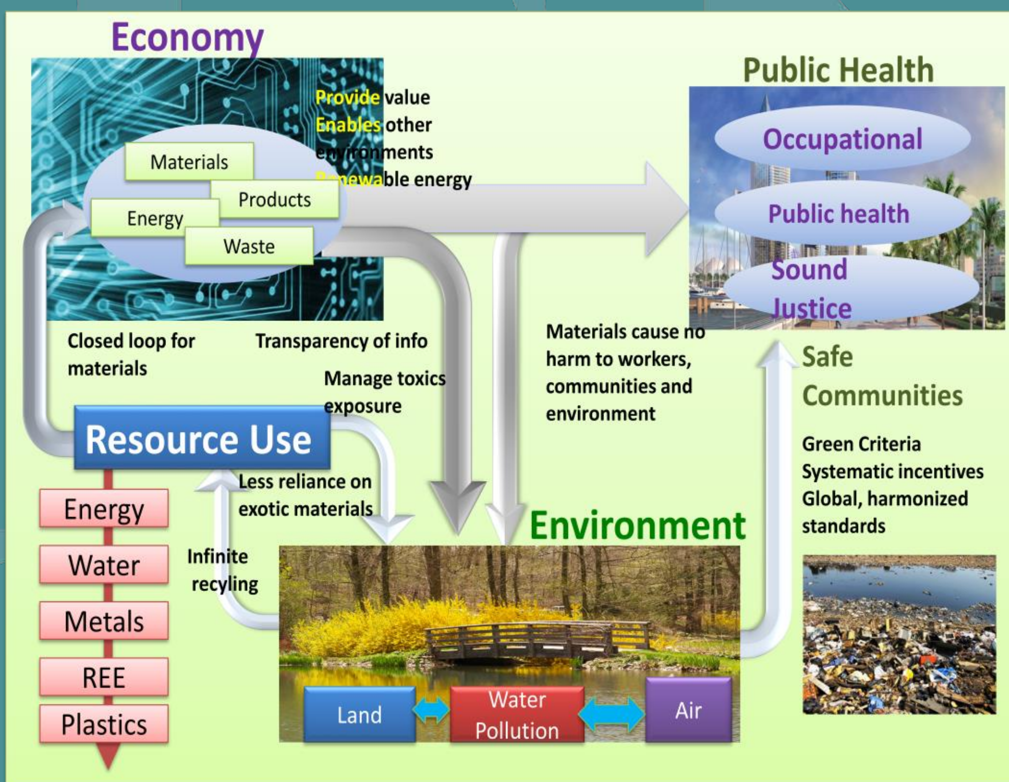
Sustainable Electronics Roadmap



Office of Research and Development
National Risk Management Research Laboratory
Sustainable Technology Division
Cincinnati, OH 45268

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November 2013

Sustainable Electronics Roadmap

Sustainable Electronics Forum

October 15-18, 2012
The Johnson Foundation at Wingspread
Racine, WI

by

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Disclaimer

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Table of Contents

ACRONYMS AND ABBREVIATIONS

BFRs	Bromine-free flame retardants
CAD	Computer- Aided Design
CARE	Comprehensive Approach for the Resource-and Energy-Efficiency
DfE	Design for the Environment
DOE	Department of Energy
DRC	Democratic Republic of the Congo
EGG	Electronics Goes Green
EICC	Electronic Industry Citizenship Coalition
EOL	End of Life
EPA	Environmental Protection Agency
EPEAT	Electronic Product Environmental Assessment Tool
EU	European Union
GEC	Green Electronics Council
H&S	Health and Safety
HR	Human Rights
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ILO	International Labor Organization
iNEMI	International Electronics Manufacturing Initiative
ISMI	International Semiconductor Manufacturing Technology Initiative
LCA	Life Cycle Analysis
LCA	Life-Cycle Assessment
NAS	National Academy of Sciences
NGO	Nongovernmental Organizations
NIES	National Institute for Environmental Studies
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Science and Technology

NRMRL	National Risk Management Research Laboratory
NSES	National Strategy for Electronic Stewardship
OCSPP	Officer of Chemical Safety and Pollution Prevention
OECD	Organization for Economic Cooperation and Development
OEMS	Original Equipment Manufacturers
ORD	Office of Research and Development
OSHA	Occupational Safety and Health Administration
PELs	Permissible Exposure Limits
PGMs	Platinum Group Metals
PRTR	Pollutant Release and Transfer
RELs	Recommended Exposure Limits
RIT	Rochester Institute of Technology
RoHS	Restriction of Hazardous Substances
SAICM	Strategic Approach to International Management
SCG	Scientific Consulting Group
SEC	Securities and Exchange Commission
SIN	Substitute It Now
SMART2020	SMART2020 refers to a solution that uses digital components or communications, such as computer networked devices or components that allows users to make decisions based on new information, automation or system optimization.
STAR	Science to Achieve Results
SUS	Single-Use System
TJF	The Johnson Foundation at Wingspread
TRI	Toxics Release Inventory
UK	United Kingdom
UNEP	United Nation Environmental Program
WHO	World Health Organization

PART I

1. Executive Summary

1.1 Overview

The U.S. Environmental Protection Agency (EPA), Office of Research and Development (ORD), National Risk Management Research Laboratory (NRMRL), in cooperation with The Johnson Foundation at Wingspread (TJF) and the Green Electronics Council (GEC), convened a Sustainable Electronics Forum to address major research challenges, policy issues and opportunities facing the management of electronic products. The Forum brought together a small group of recognized leaders in electronics design, materials, manufacturing and recycling, to develop a shared vision and technology roadmap for sustainable electronics. In addition, the group was asked to produce specific recommendations for research agendas, standards and design challenges; and accelerate green electronic voluntary initiatives. Participants included recognized experts in the fields of eco-design and green supply chain management; optimum life-cycle utilization; and recycling and sustainable waste management. Attendees represented a broad range of perspectives from government, academia, nongovernmental organizations (NGOs) and industry.

The number and variety of electronic technologies have been growing rapidly the past four decades. Americans own more than three billion electronic products that have become critical to their way of life and the growing economy. However, as the average use-life of electronic products gets shorter, obsolete products are stored or discarded at alarming rates. This creates new challenges in the management of electronic products. Approximately two-thirds of the electronic devices removed from service remain functional. Although E-waste represents only two percent of America's trash in landfills, it contributes 70 percent of all toxic waste. Most electronic products contain hazardous heavy metals, plastics, brominated flame retardants, barium, beryllium and valuable elements such as precious metals and rare earth elements. The human health risks associated with placing such products into landfills or incinerators where these hazardous elements can enter the air and water streams are high. Hence, there is an increasing challenge of reducing the use of virgin materials, recovering useful elements from the waste, and protecting human health and the environment from the harmful effects associated with the unsafe handling and disposal of these products (*National Strategy for Electronic Stewardship, NSES)*.

Electronics design and manufacturing that is innovative, flexible and pragmatic could transform the industry's energy savings, reduce emissions and conserve resources. Scientific research and technological developments are needed for the design of greener electronics that minimize environmental impacts across the entire lifecycle of the products and promotes consumer awareness. Innovative solutions that integrate electronics manufacturing and recycling would allow Americans to sustainably manage the electronics used today while simultaneously promoting novel and innovative technologies of the future to meet market challenges *(NSES*).

1.2 Sustainable Electronics Forum

EPA, in cooperation with The Johnson Foundation at Wingspread (TJF) and the Green Electronics Council (GEC), convened a Sustainable Electronics Forum (referred to as "the Forum" in this report) held October 15-18, 2012, to address major research challenges, policy issues and opportunities facing the management of electronic products. The Forum brought together a small group of recognized leaders in electronics design, materials, manufacturing and recycling, to develop a shared vision and technology roadmap for sustainable electronics; produce specific recommendations for research agendas, standards and design challenges; and accelerate green electronic voluntary initiatives.

The Forum employed a "futures" approach to develop a shared vision of the challenges and opportunities ahead for sustainable electronics. Discussions progressed toward the development of a Sustainable Electronics Roadmap as an outcome that articulates the collaborative vision of the group and details methods by which sustainability objectives can be achieved.

1.3 Forum Objectives

Specific objectives of the Forum were to:

- Develop a shared vision of the appearance of truly sustainable electronics and provide clear end-goals for design standards development.
- Promote the integration of end-of-life considerations into front-end product designs.
- Discuss methods to extend the useful life of electronic products and assess the optimal amount of time to keep products in operation.
- Support the creation of environmental criteria for refurbished equipment.
- Address other high-priority questions and challenges identified by the stakeholder community.

1.4 Sustainable Electronics Vision

In order to create a shared overall goal for the roadmap, participants worked together to develop a high-level vision that considers the future of sustainable electronics. During the visioning process, meeting facilitators from Forum for the Future presented four alternate scenarios for the future of technology. Participants were asked to discuss what a sustainable information and communications technology (ICT) industry would look like in each scenario. Bringing together the common themes from each of these different scenarios allowed the group to shape the attributes of a sustainable ICT industry and draft the following high-level vision statement:

Vision Statement

Sustainable ICT will enable us to protect and enhance human health and well-being and the environment over generations while minimizing the adverse life-cycle impacts of devices, infrastructure and services.

The group used the Sustainable Economy Framework developed by Forum for the Future that defines the characteristics of a sustainable economy- one that operates within safe environmental limits and enriches people's lives. The sustainable economic framework expands this vision for particular social and environmental constraints, including greenhouse gas emissions and human rights; and considers the actions that would be needed to deliver on the vision statement. This was the first step in developing the roadmap themes based on the vision statement.

1.5 Next Steps

The Forum organizers expressed appreciation for all of the participants' time and effort in developing the initial framework for the Sustainable Electronics Roadmap. The important sustainability themes and concepts identified at the Forum will need to be further refined and prioritized. This roadmap is a dynamic document that will be reevaluated periodically to incorporate new market and technical information. Participants suggested using an online forum to continue discussions and to ensure that research priorities keep pace with the needs of both the electronic industry and the stakeholders. Ultimately, the roadmap will guide the electronics industry toward a sustainable future.

2. Introduction

This background briefing presents key themes and viewpoints raised during research and interviews with stakeholders. Any opinions expressed herein should not be attributed to either Forum for the Future, The Scientific Consulting Group, Inc., or the U.S. Environmental Protection Agency (EPA).

2.1. Issues and trends that will contribute to a sustainable electronics industry

There are macro-level changes that drive increased demand and competition for resources. The global middle class will grow to four billion people in the next 30 to 40 years. As emerging economies get wealthier, we will see increased demand for consumer products, electronics and consequently, an increase in the demand for raw materials. Increasing numbers of affluent consumers will drive intangibles such as ease-of-use, safety and design. As resource demands grow, we will see increased competition for resources. The way that scarce natural resources, including rare earth minerals, will be apportioned among countries could have far-reaching impacts on the electronics industry. These trends will combine to create business advantages from sustainability, including minimization of raw material use, effective take-back and raw material recovery programs.

Energy prices will affect both the manufacturing and use of electronics, so we need to focus on the total energy footprint at all scales- from cloud computing servers to handheld devices. As energy prices increase, the pressure to deliver products with improved energy efficiency will also increase, despite any added features and functionality. As cloud computing has grown exponentially, there are a number of claims about potential energy savings from this shift to the cloud. The environmental impact of cloud computing, including potential energy savings has yet to be fully ascertained and may become an increasingly important part of the agenda

- *Innovation in materials and product design*

Driven by the rapid pace of technological improvements, consumer demand and lack of modularity leads to a large number of devices becoming rapidly obsolete. This issue will only increase as consumer demand in emerging economies surges. Modularity, along with a potential shift from a product model to a service model with upgradeable components, could offer solutions in the future. These solutions will be fully realized where there is intelligent integration of systems across the supply chain. This involves linking designers, component manufacturers, recyclers and smelters together to fully optimize the product and its resources.

The desire for light, small and energy-efficient electronics needs to be balanced with devices less recyclable and having shorter lifespans. Miniaturization increases computational efficiency, but not necessarily per unit energy use. Any benefit also has risks.

Increased interest and sophisticated application of biomimicry will impact the electronics industry in the coming years and may lead to a range of new devices (many of which may be micro-devices), and new applications of technology. Some of these applications may have far-reaching and unpredictable impacts on people and the environment.

The rapid pace of technological advancement offers a host of opportunities for better and more efficient devices, yet can also lead to manufacturing changes and the potential for increased waste in manufacturing. New technologies (e.g., green chemistry) minimize hazardous materials and can help manufacturers move away from unsafe materials in production and whole lifecycles. Currently, the Organization for Economic Cooperation and Development has a sustainable materials management program. Similar initiatives could help preserve natural capital, reduce use of toxic materials and increase the use of recyclable materials.

2.2 Opportunities and barriers to achieving a sustainable electronics industry

Longer term trends combine with current activities to create risks as well as opportunities to achieving a sustainable electronics industry. There are a several areas where additional research and knowledge are needed for the industry to make sustainable choices on materials, lifespan, energy optimization and other issues (Table 1). One key theme is moving from "back-end" (focusing on emissions) to "front-end" (resource consumption), by determining what will produce the maximum sustainability results given the limits of physics and money. Another theme is the huge barrier that current business models represent by making take-back schemes hard to fund and basing profits on high product turnover.

Table 1. Activities affecting the future of sustainable electronics.

Activities	Opportunities	Barriers/risks	Questions that should be addressed by research
Definitions of "green"	Better definitions about what makes specific electronics green will help purchasers distinguish products with less impact on the environment.		Set a clear definition for "green" and "sustainable." The research style needs to change from back-end (emissions) to front-end (resource consumption).
Definitions and harmonization	The global pocketbook can be used to drive change.	We currently lack international standards.	Need to determine what is most efficient at the component

Activities	Opportunities	Barriers/risks	Questions that should be addressed by research
of standards	EPEAT® is a good first step that could be used to create a global standard.	Standards do not keep pace with rapidly changing industry.	level. How can we harmonize and simplify standards, including making them accessible to consumers? Need integrated process and dynamic tools for real-time decisions about materials and products.
Life-Cycle Analysis **Life-Cycle Analysis (LCA) (continued)**	LCA offers many promising opportunities to achieve sustainable goals. Expanding knowledge in chemical analysis will enable better materials choices and minimization of toxic materials.	There are a number of gaps in LCA capacity (e.g., water footprinting has not been sufficiently addressed). There is a need to move beyond "one-factor" criteria. Industry tends to outsource chemical analysis to suppliers to meet performance goals. Original equipment manufacturers (OEMs) have insufficient internal knowledge.	Need to agree on the criteria for LCA and build consensus and alignment of criteria so that we have consistent threshold values. Need to address trade-offs in selecting materials. Need to address tension between lighter materials, toxicity, energy use, recyclability and lifespan of materials. Measurement of exposure throughout the lifecycle, including cell phone radiation.
Smart grids	Smart grids may offer opportunities for smaller electronics.	Brings a proliferation of small electronics, could increase overall	

Activities	Opportunities	Barriers/risks	Questions that should be addressed by research
		electricity use (e.g., if 10W connectivity 24/7) unless done right.	
Consumer demand	Global pocketbook can be used to drive change.	Insufficient demand from public at present; very small percentage of customers are willing to offset performance or price for "green" performance.	How can we enable consumers to make better decisions and change behaviors?
Device energy use **Device energy use (continued)**	With scaling, we can lower energy use when the device is not actively used and match power use to task.	We lack sufficient data on devices' energy use, currently focusing mainly on worst offenders. Always connected devices negate low standby power modes.	We need a framework for power scaling. Better data on types of devices, numbers, and energy use, especially pattern of use.
Move to handhelds	Miniaturization of devices can lead to reduced power demands and minimizes usage of raw materials.	Miniature devices can be more difficult to recycle.	What is the net impact on energy demand and usage from miniaturization?
Systems approach and collaboration **Systems approach and collaboration (continued)**	The issues and systems involved are complex and can best be addressed through collaborative approaches. Need to understand how chemistry research and innovations fit into the bigger picture of resource availability and systems thinking. Need to look at how all players in the supply chain can be mutually supportive	Industry secrecy makes collaboration difficult. Current standards do not sufficiently admit complexity. Currently very little intelligent integration of systems. The fast-paced nature of the sector makes standard setting difficult. Standards	Create opportunities for collaboration and address potentially competitive issues.

Activities	Opportunities	Barriers/risks	Questions that should be addressed by research
	to drive greater sustainability.	may not be able to keep pace with the rate of change.	
End-of-life (EoL) management, take back and recycling	Companies need product stewardship programs, advance leasing of products concept, enable "trading up" and resale of lower level models. Policies and tools to support this are needed. Need to educate consumers on EoL issues.	Developing national growth: challenge is to create recycling programs so they skip the West's throwaway consumerism. Lack of agreement is a barrier.	What is the best method to treat EoL processing and what is the role of OEM? How can we create recycling programs that enable us to overcome our "throwaway" consumerism model?
Data center energy usage	Data center energy usage has grown less than projections, in part due to greater realization of efficiencies than projected. Move to cloud could entail a number of energy saving benefits.	Data center usage is projected to continue to grow sharply and not enough is known about the real energy impacts.	How do we address risks associated with "Big Data"? Need more scientific research on the energy tradeoffs, impacts of move to cloud and increased data center usage. A research-based national plan for energy generation is important.
Modularity and service models	Shifting from a product model to a service model could enable significant savings on materials and maximize device utility.	Current trends are for thinner, lighter devices, not modularity.	Service models: research into possible viable models for providing upgradeable services and components rather than new devices. Need to understand where the evolutionary plateau

Activities	**Opportunities**	**Barriers/risks**	**Questions that should be addressed by research**
			is for different product categories.
Raw materials, including rare earth minerals	Miniaturization offers opportunities to minimize raw materials usage. Many currently used materials are recyclable, which can help minimize demand for mining of metals, etc.	With device proliferation, shorter life-spans and lighter, thinner devices that are less recyclable, resource demand is projected to continue to grow. Many deposits of rare earth minerals are in conflict-ridden areas.	What is the best way to minimize resource consumption, including copper, indium, tin, lithium, myobium and rare earth elements? What are viable alternative materials? To have a better understanding from both the supply and recovery side as to which materials are really most critical.
Supply chain **Supply chain (continued)**	There are significant savings opportunities from addressing energy consumption in the supply chain.	Many devices are manufactured in countries with poor safeguards and implementation of health and safety policies as well as environmental management. Despite some good attempts to track supply chain issues, much more needs to be done. Concerns over mining of conflict minerals.	The entire value chain from suppliers to customers must be considered.
Corporate reporting	Increased expectation of transparency is putting pressure on corporations to disclose more in their reporting.		Need to develop methodologies to be able to allow verifiable comparisons between companies and products.

2.3 What capacity, knowledge and skills does the electronics industry need to develop to be sustainable?

Factors influencing sustainable electronic industry include:

- *Building broad knowledge*

  Several interviewees expressed the need to build broad-based sustainability knowledge in the company. A subset of people will need detailed technical knowledge about LCAs and other processes; while a wider group simply needs to develop a general knowledge of sustainability concepts and trends.

- *Educating the supply chain*

  The supply chain needs a broader capacity in sustainability issues. When assessing the need for building knowledge, interviewees emphasized the importance of the entire value chain from suppliers to purchasers and customers. Companies need to know what is in products and whether materials are safe. It's important to distinguish between the requirements of the large (generally more sophisticated) manufacturers, and the smaller ones that may need more help and guidance. We need to improve the management and handling of electronics during the manufacture and EoL phases of the lifecycle, not only for toxics control, but to reduce the overall energy burden of the sector.

- *Skills for effective policy engagement*

  Societal norms and political will, play a critical role in establishing meaningful standards that support a sustainable electronics industry. The industry may have the right technical capacity, yet lacks the knowledge and skills for how to effectively engage policy makers.

- *Scientific assessment capabilities and life-cycle evaluations*

  The electronics industry needs to build capabilities for chemical assessments (materials that go into the products), LCAs and water footprinting. Little information is available on the life-cycle impacts of mining, toxic material exposures from production, monitoring for multiple chemicals and potential carcinogens. An information gap regarding chemical assessments currently exists, creating a significant need for industry to build and strengthen skills to assess these areas, and communicate impacts from a life-cycle perspective.

- *Technology capacity and engineering skills*

  Interviewees pointed out that many of the advocates and others active in this area lack technical backgrounds. This can be a hindrance to developing an evidence-based process and set of standards. Others believe that the technology and skills are there and that the real need is to implement it on the ground, to involve those who will be key to its success.

- *Systems perspective*

  A more systemic perspective for electronic applications will yield better results than a single-step approach. A systems approach should encourage the development of reliable, long-living products that generate revenue by refurbishing old objects rather than producing new ones. The big challenge is to extend product use life, while supporting an innovative industry.

2.4 What objectives should be designed for voluntary electronic standards; to encourage and achieve a sustainable electronics industry?

Stakeholders mentioned a number of important objectives for voluntary standards for the electronics industry, including providing consistency and clarity in an increasingly complex standards patchwork; rewarding innovation, leadership and good performance; and providing incentives for innovation.

Specific objectives mentioned include:

- *Promote leadership:* Standards need to provide a path to progress for industry, and encompass more than just threshold standards.
- *Reward innovation:* Standards should encourage a "race to the top", and reward innovative designs. Standards organizations should set broad parameters and then let companies innovate to meet those standards without being too prescriptive. They must encourage not stifle innovation.
- *Comprehensiveness of categories*: Standards should address all general electronic categories, with specific performance categories for certain products. Possible issues include energy efficiency, maximizing the useful life of devices, material recovery at EoL, and reducing hazardous substances (for plant workers, users and disassemblers). A variety of standards could be appropriate.
- *Comprehensiveness of footprint:* Standards need to cover much more of the footprint and factor in positive gains from the use of products.
- *Consistency and clarity:* Consistency and clarity are important, as businesses now face a patchwork of standards. There are more than 500 sets of green purchasing standards available in this field, and determining how best to police them all and ensure they are meaningful should be an objective. Reuse and recycling goals should be combined.
- *Address the supply chain:* Energy efficiency has been addressed to great length and much has been achieved. The next three to four years in standards development should be focused on the supply chain to ensure that products are fulfilling standards. This should include ethical issues, such as working conditions and conflict minerals. The electronics industry needs to be the standard setter for the entire global supply chain.

- *Facilitate deployment by incentives*: Standards should be designed together with incentive programs to drive market transformation. Coalitions with other major purchasers (e.g., hospitals), or industries can also incentivize adherence to standards.
- *Address real impacts through stakeholder engagement:* Standards should raise the bar on principles for environmental and social responsibility. They should also be designed around "real impacts" through a stakeholder-driven process, where the standards are vetted by all perspectives. At the same time, however, the standard must be sufficiently rigorous, ambitious and scientific in its approach.

2.5 What could federal and state governments and nongovernmental organizations (NGOs) do to promote the design and development of more sustainable electronics, advance science and create awareness?

- ***Green procurement will be an important market incentive***
  Using the leverage of federal agencies' purchasing power can drive behavior toward more sustainable design, energy efficiency and safe handling of used electronics. The U.S. Government purchases eight percent of the world's goods and services. For example, if state or federal governments were to require recycling programs for procurement of electronics, this could spur innovation and promote research and development into both recyclability and optimal recycling programs. The U.S. Department of Energy (DOE) and EPA are seen as the natural agencies to spearhead this effort. The government also can play an important role in setting the bar for training and certification of recyclers. Establishing green purchasing criteria sends an important message and helps create a market. The Electronic Product Environmental Assessment Tool (EPEAT®) was a very important first step in this regard.

- ***Government support to advance science and partnerships***
  Several interviewees noted the role of government in providing direct support and grants to advance science in the sector. Grants such as those funded by EPA's Science to Achieve Results (STAR) program were mentioned as an important vehicle to support industry, NGO and university research. Continued support for research at DOE laboratories is seen as an important enabler. Toxicology, total LCA (not just handling of used electronics), energy optimization, data center optimization and other issues are all areas that require more research, according to interviewees.

- ***Standard-setting: voluntary standards and regulation***
  Several interviewees pointed to the federal government's role in developing clear and consistent standards and encouraging their wide adoption. Some recommend making EPEAT® an international standard by encouraging other green standards to collaboratively develop criteria for EPEAT®. Performance needs to be measured accurately and consistently. A standard labeling scheme would provide incentives for industry. At the same time, the government has a clear role in creating a baseline and discouraging "free loaders." Voluntary standards may work best to pull up the top of the market and should be coupled with mandatory standards to create a "floor" that raises the

bottom of the market. In developing standards, there is a need to strike the right balance between broad direction and specific; prescriptive standards; and the allowance of flexibility to account for new technologies. There should be a distinction between the baseline law and implementation rules. Both federal and state governments should continue to encourage and accelerate the pace of standards for currently unregulated products.

- ***Encourage and reward leadership***
  Federal and state governments should encourage innovation and reward leading performers. This could be accomplished through the creation of broadly accepted performance evaluations that recognize leaders or awards for best in class performers. Subsidies are another option, however, some interviewees cautioned against the use of subsidies to artificially bolster initiatives that would not stand on their own.

- ***Social awareness—is it the right focus for government?***
  The government could also play a role in creating social awareness of sustainability impacts of the electronics sector, and communicating the full costs of electronic ownership to consumers. Education in this area should include promoting an understanding of the paradox of electronics (i.e., electronics can have simultaneous pros and cons for sustainability). Some interviewees were uncertain whether this is the right focus for government or the right motivator. This may be more the role of NGOs and civil society activists.

- ***Role of NGOs in awareness building and creating demand***
  NGOs could advance demand for greener electronics. Government and NGOs could ensure that consumers see the face of health and environmental issues (e.g., workers and children suffering from the production through the disposal phases), and educate consumers about the complex sustainability issues surrounding electronics. This also should extend to helping the public understand the importance and purpose of eco ratings, which currently have little traction with consumers. NGOs should focus less on bans that will not succeed and can put people out of work.

2.6 What changes outside of the industry will enable or hinder the transition to a sustainable electronics industry?

Findings from the interviews indicate that a number of macro factors will play a role in creating a sustainable electronics industry. Several of these factors can impact the industry in either direction.

- ***Will consumers value sustainability if it requires a trade-off?***
  One driving factor will be whether consumers will still value sustainability if it requires a performance or price trade-off. For example, the drive to miniaturization and lightness of devices may have negative impacts on recyclability or longevity. Will consumers accept a heavier device if it has sustainability benefits? Several interviewees pointed out that there is a need to better educate consumers about the sustainability of electronics and

potential trade-offs. Some interviewees noted that many consumer electronics now are seen as a fashion accessory, which creates a culture of disposability beyond the technology itself. This will be a problem, particularly if the industry does not have well-defined waste streams for recovery of complex materials. As consumers start to see the impacts of climate change more clearly, there also may be a significant push for more sustainable electronics. We may see an increased demand for conflict-free electronics.

- ***Taxation as a way to push the sustainability agenda***
  Taxation could become an important tool in driving better sustainability performance. Taxing consumption instead of income could underpin a "green" taxation system. We also could start to see taxation of greenhouse gases, with implications for manufacturing, energy efficiency and end-of-life.

- ***Oil and energy prices***
  If oil prices increase, this will have a number of implications for the industry. One potential outcome is that as transportation costs rise, local manufacturing (close to the customer base) may become more attractive. Rising energy costs also would help push energy efficiency. If energy prices do not rise, however, standards may be necessary to drive efficiency forward.

- ***Increasing resource scarcity—apportioning of resources***
  One of the biggest issues for the industry over the next 10 years may be how to apportion increasingly scarce natural resources such as silicon, energy and various metals, in the face of rapid economic growth in developing economies.

- ***Federal policies on energy efficiency***
  Federal energy efficiency policies will have a major impact on enabling a sustainable electronics industry. DOE standards, ENERGY STAR and other standards could be useful. If these programs are not sufficiently funded, it would lead to adverse effects for the industry. State-level policies on decoupling and rate recovery could reward utility companies for saving energy (e.g., energy as a service, not selling kilowatt hours).

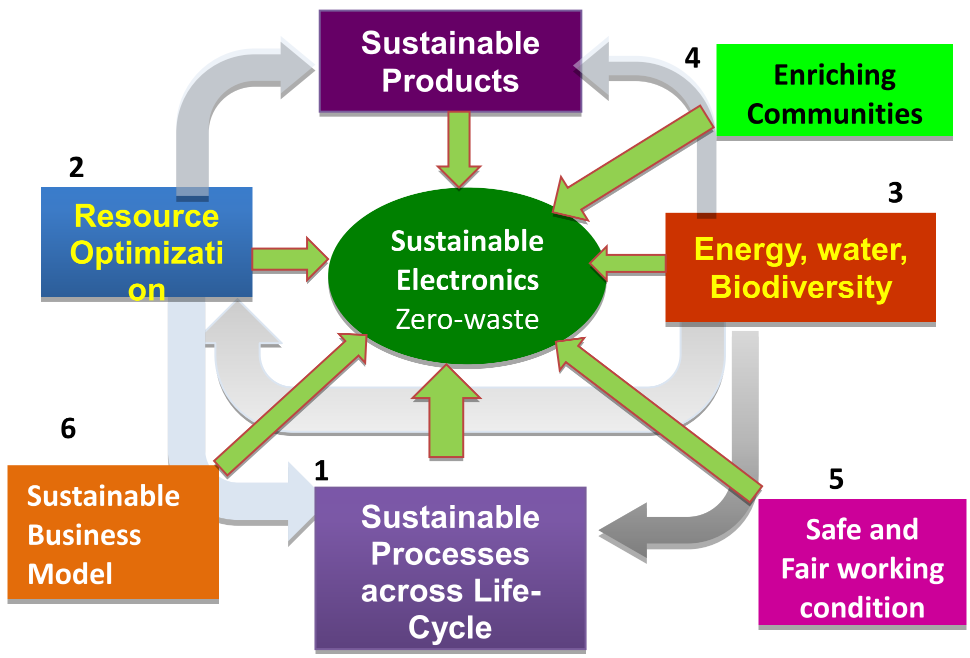
- ***Evolving sustainability policies in developing economies***
  Much e-waste currently is handled in developing economies. As these countries develop legislation that regulates the e-waste business, the shape of the electronics value chain may shift—altering what can and cannot be recycled where, and changing the flow of raw materials back into the system.

- ***Short-termism***
  Wall Street demands are huge impediments to long-term solutions. To overcome this, there is a need to take a collaborative approach, including collaboration and partnerships on research on economic models, green chemistry, modularity, repairability, durable materials and other issues.

3. Sustainable Electronics Roadmap

The group selected roadmap themes based on those developed by the Electronics TakeBack Coalition by Barbara Kyle including:

1. Materials and Processes Cause No Harm
2. Resource Optimization
3. Energy, Water and Biodiversity
4. Community Enrichment
5. Safe and Fair Working Conditions
6. Business Models



For each issue, participants considered various questions including:
What are the key research questions and recommendations?
What standards are needed?
Who needs to be involved?
What is the role for regulation?
What other approaches should be used to tackle the issue?
What resources are available?

They also identified potential barriers and approaches that could be used to solve each issue. Participants developed draft roadmaps that indicated short-term (three- to five-year), long-term (2030) goals, as well as milestones for five-year intervals. The roadmaps were completed to varying levels of detail by each group. Specific issues that were explored more in-depth are described following the roadmaps for each theme, as well as notes from the group discussion.

3.1 Materials and Processes Cause No Harm

The goal for 2030 is to limit the harm posed by all ICT materials and processes.

Issues

- Identify the chemicals in products.
- Identify the chemicals used in production.
- Identify the chemicals used in the extraction of virgin materials.
- Identify the chemicals used in EoL processing.
- Determine how to eliminate hazardous materials across the lifecycle.
- Quantify hazardous emissions to air, water and land.

Key Research Questions

- How can better test methods be created to verify the materials and chemicals in products?
- How can benign chemical alternatives be developed and compared to existing chemicals and alternative materials?
- Which processes result in emissions?
- What chemicals and processes are used in materials recycling and recovery?
- How can the chemical industry culture and mindset be changed to incorporate sustainable principles?
- What standard life-cycle analysis (LCA) tools can be developed to promote consistent use of the most benign and efficient materials?
- How can original equipment manufacturers (OEMs) be encouraged to use alternative, less toxic chemicals?

Standards Needed

- Consensus on a harmonized standard for alternative assessments and lists of benign and harmful chemicals.
- Integration of a criterion for making information publicly available and verifiable.
- A system that identifies all processes used to develop ICT products and the chemicals used in those processes.

3.2 Resource Optimization

Resource optimization is comprised of sustainable inputs (e.g., minimal use of critical minerals and virgin materials) and outputs (e.g., zero waste and maximum recycling).

The key goal for sustainable resource optimization is to obtain radically better closed-loop resource management by 2030, where it makes sense.

Issues

- Define "where it makes sense," in the context of input and output of resources, to have closed material loops.
- Improve collection of electronic products for EoL management.
- Design products for easy disassembly, efficient tracking of devices, optimal materials recovery and minimal materials use.
- Increase the transparency of material flows throughout the lifecycle.
- Improve system design optimization and control (e.g., processing).

Key Research Questions

- Does bio-based content negatively impact plastics recycling?
- What are the tradeoffs between durability/longevity and lightness/energy-efficient attributes?
- What is the best way to draft a criterion that will incentivize recycling of critical materials?
- What is the average lifespan of an electronic product before it is discarded?

Standards Needed

- Performance standards for smelting and the steps leading to smelting.
- Critical materials criteria might be needed.

3.3 Energy, Water and Biodiversity

The goal for 2030 is for ICT manufacturing and EoL processes to realize zero net energy and water use while taking steps to maximize biodiversity.

Issues

- Maximize the benefits of ICT applications.
- Decrease manufacturing and supply chain energy use, with the goal of zero net energy and carbon dioxide from manufacturing.
- Decrease net water use and improve the appropriateness of manufacturing facilities' locations.
- Increase biodiversity through the consideration of ICT-related materials and processes that can affect natural resources and habitats.

Key Research Questions

- What demonstration case studies can be developed to model efficient water and energy use?
- What models can be developed to understand the benefits of biodiversity?

Standards Needed

- Standardized energy performance indicators

3.4 Community Enrichment

The goals for the industry by 2030 are to responsibly extract all manufacturing inputs, use no materials sourced from conflict areas and ensure environmental justice for all communities.

Issues

- Develop a procedure to guarantee prior and informed consent before a new mine is opened.
- Create models to bring together the formal and informal recycling sectors.

Key Research Questions

- What is the best way to measure positive and negative impacts of ICT manufacturing at various levels of the supply chain?
- How can benefits be defined and what indicators can be developed to measure benefits?

Standards Needed

- Integrate the Framework for Responsible Mining into existing standards.
- Expand U.S. conflict mineral disclosure to include conflict regions beyond the Democratic Republic of the Congo.
- Incentives for OEMs that offer redemption value for ICT products.

3.5 Safe and Fair Working Conditions

The goals for 2030 are to have all ICT hardware manufactured in facilities with best-in-class health and environmental safety, and no forced overtime or child labor.

Issues

- Put a "human face" on occupational and environmental health.
- Make an effort to identify best-in-class environmental standards.
- Adopt comprehensive health monitoring and industrial hygiene monitoring.
- Adopt International Labor Organization (ILO) conventions on living wages and child labor.
- Develop meaningful indicators for social impacts, such as forced labor.

Key Research Questions

- What are the global best practices for health and safety safeguards?
- What new standards are needed?
- What indicators can be developed for social impacts such as forced labor?

Standards Needed

- Global standards based on the Strategic Approach to International Chemicals Management (SAICM) recommendations.
- Incorporation of absolute health, safety and environmental standards into the Electronic Industry Citizenship Coalition (EICC).
- Adoption of ILO labor standards into the EICC.

3.6 Sustainable Business Models

The principal 2030 outcome relating to business models is that all decisions throughout the supply chain are aligned with sustainability objectives.

Issues

- ICT functions as an enabler of sustainability.
- Internalize all costs throughout the lifecycle.
- Increase product utilization by novel methods, such as lease models.
- Investigate the role of consumers and research consumer behavior.
- Improve corporate culture and governance.
- Align decisions with the informal sector.

Key Research Questions

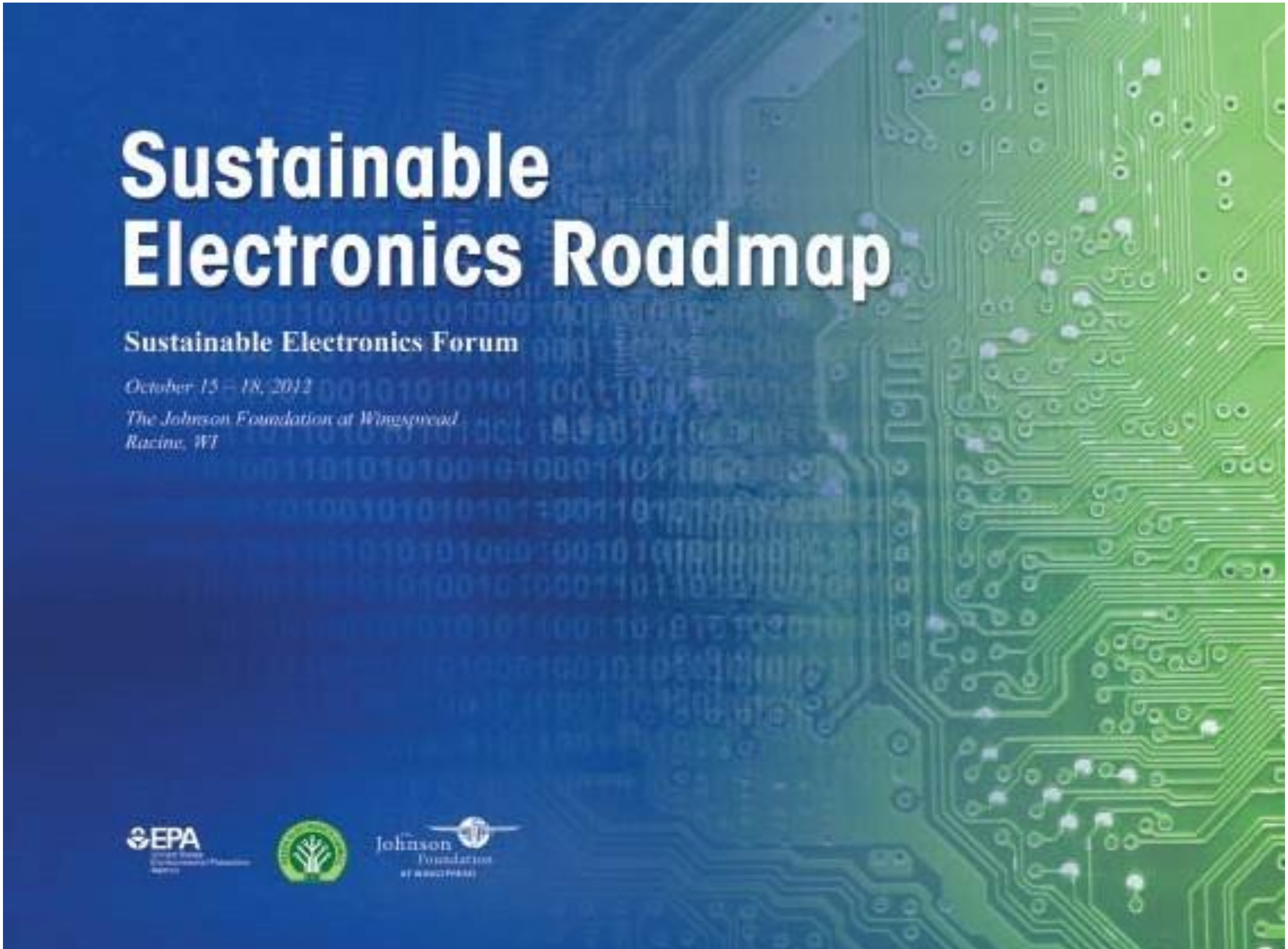
- How can costs be internalized throughout the lifecycle?
- What methods can be established to encourage or require transparency?

Standards Needed

- Common methodology for calculating sustainability impacts and benefits.
- Platforms to share tangible actions for improvement opportunities for industry, government and consumers.
- Standards to enable interoperability between technologies and software.
- Phase-in of standards such as carbon, water and toxics to internalize the cost of externalities.

Part 2

4. Roadmap Milestone and Research Issues


Sustainable
Electronics Roadmap
Sustainable Electronics Forum
October 15 – 18, 2012
The Johnson Foundation at Wingspread
Racine, WI
EPA
Johnson Foundation

Materials and Processes Cause No Harm: Roadmap

2030 Outcome: Limit the harm posed by all information and communication technology (ITC) materials and processes.

Issues | 2012 | 2015 | 2020 | 2025 | 2030 | 2030 OUTCOMES

What Chemicals Are in Electronic Products?

- Computer OEMs propose criteria (optional) to EPEAT[®] 1680.1 for getting full chemical inventory for products
- OEMs agree on a format for how they will ask their suppliers for full product chemical inventory (i.e., EIC 62474)
- Leadership computer OEMs request full product chemical inventory from suppliers
- iNEMI Road-map includes full chemical inventory of products; sustainability consortium
- Full inventory of chemicals residing in electronic products by OEMs
- Tool exists for designers to evaluate material options that include all chemicals, hazards and manufacturers for a reasonable price
- Developing improved test methods for chemicals in products
- Inventory of chemicals in products is transparent throughout the supply chain
- Gather hazard information for all chemicals in products and continue to update periodically
- Full inventory of chemicals residing in products is publicly available by OEMs
- OEMs receive full product inventory for each new product before it is released on the market

2030 Outcomes:

A complete inventory of all chemicals in production of electronic products, including hazards, is verified and publicly available. The inventory identifies the manufacturers of the chemical, material or product.

CAD Tool is fully populated with material, chemical, product hazards and manufacturing information.

2012 2015 2020 2025 2030

What Chemicals Are Used in the Production of Electronic Products?

- Electronic Industry Citizenship Coalition (EICC) process chemical groups—looking at processes
- Develop a system that identifies all processes used to develop IT products
- What chemicals are used in these processes, generally?
- From generic processes, identify target "hotspots" of chemicals in production
- Identify best practices of communication through the supply chain, such as those used in the pharmaceutical industry

2030 Outcomes:

A complete inventory of all chemicals in production of electronics products, including hazards, is verified and publicly available. Manufacturers of chemicals are identified.

2012 2015 2020 2025 2030

What are the hazards and social impacts related to the extraction of materials used in electronic products?

- Identify virgin materials used in electronic production
- Continue to reduce the use of virgin materials
- Increase the use of high-quality recycled/recovered materials
- What chemicals are used in materials extraction? What are their impacts? Are there alternatives? Can they be sourced from different mines?

2030 Outcomes:

Virgin materials are sourced from certi- fied "safe" mines and/or facilities.

Recycled materials are sourced from certified facilities, and adequate supplies of feedstock are available.

Use only biologically benign substances in materials extraction and production of electronic products.

1 2012 3 2015 5 2020 7 2025 9 2030

2 4 6 8

Materials and Processes Cause No Harm: Roadmap

Issues	2012 – 2015 – 2020 – 2025 – 2030	2030 OUTCOMES
How Do We Eliminate Hazardous Materials Across the Lifecycle of Electronic Products?	Harmonized agreement on methodology to conduct alternative assessment, including hazard assessment Gather hazard information for known "bad" chemicals and continue to update the information Lobby Congress for funding for increased group alternative assessment. Include chemical phase out schedules along the way Increased group alternative assessments being done by OEMs with EPA involvement Find alternative chemicals, materials, or product designs to known "bad" chemicals Assessments conducted routinely and information updated periodically Attain international harmonization of approaches to sustainable electronics Develop new biologically benign substances Incremental innovation Agree on list of "bad" chemicals and list of "good" chemicals (include focus on workers) Identify "bad" chemicals and their manufacturers, identify "good" chemicals and their manufacturers and make information publicly accessible (i.e., CleanGredients®) Develop methods for company chemicals, materials and product design Industry requests chemical industry to develop alternatives to chemicals on the "bad" list Continuous updating of "good" and "bad" lists (2020–2030)	No chemical is selected unless it is on the "good" list or an alternative assessment (to a "goodness threshold") is conducted.
Hazardous Emissions to Air, Water and Land	Develop clean emissions standard for production facilities Develop a system for ongoing monitoring and compliance to the standard All production facilities are certified for clean emissions	Elimination of hazardous emissions to air, water and land from the production of electronic products.
Chemicals Used in EoL Processing	Research questions: What end-of-life recovery processes use hazardous chemicals? Are there safer processes that some processors could use now? If yes, how do we incentivize their use? If no, how do we develop alternative chemicals or processes?	

Materials and Processes Cause No Harm: Notes

Issue: What are the hazardous emissions to air, water and land from electronics production?

What are the key research questions?

- Which processes result in which emissions?

What standards are needed?

- Knowledge of alternative processes.
- Standards for conducting workplace air monitoring for toxics exposure for specific types of production and for each chemical of concern
- Standards for worker health monitoring are needed for the various types of processes. The kinds of monitoring and the kinds of chemicals to be monitored should be determined.

Who needs to be involved?

- Supply chain, nongovernmental organizations (NGOs), and United Nations staff for Pollutant Release and Transfer Register (PRTR) activities.

What other approaches should be used to tackle the issue?

- All of the supply chain should perform Toxics Release Inventory (TRI) or PRTR reporting, but at a level equivalent to U.S. TRI reporting. The approach should be in the standards.

Issue: How do we eliminate hazardous materials across the lifecycle of electronic products?

What resources are available?

- TRI reporting in the United States.
- PRTR reporting in some other countries.

What are the key research questions and recommendations?

- Develop methods to compare alternative chemicals, materials or product designs.
- Develop biologically benign alternatives, including new chemicals and materials.

What standards are needed?

- Consensus on a harmonized standard for alternative assessments.
- Consensus on a list of benign chemicals.
- Consensus on a list of harmful chemicals.
- Tools for conducting alternatives assessments, including hazard assessment.
- Computer-aided design (CAD) tools that provide information on the chemicals used, associated hazards and the manufacturer.

Who needs to be involved?

- Tool developers, original equipment manufacturers (OEMs), chemical industry, NGOs, EPA, recyclers, and CAD tool developers.
- Purchasers/those writing government specifications.
- EPEAT®.

What other approaches should be used to tackle the issue?

- Collaborative research (government or industry as convener) and alignment of goals.
- Water safety experts.

What resources are available?

- Some chemical hazard assessment tools, such as Toxcast, GreenScreen, Design for the Environment (DfE), life-cycle assessment (LCA) and toxicity assessment tools and models.
- Some alternatives assessment protocols.
- Some supply chain software tools.

Issue: What chemicals are used in the extraction of the virgin materials used in electronic products?

What are the barriers?

- Lack of agreement on the preferred materials.
- Lack of a method to bring information on hazards and alternatives to designers.
- Lack of funding for group alternative assessments.

What are the key research questions and recommendations?

- What chemicals are used as part of extraction and what are their impacts?
- Are there alternatives?
- Can chemicals be sourced from mines using safe chemicals/lower impact processes?

What standards are needed?

- Outer edge.

Who needs to be involved?

- Mining industry, developers of the Framework for Responsible Mining, Earthworks (NGO active in mining issues, formerly called Mineral Policy Center).

Issue: What chemicals are in electronic products?

What other approaches should be used to tackle the issue?

- Government research and convening.

Materials and Processes Cause No Harm: Notes

What are the key research questions and recommendations?

- How to create better test methods for verifying which chemicals are in products?
- How to get better information on fate and transformation of chemicals?

What standards are needed?

- Integrate a criterion for a full chemical inventory into all standards used by EPEAT®.
- Integrate a criterion for making information publicly available and verifiable.

Who needs to be involved?

- OEMs, chemical industry, product design tool developers, technical experts, NGOs, EPA.
- EPEAT® to support purchasing.

What other approaches should be used to tackle the issue?

- Include chemical disclosure in the Sustainability Consortium.
- Integrate chemical and manufacturer inventory and hazard information into CAD tools.
- Create an expert exchange program between the pharmaceutical and IT industries.

What resources are available?

- International Electrotechnical Commission (IEC) 62474 standard and National Science Foundation (NSF) 355 standard.
- BomCheck software tool and other materials declaration software tools.
- MIQ tool developed by the Green Blue Institute.
- Glaxo Smith Kline/Pharmaceutical Roundtable tool.

What are the barriers?

- Limited list of chemicals covered by the IEC 62474 standard.

Issue: What chemicals are used in the production of electronic products?

- Lack of collaboration to collect chemical information.
- Lack of publicly available tools to perform full chemical inventories.
- Chemical industry resistance.
- Challenge in handling proprietary information.
- Fear of liability.
- Lack of transparency in the supply chain.

What are the key research questions and recommendations?

- What are the processes used to develop ICT products?
- What chemicals are used in conventional processes?
- Are there alternative processes that are inherently biologically benign?

What standards are needed?

- A system that identifies all processes used to develop ICT products and the chemicals used in those processes.

Who needs to be involved?

- OEM, suppliers/supply chain, chemical industry.
- Industry research associations.

What other approaches should be used to tackle the issue?

- Government should advocate, collaborate and support research.

What resources are available?

- NSF 355 standard.
- Sustain™ tool.
- iNEMI and International Semiconductor Manufacturing Technology Manufacturing Initiative (ISMI).

Research Needs

1. Create better test methods for verifying which chemicals are in products.

2. Generate better information on fate and transformation of chemicals through life-cycle steps and through processing (EoL).

3. Develop methods and refine tools for comparing alternative chemicals, materials or product designs.

4. Develop biologically benign alternatives such as new chemicals and materials.

Extraction

5. Determine what chemicals are used to extract the various minerals used in electronics manufacturing.

    - What are their impacts?
    - Are there safer alternatives?
    - Can minerals/chemicals be sourced from mines using safer chemicals/lower impact processes?

Process Chemistry

6. Map the processes used to develop IT products.

    - What are the chemicals typically used in these processes? (not exclusively used in the electronics industry) EICC phase outs.

Materials and Processes Cause No Harm: Notes

Process Chemistry Notes Continued

- What are the hazard "hot spots" in production?
- Are there alternative chemicals or processes that are inherently biologically benign?

Emissions

7. Which processes result in which emissions (air, land, water)?
8. What is the best way to integrate alternative assessment information into CAD tools?
9. What chemicals are used in materials recycling/recovery and processes? (Karsten Schischke)
10. What steps can be taken to change the chemical industry culture/mindset?

- Chemicals are being used to make a process serve a function.
- Need a "toxic process" category, not just material. May not be a chemical substitution—need other technology solution.
- Need to include drivers such as standards and regulations.
- Tighten/extend "bad" list over time.
- Cross reference and identify potential community impacts, including monitoring.
- Make sure impacts of chemicals extraction in the recycling process are addressed.

Steps for Next 3-5 Years

- Receive EPA Green Chemistry award for brominated flame retardant alternatives.
- Integrate these ideas into the iNEMI (Bob Pfahl and Carol Handwerker) roadmap and Sustainability Consortium (Randy Kirchain and Scott O'Connell).
- Integrate drivers into the IEEE1680.1 standard and the server standard (both efforts launching in early 2013).
- Include presentations on this topic at Electronics Goes Green and the Comprehensive Approach Resource and Energy-Efficiency Electronics Conferences.
- EPA could hold meetings with leading computer OEMs and NGOs to prepare proposals for the 1680.1 standard.
- Create roadmap for next products to build standards for Green Electronics Council.
- EPA Market.2 and .3 and other standards used by EPEAT® provided to federal purchasers.
- Create consortia to gather chemical information for IT so the information can be shared and create shared repository (EPA/ORD and EPA/Office of Chemical Safety and Pollution Prevention and industry).
- EPA should make CompTox publicly accessible and usable.
- Create a registry of preferred chemicals (e.g., CleanGredients® type approach) and make accessible. Start with one chemical class such as flame retardants, colorants, plasticizers (Helen Holder, DfE).
- Create an EPA Green Star program to direct purchasers to products meeting EPA and stakeholder-approved standard that includes the ideas from the Roadmap.

Existing Tools

NSF 355 Standard
EIC62474 Standard
Green Screen Tool
State of California Chemical Effort
State of Washington Work on Alternative Assessment

Resource Optimization: Roadmap

2030 Outcome: Radically better closed-loop management of resources (where it makes sense).

Issue	2012	2015	2020	2030
1. Define what "makes sense" for optimized resource recovery	Determine boundary conditions for definition of criticality, environmental dimensions only, or also economic and strategic, resources of concern, e.g., metals (PM, SPM, PGM), REs, bulk materials (plastic) Document state of the science & policy for optimized resource recovery Apply criteria & prioritize resources Define quantified goals per priority re- source Determine optimal end			
2. Quantify "Radically Better" for resource recovery sysems	Assess product types and major components that contain signifi- cant quantities of priority resources, e.g., absolute amount and average percent composition of priority resources per unit waste stream Define criteria for prioritization of product types and components Apply criteria & prioritize product types and components Document state of the science regarding e-scrap resource	Determine optimal end use of priority products and components Define quantified goals for priority products and components (this will be the measure of "optimal") Write up results of task A & B and distribute for input		
3. Collection	Document state of the science & policy regarding e-scrap collection, Identify significant collection system factors that affect recovery of priority resources	Define collection system goals: percent of priority devices collected into responsibly managed channel; percent of products properly handled, sorted and delivered to optimal channel; percent of collection programs effectively account for material flows		

2030 OUTCOMES

3. X% of prioritized devices collected into a responsibly managed channel

4. Proactive eco design that takes into account:
   - design for disassembly
     - life extension (reuse, refurbishment)
     - recycling
   - design for recovery
     - avoid incompatible material mixes as long as it does not interfere with essential functionality
   - design for tracking and detection
   - design for less material use considering tradeoffs (e.g., economic viability, recycling, durability)

5. Transparent material flows (destination volume) for 100% of prioritized products
   - Commonly accepted standards for scope, quality and format of data
   - Monitoring standardization and process certification
   - Define responsibility and accountability
   - Tracing and tracking technology
   - Prioritize products (absolute amount of material content) and potential toxicity
   - Transparent to whom?

6. Optimize system for priority devices
   - Economic drivers
   - Technical (interface and process technology)
   - Rules/incentives

Resource Optimization: Notes

What are the key research questions?

- Building on existing studies, which scarce, strategic and critical materials need to be prioritized for electronic sector conservation?

What standards are needed?

- Critical materials criteria may be needed (e.g., recycling, conservation, substitution).
- Performance standards for smelting and for the steps leading up to smelting. These need to be flexible enough to deal with smelters focused on primary ones that also process printed wiring boards.

What other approaches should be used to tackle the issue?

- Primary mining smelters have similar issues for optimizing recovery.
- The Chinese government needs a smelter dedicated to e-waste; current smelting processes are optimized for primary ore and have low yields for other materials.
- Specific smelters are needed for recovery. Many recoverable materials are just by-products.

What are the barriers?

- There are no venture capitalists investing in these ventures.
- Governments could consider funding applied research as well as basic research.

EcoDesign

- Design for disassembly, life extension (refurbish), recycling, reuse.
- Design for recovery (thermo-metallurgy chemistry). Avoid material mixes as long as it does not interfere with essential functionality.
- Design for tracking and detection.
- Design for less material use considering tradeoffs (e.g., economic viability, recycling, potential durability).

Transparency of Material Flows (Destination Volume) 2030 Outcome:

100% of Prioritized Products

- Responsibility and accountability
- Hard data; mass balance
  - commonly accepted standard for scope, quality and format of data
  - monitoring standardization and process certification
- Tracing and tracking technology
- Prioritize products
  - material content/total absolute amount of material
  - material potential toxicity
- Transparent to whom?

System Design/Optimization/Control 2030 Outcome:

- Optimized system for priority devices
- Economic driver
- Technical (interface, process technology)
- Rules/incentives

Additional Notes

- NGOs, government and academics look at the system. Industry looks at their own piece of the problem. This must be multidiscipline, multi-stakeholder. These are all very complex systems, and we cannot achieve perfection. There is no 100% truth. There is an optimum, which means there is compromise. Everything needs to be piloted with all the available information brought to bear. This is a problem for funding. Funding is needed but government agencies prefer basic research, not applied.

- Do not forget recovery of nonmetallics. How can recovery of polymers, bio-based, etc., be optimized?

- How do we balance maximizing recovery yield goals against the environmental costs of extraction?

- Integrate incentives to conserve, reuse and recycle critical minerals into standards used by EPEAT®.

Research Questions:

1. Does bio-based content negatively impact plastics recycling?

2. What are the tradeoffs between durability/longevity and other (lighter, energy efficient) attributes and how do we decide what is “best” to incentivize?

3. What is the best way to draft a criterion that will incentivize the recycling of critical materials (to put into IEEE standards)?

Resource Optimization: Roadmap (continued)

2030 Outcome: Radically better closed-loop management of resources (where it makes sense).

Issue	2012	2015	2020	2025	2030
4. Address Optimization of the Processing System	Review literature & document state of the science & policy regarding e-scrap processing	Identify significant processing system factors for critical resource recovery Define measures of processing system effectiveness Define processing system goals: percent of priority devices optimally processed; X% of products sent to optimal end-treatment system Define best practices for optimal processing systems			
5. Address Optimization of the Final Treatment System	Review literature & document state of the science & policy regarding e-scrap final treatment systems Identify significant treatment system factors	Define measures of treatment system effectiveness Define treatment system goals:, X% of priority devices optimally treated X% recovery of critical resources Define best practices for optimal end			
6. Reporting: Interim and final	Define optimal channels for EoL management – collection thru treatment	Draft interim report for broad distribution and input – Report will address optimal priority resource recovery for electronics EoL management Solicit and review input and finalize report	Develop eco-design guidance, EoL infrastructure development recommendations Define performance standards for ewaste–handling smelters and performance standards for ewaste collection and processing	Integrate implementation elements into Interim Report and	
7. Implementation			Adopt eco-design guidelines into EPEAT, Promote development of EoL infrastructure Implement performance standards	Implement performance standards for ewaste collection and processing Implement transparency measures for prioritized materials and product flows; Evaluate system	

2030 OUTCOMES

3. X% of prioritized devices collected into a responsibly managed channel

4. Proactive eco design that takes into account:
   - design for disassembly
     - life extension (reuse, refurbishment)
     - recycling
   - design for recovery
     - avoid incompatible material mixes as long as it does not interfere with essential functionality
   - design for tracking and detection
   - design for less material use considering tradeoffs (e.g., economic viability, recycling, durability)

5. Transparent material flows (destination volume) for 100% of prioritized products
   - Commonly accepted standards for scope, quality and format of data
   - Monitoring standardization and process certification
   - Define responsibility and accountability
   - Tracing and tracking technology
   - Prioritize products (absolute amount of material)

Additional notes (continued)

4. What is the average lifespan of an electronic product before it is discarded? How many are refurbished versus shredded?

5. How much of the brominated flame retardants are present in recycled content plastics, and do they leach out in dust more than from virgin plastics?

6. How much does the plastics recycling stream fluctuate and what is the recovery rate of different resins?

7. Is metal better than plastic?

From Christian Hageluken's presentation:

- Mechanical processing of complex products without dissipation of technology metals.
- Pre-shredder technology to remove magnets, circuit boards, batteries, etc.
- Thermodynamics of complex (incompatible) metal mixes (pre-competitive).
- Optimize metal yields and energy efficiency of metallurgical processes.
- Recycling of rare earth metals such as, gallium, germanium and tantalum.
- Pilot plants, scale up ("crossing the valley of death").
- Interface optimization mechanical processing ↔ metallurgy.
- Recycling of slags, flue dust, ashes, landfills, tailings, and so forth.
- Metal recycling from functional surfaces (e.g., LCDs).
- Interface logistics and mechanical processing
  - Number of collection categories (separate vs. joint); appropriate pre-sorting intensity.
  - Optimal infrastructure for relevant small devices (e.g., mobile phones, USB memory sticks, batteries).

Energy, Water and Biodiversity: Roadmap

2030 Outcome: ICT manufacturing and EoL process to realize zero net energy and water use while taking steps to maximize biodiversity.

Issue	2012	2015	2020	2025	2030	2030 OUTCOMES
Scoping inventory of Tool Box	Promotion of ICT sensors for existing and new applications	Research agenda roadmap Sensory benefit assessment Energy benefit of ICT				Maximize benefits of ICT deployment
Metrics Measure Progress	BLACK BOX - Industry level - "Average" processes - For United States only Energy performance indicators collected on plant level LCA on a case-by-case basis/significant data gaps are uncertain LCA/Product Carbon Footprint - generic, standardized data models	Environmental Protection Index data ready for publication OEMs set supply chain standards Policy can set incentives for low energy consumption		Maximize renewables Minimize energy demand Maximize materials efficiency		Contexts refined by place/culture
Energy	Quantifying ICT-related savings at largest/meta level Quantifying ICT-related savings (e.g., case studies)	Research and development for next generation energy saving technologies OEMs set supply chain for WPI				Zero net energy/CO_2 manufacturing
Water	water performance indicators (WPI) on plant level	WPI data ready for publication Set incentives for low water consumption		water use reduction yields protection or enhancement of regional biodiversity		Zero net water (appropriate to location)
Biodiversity	Monitor and understand biodiversity at regional level Metrics and thresholds established to support regional biodiversity	Understand variables that enable enhancing biodiversity on regional level	Link biodiversity to resource use and design decision making			Zero biodiversity negative impact or improves biodiversity
Research Opportunity	Needs: 1. Infrastructure impacts and analysis 2. Simulation tool 3. Harmonization with meta level and design decision making 4. Link to design					

Enriching Communities: Roadmap

2030 Outcomes: Communities benefit proportionally from extraction, production and EoL activities and are able to exercise self-determination in the development.

Issues	2012	2015	2020	2025	2030	2030 OUTCOMES
	Convene experts to identify best practices in extraction and create a framework for responsible mining	Expand existing disclosure requirements to include other conflict areas beyond DRC			No ICT materials sourced from conflict areas	All ICT materials sourced out of responsible extraction areas
			Require closure plans and bonding before opening new mine			
	Identify conflict areas beyond DRC	Establish a process to guarantee free, prior and informed consent before a new mine is opened				
	Research policy options for minimizing factories/ companies "shopping" for local communities offering destructive perks such as tax breaks, regulatory relief, etc. (National Governors Association has done this)					
	U.S. export ban on e-waste	All ICT hardware has a small redemption value/ refund fee for returning EoL hardware to responsible recycling programs				
	Pilot project to develop workable model to bring together informal collection and formal recycling					

Issues

Maximize the benefits of ICT applications.

Decrease manufacturing and supply chain energy use, with the goal of zero net energy and carbon dioxide from manufacturing.

Decrease net water use and improve the appropriateness of manufacturing facilities' locations. We need baseline reporting on water use per facility with goals to reduce it.

Increase biodiversity.

Key Research Questions

- What demonstration case studies can be developed to model efficient water and energy use?
- What models can be developed to understand the benefits of biodiversity?

Additional Notes

Comments From the Working Group:

- Started with issues but found lots of intersections, so restructured.

- Maximize benefits of ICT: there are case studies and good data on sectors such as buildings and lighting, but lots of things that we do not know about benefits of ICT. For example, what are the benefits of email or of downloads? There is no broad understanding of precise benefits and how these change over time and space. The first thing in the process is understanding the array of applications. We need some way of understanding where we stand and where to go to maximize deployments.

- Better promotion of energy efficiency: simple, cost-effective measures. Barriers should be considered through a life-cycle view. We need to deploy what is there. What are the benefits if we tap into new markets and applications? Need research roadmaps and agenda involving building quantitative tools and models to identify credible tools. Need policy roadmap to maximize deployment and to overcome market barriers.

- Information asymmetry: there are solutions that building owners or manufacturers might not want to try because the outcomes are uncertain. So we need demonstration case studies. Need tested, proven data to act on. Overcome early adoption barrier. No demonstration studies for transportation. Need a neutral place where technology is tested. Need to identify new opportunities to overcome secrecy barrier. Better models will help us understand benefits.

- Research roadmap: invest in traditional approach with measurement verification, tracking and documenting benefits with deployment of ICT.

- Zero net energy CO_2 manufacturing: there is a lot of secrecy in the supply chain. Current carbon footprint appears to be really high. Need better, more detailed data to develop energy performance indicators.

- Energy used for unit of production: we know this for steel, but not for complex electronics and water use per unit of production. Energy STAR has energy performance indicators for some labels. Takes 2-3 years to develop—a long time. Such indicators provide a metric for where we stand today with respect to energy use. Need some effort to understand energy use. Need to measure performance over time. Then OEM can set supply chain standards. Best/worst practices. OEM compared to other OEMs in non-confidential way with anonymous benchmarking tools.

- Policy makers need to know best practices and where to push.

- R&D: policies for R&D demonstrations. This is done for other industries, and can be applied to electronics. Minimize energy demand and maximize materials efficiency. Companies need to minimize use of water and toxics, which seems feasible; eventually they could get to zero net CO_2 in manufacturing.

Enriching Communities: Notes

What are the key research questions?

- Better mining practices, mapping additional conflict regions beyond the Democratic Republic of the Congo (DRC), policy options to minimize companies "shopping" for perks in communities, and a pilot program to bring together informal e-waste collection with formal recycling.

What standards are needed?

- Integrate the Framework for Responsible Mining into existing standards.
- Expand U.S. conflict mineral disclosure to include conflict regions beyond the DRC.
- EPEAT® optional points for offering redemption value for ICT.

Who needs to be involved?

- Mining stakeholders.

What other approaches should be used to tackle the issue?

- State and local government for EoL issues, and policies to reduce "shopping" for perks.

What is the role for regulation?

- Enforce an export ban for e-waste in the United States and also develop redemption value for e-waste.
- Expand U.S. conflict mineral disclosure to include conflict regions beyond the DRC, perhaps through the U.S. Securities and Exchange Commission (SEC).

What resources are available?

- The U.S. and European Union (EU) governments are available for conflict material issues.
- Basel, NGOs, EU and other governments are available for EoL issues.

What are the barriers?

- Avarice.
- OEMs are high in the supply chain.
- A small portion of the market for some metals means less leverage.
- Costs are externalized.
- Ignorance and apathy from consumers.

Safe and Fair Working Conditions: Roadmap

2030 Outcomes: All ICT hardware is manufactured in facilities with best-in-class health, safety and environmental standards globally with living wages, no forced overtime, no forced labor, no child labor, and no discrimination and where workers have freedom of assembly.

Issues	2012	2015	2020	2025	2030	2030 OUTCOMES
Health and Safety Standards	Put human face on harm to make it visible Fair and just compensation for occupational illness HSS1—Identify best-in-class protective health, safety and environmental standard (globally); Equal protection for workers and residents to include the same health-based exposure limits and standards HSS3—Identify best vehicle(s) to implement and enforce best-in-class protective health, safety and environmental standards throughout the global ICT supply chain. Consider EICC, WHO, national and global governments Identify full supply chain Characterize TRI/PRTR emissions for supply chain	HSS1-implement comprehensive health monitoring and industrial hygiene best practices throughout ICT supply chain globally HSS4—Examine PELs and RELs to lower where needed for common chemicals used in ICT manufacturing Collaboration to improve EICC with key organizations like NGOs and international institutions and national governments	Collaboration on EICC implementation	Implement		
Social	Scan/benchmark other industries and efforts (e.g., Fair Factories clearinghouse for apparel and footwear) Adopt ILO conventions on: living wages, forced overtime, child labor, discrimination and freedom of association In EICC Worker education's empowerment training implemented throughout supply chain with cooperation of NGOs, worker	Develop meaningful indicators on social impacts, including living wages, no forced or child labor, no discrimination, freedom of association				

Safe and Fair Working Conditions: Notes

What are the key research questions and recommendations?

- What are the global best-in-class health, safety and environmental standards that should be adopted at all ICT manufacturing facilities?
- Should any key Recommended Exposure Limits (RELs) or Permissible Exposure Limits (PELs) for common chemicals be lowered or adjusted for the ICT industry?
- Benchmark other industries and efforts to address social issues.
- Need to identify chemical inventories in production facilities; identify existing OSHA and environmental standards for each one (where they exist); harmonize these standards to the most health protective; establish new health based limits for those materials (including mixtures) where there are currently no existing health standards
- Develop meaningful indicators for social impacts.
- Characterize the TRI and PRTR emissions in the supply chain.

What standards are needed?

- Global standards based on the Strategic Approach to International Chemicals Management (SAICM) recommendations.
- Incorporate absolute health, safety and environmental standards into the EICC.
- Adopt International Labor Organization (ILO) labor standards into the EICC.

Who needs to be involved?

- Global subject matter experts and multiple stakeholder groups.

What is the role for regulation?

- Need regulations to implement global standards.

What other approaches should be used to tackle the issue?

- EICC needs to become multi-stakeholder and lead implementation efforts.
- Social media needs to put a face on human and environmental harm.

What resources are available?

- Lots of dispersed expertise.
- Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH), ILO and World Health Organization (WHO).

What are the barriers?

- Lack of resources and visibility.

Business Model: Roadmap

2030 Outcome: All decisions throughout the supply chain are aligned with sustainability objectives.

Issues	2012 – 2015 – 2020 – 2025 – 2030	2030 OUTCOMES
ICT as an Enabler of Sustainability	SMARTer grid—avoided cost recovery for utilities (2015); ICT providers earn carbon credits (2020)	ICT enables smarter use of natural resources.
Internalization of All Costs Throughout Lifecycle	Propose model (2012); Voluntary standards (2020); Decision on regulation (2025); Analyze → Report → Report → Regulation? (2015–2030)	All external costs are embedded in product/service.
Increase Product Utilization	One device supports several generations of operating systems (2012); Allow commercial terms—i.e., ANSI standards to promote longevity (2015); Organize process to explore end-of-ownership application → Implement EOO: Voluntary Mandatory	100% utilization of all ICT through lifecycle.
Role of Consumer (Research) Research why consumers do not use EoL services, energy features • Trust in EoL • Separation anxiety • Relationship, continuity	Design and try interventions -> evaluate them; Market incentives to encourage what works (2020)	Consumer behavior aligns with sustainability goals.
Corporate Culture and Governance	Research board make-up and transparency goals (2012); Develop "standard" for boards and certification (2015)	Business, investor and supply chain decisions are consistent with long-term sustainability.
Informal Sector	Research effectiveness of EoL schemes, consider device "bounty" In the developing world and appropriately support informal sector (2012)	Informal sector is focused on collection and disassembly and refurbishment.

Business Models: Notes

Issue: Quarterly Earning matrix

How could investments in the electronics industry support requiring:

- Companies to report on their long-term strategy and how it makes the business more sustainable.
- Business to demonstrate that they have a plan to address the impacts of future systemic risks including climate change, water stress, biodiversity, population growth, urbanization and changing demographics.
- Companies to report in their accounting the value of natural, human and social capital, so that investors can understand the importance of factors which are often overlooked. This will enable the strategic reporting outlined above.
- Are there examples of these strategies working in any sector?
- Is there voluntary reporting that companies could begin to do?

Who should be involved?
Fund managers, SRIs (socially responsible investment

Issue: Product Longevity

How do we shift from a business model where OEMs' primary earnings come from customers replacing existing products by buying new ones? How do we incentivize companies to design and build products to be long lasting and upgradeable, easy to repair, and easy to refurbish for a significant reuse phase?

Key research questions

Understanding what's happening now

- What is the current rate of product turnover for each major product category?
- How much is due to product failure vs owner preference for new features or performance of new devices?
- How much is due to software issues? New operating system software? New software won't run correctly on old product?
- How prevalent is the notion that "since it's already 2 years old, it will probably die soon anyway, so I might as well get a new one"?

Product longevity and ease of repair and upgrade.

- Does it cost more to make a computer that is more durable and longer lasting? Is this an issue of design? Of manufacturing quality? Of materials? Of manufacturing control? What companies have tried to significantly lengthen their "mean time to failure" of certain products, and what changes yielded results?
- Would consumers (or any subset of consumers) pay more for a category of product (like a laptop) that was guaranteed to be more durable, and to have more value to resell? Would we pay more for the "Volvo" of laptops?
- How do changes in operating system software drive replacing rather than upgrading existing hardware. Is there a difference in the rate of upgrading vs replacing between consumers and business owners? Is there a difference in the rate of upgrading vs replacing between various software platforms? If so, what are the lessons we can learn from these differences?
- Truly modular design. How could a truly modular design enable ongoing upgrading, rather than replacing hardware? What would a truly modular device look like?

Who should be involved?
Reuse groups, repair groups (like iFIXIT), companies selling extended warranty work, OEM repair vendors, non-OEM repair vendors, consumer behavior

Issue: Service Model Vs Purchase Model;

Some suggest that we would see more advances in sustainability if electronics companies moved to more of a lease and service model, where customers didn't buy products, but leased them from the OEMs, bringing them back to OEMs for upgrades or replacements when necessary.

Key research questions

- Develop this concept and determine how it could make economic sense for a Brand.
- The computer companies mostly have leasing divisions for large businesses.
- Are there lessons to be learned there?
- How could that model succeed with consumers? What kind of service infrastructure would the Brand need to put into place for it to succeed?
- Does current leasing program result in longer product lifetimes? Does it result in fewer products consumed?

Who should be involved?
Experts in leasing electronics, thought leaders on sustainable economies,

Issue #4: Cost Internalization.

How do we shift from a business model where many costs (across the entire lifecycle of the product) are externalized, to where the true costs from each phase of lifecycle, are reflected in product prices, and are paid by the consumer? The "Vision 2050" plan by the World Business Council for Sustainable Development calls this "True Value, True Costs, True Price."

Key research questions

- How would a company asses the true costs for each phase of the lifecycle? What are the costs that are currently internalized into the product price, and what are the costs that are currently externalized? If a company wanted to start to analyze and track these externalized costs, how would they do it? What are the categories of externalized costs in each phase of the lifecycle? And what is the appropriate methodology for itemizing costs in each category?

Who should be involved?

- People with expertise in the externalized impacts in each phase of the supply chain (NGOs, government agencies, UNEP)
- OEM, industry experts with information on costs, bill of materials for different phases of supply chain

Business Models: Notes

Issue: ICT as an Enabler of Sustainability

What are the key research questions and recommendations?

- How can ICT enable smarter and more efficient use of natural resources (e.g., energy, water)?
- In which industries can ICT be most effective in driving sustainability improvements and what is needed to enable such changes (e.g., capital, policies)?
- How can different service models drive sustainability improvements?

What standards are needed?

- Common methodology for calculating sustainability impacts and benefits.
- Platform to share tangible actions for improvement opportunities (e.g., industry, government, consumers).
- Standards to enable more interoperability between technologies, software and so forth.

Who needs to be involved?

- OEMs, service providers, governments, consumers and utilities.

What is the role for regulation?

- Regulation could develop policies to incentivize opportunities (e.g., economic).

What resources are available?

- ICT company resources, utility resources, government funding/policies and university resources.

What are the barriers?

- A better connection is needed between utilities and ICT providers to more rapidly develop sound solutions.
- Policies/markets do not internalize costs of natural resources, thus minimizing opportunities for change.

Issue: Internalization of Costs of Externalities

What are the key research questions and recommendations?

- Survey of available tools.
- Success analysis of tools.
- Valuation methods.
- Need tool to identify all current costs that are externalized throughout the lifecycle of electronics products

What standards are needed?

- Proposed phase-in of standards (i.e., carbon, water, then toxics, then valuable metals and so forth).

Who needs to be involved?

- Environmental groups, legislators, Congress, the Administration, agencies, U.S. trade negotiators, international trade partners, University researchers

What resources are available?

- Knowledge gained from carbon trading and carbon tax initiatives.
- Grant funding.
- Political pressure.
- Support from environmental voters and activists.

What are the barriers?

- Politics.
- Weak economy.
- Discord in the carbon tax universe.

Additional Notes

1. Build and vet the model (limited scope, such as carbon, water)
2. Voluntary transparency/limited scope
3. Evaluate
4. Voluntary standards
5. Determine path (voluntary, market, mandate)

Iterate:

- Create path
- Reduce political and economic shock
- Phase
- Respond to data and science
- Guide to path—voluntary, market, mandate

Business Models: Notes

Issue: Increase Product Utilization

- Difficulty in assigning values.
- Resistance from impacted industries.
- Political contributions from impacted industries.

What are the key research questions and recommendations?

- Use products longer, increase durability and collect unused products out of storage.
- How many ICT products are un/under-utilized by consumers?
- What is the amount and length of time of stored electronics?
- What are the trends in product longevity?
- How long can hardware provide value in the marketplace?
- Need to distinguish market demand for products and which section of the population includes early adopters versus those willing to use older technology.

What standards are needed?

- Software standards development to allow applications and content to be accessible via multiple hardware platforms.
- Service-based ICT solutions model. Can we create a system for this process?

Who needs to be involved?

- Software and hardware firms need to develop platform standards to allow for multi-platform solutions.

What is the role for regulation?

- Allow ICT service providers to sell resource use as a utility to avoid the problems of financing a distributed power grid network.

What other approaches should be used to tackle the issue?

- A service-based ICT solutions delivery model should be developed and demonstrated to succeed in satisfying the needs of customers while better managing products for optimal resource use.

What resources are available?

- Current research on storage rates of unused ICT products in Japan and the United States performed by Dr. Eric Williams.

What are the barriers?

- Limited knowledge of who owns the ICT. If a user only leases a product (rather than purchases and owns it), or is just sold access to content, are they able to emotionally divorce themselves from the product?

Issue: New Business Model: Role of Consumer Research

What are the key research questions and recommendations?

- Why do consumers not use services to return unwanted/EoL products?
- Why do consumers inconsistently use energy-saving product features?
- Will consumers trust that private data will be wiped in the EoL/refurbishment/recycling process?
- How can consumers be motivated to develop a continuous relationship with their data instead of a physical hardware product?

What standards are needed?

- Standards may be needed to motivate and incentivize customers to drive the ICT industry (e.g., manufacturers, retailers, refurbishers) to enable an extended product life.

Who needs to be involved?

- Behavioral psychologists, marketers and consumers.

What is the role for regulation?

- Unclear role for regulation until the key drivers or incentives to shift behavior are determined.
- Regulations could be used to drive interventions.

What other approaches should be used to tackle the issue?

- Education and awareness to drive shifts in consumer behavior.

What resources are available?

- Existing consumer research.
- Transformational shifts that have occurred already in other regions to become more sensitive to environmental topics.

What are the barriers?

Issue: Corporate Culture and Governance

- Humans form emotional bonds with their hardware products and tend to hoard them.
- Distrust in data security.
- Financial incentives are not enough.

What are the key research questions?

- What composition or other characteristics of corporate boards enable and support sustainable thinking?
- Where in a corporation lies the power to support/implement sustainability thinking?

Business Model: Notes

- Short-term view: What needs to change to enable long-term investment and change? Is everything limited by market organizations or quarterly profit reports?

What standards are needed?

- Develop a research-based standard—maybe a certificate program—for "long-termism."

Who needs to be involved?

- Investors and board members.

What is the role for regulation?

- No role for regulation.

What other approaches should be used to tackle the issue?

- Self-reflection and analysis of OEM companies.
- Short term: education and public discourse on balancing ethics versus financial gains.
- Long term: internalize costs.

What resources are available?

- Green investing community.
- Global Reporting Initiative.
- Dow-Jones Sustainability Index.

What are the barriers?

Issue: Informal Sector

Lack of models for balancing morals/ethics/behavior with financial returns.

What are the key research questions and recommendations?

What incentives are needed to redirect dangerous materials processing from the informal to formal sectors?

- What financing and institutional arrangements are needed?

What standards are needed?

- A set of practices and a price-setting system to collect devices or parts.

Who needs to be involved?

- OEMs, government and the informal sector.

What is the role for regulation?

- Regulation ensures appropriate financial incentives.

What resources are available?

- The work of groups at the Swiss Federal Laboratories for Materials Science and Technology (EMPA; Switzerland); the National Institute for Environmental Studies (NIES; Japan); and the Rochester Institute of Technology (RIT; United States).

What are the barriers?

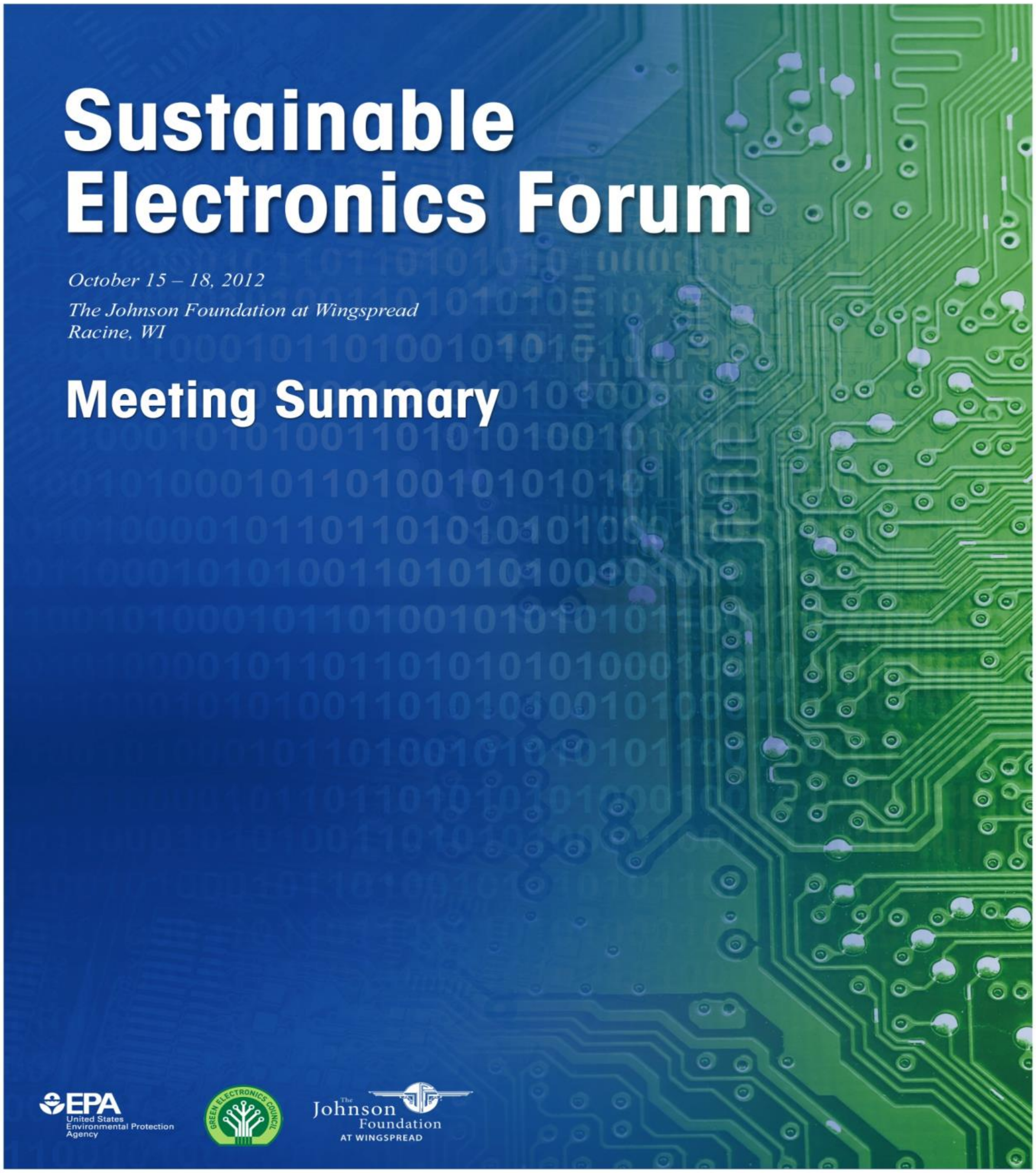
- Perception that informal recycling can only be mitigated by banning the whole informal sector governance and financial constraints in developing countries.
- Domestic imperative in China to develop manufacturing rather than promote reuse.

Additional Notes

1. Next steps: gather information from existing roadmaps: iNEMI; GreenTech
2. Upcoming events:
   - 2012 Eco-Design, Japan
   - 2013 International Symposium on Sustainable Systems and Technology, USA
   - 2014 Care Innovation, Austria
3. Websites
   - iNEMI.org
   - greentech.org
4. Publications
   - *Resource Conservation and Recycling*
   - *Environmental Science and Technology*
   - *Journal of Industrial Ecology*
5. Additional Events/Forums for EPA to organize
   - Education of EPA
   - Education by EPA of the consumer
6. Recommendations for EPA
   - Education on sustainability
   - Benchmarking of other countries
7. For other players
   - Recommend business incentives for the informal sector.

PART 3.

5. Meeting Summary



5.0 Day 1 – October 16, 2012

5.1. Welcome and Conference Objectives

Representatives from each of the Forum co-sponsors: EPA, GEC and TJF, gave a brief introduction to the Forum and spoke about Forum goals for their respective organizations. The Sustainable Electronics Forum was facilitated by Ms. Helen Clarkson and Dr. James Taplin of Forum for the Future, who introduced their organization, described the meeting process and Forum objectives.

U.S. Environmental Protection Agency
Alan Hecht, Director of Sustainable Development, ORD

Dr. Alan Hecht welcomed all participants to the Forum and expressed gratitude for their preparation and involvement. He thanked TJF for hosting the event and EPA colleagues: Drs. Meadow Anderson, John Leazer and Endalkachew Sahle-Demessie for helping plan the Forum. Dr. Hecht remarked on the incredible assembly of experts in sustainable electronics who possessed insight to contribute to the roadmap development. The outcome of the discussions will be helpful for EPA as well other federal agencies and the private sector.

EPA is focusing on the theme of sustainability to guide current projects and future initiatives. The Agency's traditional role as a regulator of industry has been evolving toward a proactive, holistic approach to achieve sustainable outcomes. Understanding the economic, social and environmental impacts of various actions helps decision makers move in a sustainable direction.

In 2011, EPA commissioned a National Academy of Sciences (NAS) report on how best to incorporate sustainability Agency-wide. The report was followed by more than 80 listening sessions that consulted a variety of stakeholders to garner feedback on how to move sustainability forward at EPA. Stakeholders responded positively that EPA should be investigating how to solve current global issues, not those limited to regulation. They agreed that problems will be solved by applying a "sustainability lens" to global issues. As a consequence of these discussions, EPA developed a sustainability plan that currently is under review.

The Agency is developing breakthrough objectives to address high-priority sustainability goals. Zero waste is a long-term objective, and to achieve this goal, science and technology advances are needed. One example is the underlying science that will enable developed products to be more recyclable. Partners such as the National Institute of Science and Technology (NIST), are collaborating on initiatives to enhance the recyclability of rare earth elements, leverage tools for product labeling and improve recycling guidelines.

Dr. Hecht emphasized that through collaboration, government and business can achieve tremendous success, especially in the areas of electronics manufacturing, labeling, and import and export. The long-term global sustainability issues will continue to challenge how to apply EPA's internal research capabilities to achieve breakthrough objectives. The insights, discussions and results of the Forum will help EPA plan for a sustainable future.

Green Electronics Council
Wayne Rifer, Director of Standards

Mr. Wayne Rifer encouraged participants to take advantage of the beautiful conference facility at TJF, to think big about the challenges facing the electronics industry. He explained that the role of GEC, a nonprofit organization, is to advance sustainable ICT and manage the environmental rating system known as EPEAT®. The success of EPEAT® already has contributed to making electronics more sustainable by improving the performance of registered products; and the tool is being enhanced. The global demand for ICT products is increasing, but the supply must be sustainable. From Forum discussions and other stakeholder processes, GEC would like to garner input that will influence the future direction of EPEAT®.

Mr. Rifer described the role of the four GEC representatives present at the Forum. Mr. Robert Frisbee, possessing a business background, is the CEO of GEC and directs the organization. Mr. Jeff Omelchuck, who founded GEC, runs the daily operation of the EPEAT® registry. Mr. Omelchuck also managed this event's predecessor, a workshop in 2008 that explored sustainable ICT. Ms. Pamela Brody-Heine and Mr. Rifer work together to run the standards program by engaging stakeholders to ensure that the standard-setting process is done well and fairly, and that all voices are heard.

GEC management recently decided to include in EPEAT® environmental standards for televisions and imaging equipment. Importantly, standards set a benchmark for a new product group and the process of setting standards encourages industry to engage in accomplishing sustainability objectives. GEC appreciates industry feedback and support, and could not accomplish its objectives without partnerships with industry, NGOs and EPA.

GEC staff expect Forum outcomes to guide the organization in setting guidelines for what industry should strive to accomplish. Mr. Rifer encouraged all participants to leave their stakes in the process behind, and contribute his or her unique perspective and expertise to the collective thinking about the interests of the society at large. It is important to consider everyone's perspective as the group discusses various topics, including product disassembly, resource conservation and EoL. Mr. Rifer emphasized that the goal of the Forum was to explore opportunities and differences to develop a sustainable electronics roadmap. This will detail research objectives and specific criteria for standards to inform the ICT industry of the destinations and how to proceed toward them.

The Johnson Foundation at Wingspread
Susie Seidelman, Environment Program Associate

Ms. Susie Seidelman welcomed participants to the conference facility, noting that TJF acts as a convener to encourage innovative solutions with sustained impact for important sustainability challenges. She expressed appreciation to her colleague Ms. Lynn Broaddus, Director of Environment Programs, for speaking to the assembly at the welcoming dinner last evening. Ms. Seidelman mentioned that TJF's President, Mr. Roger Dower, also was present during the meeting. She reminded participants that she and other TJF staff would be available for the duration of the Forum to provide any assistance needed.

Forum for the Future
Helen Clarkson, Director, and James Taplin, Principal Sustainability Advisor
Sustainable Electronics Forum Facilitators

Ms. Clarkson explained that the mission of Forum for the Future is to work globally with business and government to create a more sustainable world. Forum for the Future was founded in the United Kingdom 16 years ago because the environmental movement needed to establish a voice for what a sustainable future should look like and identify practical ways to achieve that future. Ms. Clarkson specializes in the "futures" process, which applies a systems approach to identify leverage points available to address change. Dr. Taplin, specializes in identifying gaps in using ICT for sustainability and which services should be provided to customers to make a more sustainable future.

Sustainability is an achievable goal, but urgent actions are needed to get there. Forum for the Future works to harness the power of companies that are looking at opportunities available through sustainability initiatives. The organization applies the same techniques and processes to companies as diverse as PepsiCo and Nike to facilitate change and help minimize the learning curve associated with sustainability efforts. Another goal of Forum for the Future is to convene diverse stakeholders to achieve consensus on important sustainability-related topics. Dr. Taplin explained that direct and indirect effects of actions on sustainability must be considered in developing a collaborative network for sustainable solutions.

5.2 Participant Introductions

The delegates introduced themselves, each stating his or her name, organization and one objective that the electronics sector should achieve by the year 2030 (see Appendix I for the list of Forum attendees). The delegates produced the following list of aspirations:

- 100 percent of electronics recycled and reused through formal channels.
- A serious cross-industry international effort to reduce toxics.
- Products that minimize energy used and maximize recyclability.
- Living in a truly closed-loop society.
- Many people in the developing world employed in recycling electronics safely.
- Electronics based on green chemistry and sustainable materials.
- A service model to address the use of materials.
- Groups of people coalescing around common goals.
- Conflict resolution between product longevity and business models.
- Use of design to address hazards throughout the lifecycle, especially production.
- A full chemical inventory of all materials in products and agreement on alternative assessments.
- Electronics viewed as having been a driver for advancing sustainability.
- Fulfilling the promise for creating healthy and prosperous lives globally, while avoiding negative impacts.
- Quantitative design tools to evaluate sustainability performance.
- Application of the social elements of sustainability to the entire supply chain.
- All manufacturing facilities practicing the best environmental and safety standards.
- Demonstration of leadership in supply chain transparency.
- Join forces to grasp opportunities to be more sustainable.
- Develop a systems integration method to better optimize resources.
- Consumers have a responsibility to influence sustainability.
- No further need for EPA because sustainability has been achieved.
- Every electronic device is designed for sustainability.
- Develop a new power system not reliant on rare earth minerals.
- Consumers expect all products to be “green.”
- Drive greater cross-industry collaboration.
- Change the business model to a service model, with multiple reuse and recovery at EoL.
- On the road toward sustainability in the right direction.
- Home-use ICT runs on zero energy.
- Unified vision of the vast benefits of sustainable ICT and a common framework to assess these benefits.

5.3 Overview of the Forum

The purpose of the Forum was "to bring together forward thinkers in electronics design, manufacturing and recycling to develop a shared vision and roadmap for sustainable electronics of the future, and produce specific recommendations for research agendas, standards setting and voluntary manufacturer initiatives." The Forum was designed such that each stage in the process built upon the one before (see Appendix II for the Forum agenda). The first stage was for participants to think about the future of sustainable electronics, including what the sector needs to look like by 2030. The second stage was to set a top-level vision to address how the electronics sector contributes to a sustainable future, how megatrends affect the sector and what key themes should be considered for the roadmap. The third stage, "roadmapping," was comprised of setting the outcomes for each theme, agreeing on goals and milestones, and populating the roadmap with details concerning research questions, standards development and voluntary initiatives.

The first day of the Forum focused on development of a collective vision for sustainable electronics and the identification of sustainability themes. These were based on topics identified by the participants through interviews in advance of the Forum (see Appendix III for a compilation of the interview results). The next two days were used to develop a roadmap that details research and standards recommendations suggested by the group. Participants considered the key research questions, necessary standards, who needs to be involved, the role of regulation, available resources, and barriers to achieving each goal. Ms. Clarkson noted that the agenda was flexible and the process would be reevaluated periodically during the Forum to ensure that progress was being made toward accomplishing the stated objectives.

The Forum was designed as a "futures" process. This is a formal technique to identify long-term objectives and how best to achieve them, thus improving decisions. The futures process strengthens long-term strategic planning; stimulates product, service and system innovation; prepares organizations for emerging trends; helps build future visions; drives organizational change; and inspires new ideas through dialogue and convening. Ms. Clarkson noted that disagreement and challenge is an integral part of the process, and better outcomes will be developed if participants consider all facets of an issue. With regard to scope, the Forum will address the integrated relationship between ICT and sustainability.

As one example, in the pre-Forum expert interviews (see Appendix III), participants identified currently unsustainable ICT business models as an important topic to address. Organizations should think about and plan for a sustainable future to remain competitive in the long term; a company with a business model based in resource depletion will not be sustainable in 30 years. Thinking about this issue now will prevent crises in the future.

5.4 Sustainable Electronics Vision

Participants worked together to develop a high-level vision for the future of sustainable electronics, and a shared overall goal for the roadmap. The participants began the vision development process by imagining how society might be 30 years from today. As a contrast, attendees were directed to think about life 30 years ago, including housing, entertainment and hopes for the future. For example, Sony released a CD player in 1982 that cost $1,000. The Cold War was ongoing, and Cal Ripken, Jr., began his baseball streak. Using these examples, participants discussed other changes seen over this period of time to explain the scale of change that could happen within a 30-year span.

One participant remarked that people communicated with letters or phone calls; email had not been invented. Climate change was not recognized as a concern; recycling did not exist; and organic food had not yet become popular. EPA's Superfund program was being established, and brown water contamination was a concern. Another participant remarked that 30 years ago marked the beginning of the proliferation of cheaper air fares, encouraging mobility. One attendee noted that it had been more difficult to find needed information 30 years ago; however, it remains difficult today because of information overload on the Internet. Several attendees concurred that quality of life is more of a challenge now, and being laid off is more of a concern. College costs have risen dramatically, and manufacturing has globalized.

5.5 Future Scenarios

Given the scale of change possible in a 30-year span, participants then used "Futurescapes" scenarios developed by Forum for the Future in collaboration with Sony to consider sustainability trends and their interactions. To stimulate broad discussions during the visioning process, the meeting facilitators presented four alternate scenarios for the future of technology and asked participants to discuss what a sustainable ICT industry would look like in each scenario. The scenarios were not predictions of the future, but rather potential options to help participants think more broadly about long-term narratives.

All scenarios began with the question, "What is the role of technology in helping people lead more sustainable lives in 2025?" The overall process was to consider the scenarios in the context of the future of sustainable electronics to develop innovative ideas about the future. The four scenarios included:

Hyper-Innovation
Rapid innovation has ushered in a low carbon world. Lifestyles and business practices have been minimally affected—people live in a fast-paced consumerist society. Against a background of diminishing resources, however, there is growing concern about the long-term sustainability of this "innovation treadmill."

Centralized Survival
Stunned into a belated response by a series of severe climate shocks in the early 2020s, governments have taken tough measures to combat climate change. People live in a world where technology has maximized its limits to impose sustainability on the population. There is a sort of "blitz" spirit despite the restrictions on personal freedom.

Shared Ownership
Growing concern about climate instability has driven governments worldwide to agree on an early response to climate change. The results are high carbon costs and an entirely new perception of ownership. People live in a world where many businesses have had to develop models that deliver a service at the lowest carbon cost.

Prosperity Redefined
After an extended recession, new priorities of "well-being" and "quality of life" are bubbling up across the world as more sustainable forms of living become established. People live in a society with strong sustainability values and connections to the community. Technology facilitates collaboration at local and global levels.

Participants broke into groups to contemplate the four scenarios and generate material to develop the vision for sustainable electronics. Each group was presented with a short video and a detailed introduction to the scenario. They were given instructions to discuss the ICT products and services that exist in that fictional world. After the groups reported back on the attributes of sustainable ICT within their prescribed scenario, the plenary assembly would identify similarities and differences between the scenarios. Common strategies that worked for multiple scenarios would be taken as particularly effective. The important ICT themes for each scenario, developed by participants, included:

Hyper-Innovation
Electronics are manufactured as cheaply as possible and trade regulations are lax, leading to high-throughput innovation. This society needs high-efficiency data centers and products that have energy-efficient infrastructure and long lives. Video surveillance is a possibility in this scenario. Biologically based materials and intelligent interfaces are more popular. People have universal access to computers, and business models have become more service-oriented.

Centralized Survival
The centralized survival society is characterized by government mandates for energy minimization, resulting in intense monitoring of personal energy use and shared use of energy-intensive products. Electronics are modular and designed for a long life. Microenergy harvesting, using kinetic energy is popular. "Smart grid" technology has improved energy robustness. All supply chain toxic materials are transparently reported and LCA tools justify each product's material composition. This is a service-based community with tools to build community connectivity.

Shared Ownership
ICT in a shared ownership society is energy-efficient and operates using a service model. The energy-consuming components of ICT are modular and cloud computing is prevalent. Electronics are produced with low-impact and lightweight materials. Metal recycling, three-dimensional printing and carbon monitoring are popular. Despite the positive impacts of a closed-loop electronics sector, people lack privacy and human interaction.

Prosperity Redefined
In the prosperity-redefined society, communal living and collective use of ICT products is the norm. An emphasis is placed on quality of life and health, and facilitated by biofeedback sensors built into every type of product. Software is universally open-source, and centralized data centers result in less client-side hardware and less waste. ICT capacity for storage, memory and computation has increased dramatically while reducing energy use. Constant and ubiquitous monitoring of all activities ensures full transparency of all processes, and enables OEMs to track products so that no resources are wasted. People have less privacy in this scenario but have decided that the benefits of a communal society outweigh the lack of privacy.

The participants discussed theme clusters from each of the four scenarios, including supply chain transparency, energy efficiency, sustainable materials and new business models. The clustered themes developed from this exercise are described in Appendix IV. Participants brought together common themes from each scenario to shape attributes of a sustainable ICT industry. They also used common themes to develop a broad vision statement to ground future discussions about the roadmap details and drive actions forward.

5.6 Vision Statements

To stimulate thinking about an overarching vision for the electronics sector, attendees arranged themselves into five groups that included representatives from each scenario group. They were instructed to draft a top-line vision statement for the industry based on previous discussions. The facilitators provided an example vision statement, which read, "Electronic devices are materially efficient, multi-functional and long-lived. They are part of a closed loop. They require very small amounts of energy to run and are usually grid-independent. They support services that are socially valuable." The following Forum vision statements were developed by the five groups:

Group 1
Sustainable ICT will enable us to maximize human potential over time while minimizing the life-cycle adverse impacts of devices, infrastructure and services.

Group 2
We envision a world where electronics facilitate social justice, equity and internalized costs; and are biologically benign across the entire lifecycle. This is based on sustainably managed renewables and nonrenewables (infinite recyclability), that maintain ecosystem services and are less resource-intensive.

Group 3
Design electronic technology and services to empower people, promote innovation; and protect and enhance human health, well-being and the environment. In order to be sustainable from a life-cycle perspective, electronic devices and services are: energy and resource efficient; nontoxic; long-lived and refurbishable (modular); 100 percent reused and recyclable; closed loop; manufactured with transparent supply chains and materials (verifiable); affordable; and designed to promote human potential.

Group 4
Universal and simple metrics exist for: material and process toxicity; resource efficiency; value efficiency (is it worth it?); safety and profitability of EoL; and enabling other industry efficiency.

Group 5
Electronics are sustainably designed to take into account responsibility for the entire lifecycle, multigenerational impacts and planetary system boundaries. This includes: closed loop, material and energy resource efficiency, benign materials, transparent supply chains, and meeting both individual and societal needs.

The participants combined elements from each of the draft vision statements to develop consensus on the following working vision statement:

Sustainable ICT will enable us to protect and enhance human health, well-being and the environment over generations, while minimizing the adverse life-cycle impacts of devices, infrastructure and services.

The group used Forum for the Future's Sustainable Economy Framework to expand this vision for particular social and environmental constraints, including greenhouse gas emissions and human rights. They considered the actions necessary to achieve the vision statement. This was the first step in developing the roadmap themes based on the vision statement.

5.7 The Sustainable Economy Framework and Implications for the Future of Electronics

During the Forum, participants considered the macro question: What would a sustainable economy look like, and how will the electronics industry fit into a sustainable economy? To frame the conversation, Forum for the Future provided an overview of the Sustainable Economy Framework (http://www.forumforthefuture.org/project/framework-sustainable-economy/overview). This is a tool that defines the characteristics of a sustainable economy in 2030 as one that operates within safe environmental limits and enriches people's lives. Forum for the Future developed the Sustainable Economy Framework in partnership with the Technology Strategy Board and Aviva Investors. It is based on the analysis of more than 40 sources and frameworks examining the topic of a sustainable economy. Sources included the World Business Council for Sustainable Development's "Vision 2050," the United Nations Millennium Development Goals, and Tim Jackson's "Prosperity Without Growth," as well as extensive stakeholder consultation.

The goal for the future is to help nine billion people lead happy, fulfilled lives. Resources are not evenly distributed, and future access to resources will change as consumption approaches finite resource limits. According to the U.S. Geological Survey, only an eight-year supply remains for some metals if they continue to be consumed at the current rate. A shift toward reincorporating resources into products will extend the availability of nonrenewable resources. The Sustainable Economy Framework was designed to clarify the characteristics of a sustainable economy, identify what needs to change, and develop research goals. The outcome goal involves universal and continuous access for current and future generations, to the resources and opportunities to live well. A stable economy, supported by a stable social and political foundation, is needed to achieve this outcome. Environmental boundaries encompass a stable economy and society. Notably, the Sustainable Economy Framework paradigm is similar to the environmental, social and economic issues that comprise the three pillars of sustainability.

Waste is one example of a Sustainable Economy Framework application. It is important that waste is not produced at a rate greater than natural systems can process it. A broad range of structures needs to be in place to honor this limit. Understanding long-term management of resources, what constitutes waste, and how to best recycle products at EoL, all play into efficient waste management. In a future closed-loop society, waste will be a commodity that will be efficiently utilized to minimize virgin resource consumption.

The participants used the Sustainable Economy Framework as a tool to explore the range of impacts from electronics. This included threats and opportunities, which will affect a sustainable economy. Notably, the Sustainable Economy Framework does not address population growth but instead looks to improve life for all people. In applying the Sustainable Economy Framework, it is important to consider hard biophysical limits. For example, crossing any environmental boundary increases the risk to operations while relieving pressure on a boundary opens new opportunities. Socio-political limits, including social and political foundations, make long-term success possible. Working where these foundations are not in place increases the threat to the success of operations. Referring to the waste example, a hard biophysical boundary is that waste must not be produced faster than natural systems can process it. To achieve that outcome, the correct socio-political foundations of "long-termism," information and supply chain skills must be in place.

Dr. Taplin and Ms. Clarkson presented a series of 32 Sustainable Economy Framework cards, each of which defines one element within the environmental boundaries or socio-political conditions. Participants were instructed to prioritize the cards with respect to their impact on electronics. They chose to focus on the environmental boundary cards, which detailed global warming/carbon reduction, chemical pollution, renewable resources, nonrenewable resources, blue water, biodiversity, land use and waste. Environmental boundary cards that were put in a "maybe" category included ocean acidification, the ozone layer and atmospheric aerosols. Socio-political limit cards prioritized by participants included equity, information, accountable government, resilience, inter-dependence of human and natural systems, skills, universal access to energy, education, science, trust, human rights, measurement and long-term thinking. Cards in the "maybe" category included civil society and poverty.

After prioritizing the Sustainable Economy Framework cards, participants formed small groups to discuss each relevant issue as it relates to a sustainable electronics industry. Attendees were instructed to think about the recently developed vision with respect to each environmental or socio-political condition. They also discussed changes within the electronics industry crucial to achieving the desired outcomes prior to 2030, and noted specific actions to be taken. Following the small group discussions, participants reported back on the issues identified for a subset of the environmental boundary and socio-political conditions, describing how the topic impacts the vision statement and any actions or priorities identified. The report back included a discussion about the following Sustainable Economy Framework topics:

Accountability. Supply chain transparency of resources is needed long term.

Blue water. Water use throughout the supply chain needs to be minimized to reduce long-term effects on water availability.

Chemical pollution. Employing LCA to evaluate the impacts of chemicals is very important; furthermore, all assessments must be transparent and standard across all businesses. An important question is what chemicals are used in materials and processes, and are they toxic. If they are toxic, what is the best way to encourage use of a less toxic or benign replacement? One strategy to address this topic is for EPA to create a standard assessment methodology for LCA so that chemicals and alternatives can be compared easily. EPA already has a database with more than 8,000 chemicals. LCA of an electronic product, however, needs to address the impact of more than one material; the efficiency of this process needs dramatic improvement.

Energy efficiency is a very complicated problem, and aggressive goals are warranted.

Equity can be considered from two sides: equal use of ICT and how that use can affect global equity. For example, global access to information can be achieved by increasing the investments of global coverage to improve infrastructure and taking industry-wide actions to stop censorship. Better transparency throughout the supply chain can be achieved if consumers and large purchasers demand living wage and benefit information for all products.

Global warming/carbon reduction. Greenhouse gas reduction can be achieved by applying a systems perspective to optimize processes related to components manufacturing. Improving system architecture and design, as well as product management, will help to mitigate global warming.

Human rights. There needs to be criteria for human rights, and contracts should be based on sustainability. Reducing the gap between those who have access to information technology and those who do not is another important priority.

Land use. Land use is an important consideration when locating manufacturing and recycling facilities with regard to global equity.

Nonrenewable resources. Innovative, minimally invasive exploration technologies to identify sources of mineral and fossil resources need to be developed. Importantly, metals are needed to produce energy, so resource limitations have energy implications. One primary extraction principal is to improve the comprehensive recovery of resources while minimizing adverse impacts. Also, resource availability and appropriate alternatives should be considered when developing and designing products to reduce material intensity in products and services. Transparency surrounding electronics' EoL will maximize recycling and reuse while minimizing pollution. Finally, any adverse effects on land, water or air from nonrenewable resource extraction should be considered, and consumers should be educated about the impacts of resources used in electronics.

Renewable resources. Renewable resources should be valued and used as often as possible in electronic production. Alternative assessments help to identify the most efficient and benign materials for a given functionality. Renewable energy resources, such as hydroelectric power, should be prioritized.

Resilience, defined as the ability for human and natural systems to cope with shocks and stress, requires participatory institutions with the credibility to advance objectives.

Science must be valued fundamentally by society. In the electronics sector, there is variability in how the science is evaluated. When possible, quality assurance processes should be implemented to increase trust and reduce uncertainty in the data. Certifications and standards are not clear or harmonized. American and European governments have the responsibility to do more evidence-based policy making, which requires better science and technology research.

Trust is when common goals and understanding are built through an open process involving all stakeholders.

Waste is defined as any substance that the owner or user discards. A more appropriate definition is "maximized material recovery." Electronic products and toxic materials should be eliminated in landfills, by improving recovery of used electronics and eliminating toxics in manufacturing. Participants discussed the possibility that a landfill is still the best option for certain materials and noted that all options must be evaluated.

Discussion

Dr. Hecht remarked that incentivization is very important to encourage businesses to move toward sustainability. The United Kingdom (UK), Technology Strategy Board's mission is "for the UK to be a global leader in innovation and a magnet for innovative businesses, which can apply technology rapidly, effectively and sustainably to create wealth and enhance quality of life," This mission works by accelerating particular sustainability topics. One example explains how funding for communities in the Future Cities project goes through a sustainability evaluation process to distribute small funding awards. The United States could similarly develop incentive awards. In light of all of the challenges of today, what are the recommendations for an improved role of the federal government in incentivizing change? Identifying important actions and who is responsible for which actions is an important step, and Dr. Hecht reminded participants to capture that information during roadmap development.

The meeting attendees discussed the differences between LCA and toxics evaluation. One participant clarified that toxicity assessment and LCA are interrelated yet distinct processes. A different perspective is to perform alternative assessments with a life-cycle outlook. An important issue to consider is what toxics are produced and in what amounts. Also, how dangerous is the cocktail of chemicals within a product? Risk assessment methodologies should be developed to prioritize actions until there is zero risk. It is important for organizations to be recognized for taking actions to reduce toxic exposure. Emissions, resource scarcity and potential toxicity are other elements to be considered.

A participant noted that alternatives assessments are used for decision making. Notably, if the outcomes identified during the Forum are reached, these chemicals will no longer be called "alternatives" as they will be part of the mainstream manufacturing process. Another attendee commented that information on toxics and alternatives needs to be public, transparent, relevant and validated to make an impact. For example, Hewlett-Packard (HP) has had success with its GreenSpring program, and those results should be shared throughout the community. Supply chain transparency is a mechanism to identify where alternative assessments should happen. Assessments are not a consensus process; rather, they are based on robust science. Businesses would need to be willing to come up with a list of "clean" chemicals that identifies the best choices despite pointing out that some chemicals are not as good. Articulating assessment results clearly, along with the uncertainty in measurements, is important, and material disclosure on electronics is needed to support scientific impact assessments. It also is important not to shift the burden of toxicity across processes.

A participant remarked that one theme on the roadmap should address developing a toolkit to assess impacts across the lifecycle of electronics. Identifying what the tools will be used for and which impacts should be measured will be important. Another participant mentioned that it would be useful to model derivative impacts and the upstream and downstream systemic implications of the chemical content associated with products.

Another important issue is the impacts from critical minerals. Some organizations have the attitude that "we will find more," which is not useful from a sustainability perspective. Tools related to mining impacts—particularly the impacts of new mines on communities and biodiversity—should be developed. Preserving natural capital and biodiversity in all facets of the manufacturing process should be prioritized, and this can be accomplished in part by requiring OEMs to disclose the origin of the materials.

Metrics are an important consideration for the electronics industry and should be used to measure progress toward goals and the minimization of harms. It would be very useful to develop a value method to balance tradeoffs when making important sustainability decisions. Although the application of new electronics can reduce emissions, it can be costly. Policy makers can correct market barriers by providing incentives.

One participant mentioned that linking the electronics business model to fashion (i.e., making sustainability fashionable), might facilitate adoption. Another participant remarked that it is important to develop an attractive long-term financial model that shifts away from "planned obsolescence." This occurs in part because consumers want the newest gadget and corporations make the most profit by selling new products. Taking the environmental load into consideration when pricing products will promote better use of resources. Importantly, sustainability practices often are financially beneficial for business. One method to incentivize these efforts is to base managers' bonuses on sustainable progress in the company. Building sustainable business models for the electronics industry is fundamental to environmental sustainability.

Another business model element is to expand water and carbon taxes, to encourage conservation of resources. One participant mentioned that many companies would find a competitive advantage if carbon taxes were levied. Another participant reiterated the importance of pricing externalities into all products, which is one area where the environmental community could help. The ecological endpoints need to be translated into price through methods such as carbon taxes.

Another need is for absolute, as opposed to relative (local), supply chain requirements. The specificity will be crucial to encourage adherence to the law.

The discussion began coalescing around specific roadmap themes. Participants agreed that health care and impacts of the application of ICT are important themes to explore during roadmap development. Energy and resource efficiency, alternatives assessment, closed-loop processes, EoL practices, supply chain transparency and product longevity are also important issues. Social elements to integrate common objectives throughout the supply chain through consumer engagement, should be considered.

The participants discussed the possibility of organizing the roadmap themes by life-cycle stage, such as product design and EoL, versus topic area or by a matrix. The purpose of the vertical approach would be to consider all trends together in harmonization. The facilitators reminded participants that regardless of the themes chosen, the roadmap should encompass a timeline for actions related to the sustainability goals.

5.8 Wrap-Up

The facilitators and participants reviewed what was achieved during the day and outlined the objectives for the following day. The seven themes that emerged from the visioning, scenarios and Sustainable Economy Framework exercises included: building the assessment toolkit, supply chain transparency, resource optimization, energy efficiency, new business models, access to ICT, and the enabling role of ICT. The outcomes of Day 1 are summarized in Appendix IV. Facilitators and participants decided that the expert presentations on the state and future of sustainable electronics, originally scheduled for the afternoon, should occur in the morning to better inform the roadmap detail development. The presentations will stimulate thought to finalize theme development. Following the presentations, participants will divide into self-selected groups to begin discussions about a roadmap for each sustainability theme. After time for discussion, each group will report back in a plenary session to garner feedback from all participants regarding the important issues, research questions and standards.

To conclude the first day of the Forum, Mr. Dower, President of TJF, welcomed participants to the facility and described his interest in the topic of sustainable electronics. He encouraged attendees to participate in the tour of the Wingspread house, designed by Frank Lloyd Wright, which would take place following dinner. Mr. Dower also noted that the Presidential debate could be viewed in the Guest House living room, and invited all participants to watch the debate together.

6.0 Day 2 – October 17, 2012

6.1 Welcome and Reflections

Ms. Clarkson welcomed the participants to the second day of the meeting, provided a recap of the meeting thus far and explained the process that would be followed for the day. The participants were tasked with thinking about the future and setting a top-level vision as a tool to guide the discussions. Ultimately, the goal was to develop questions to be answered and problems to be solved across the roadmap. The agenda included a balance of plenary discussions with the whole group and more detailed small group discussions. She instructed the participants to discuss the themes identified on the previous day in terms of setting a goal to reach by 2030. One of the goals of the following day's discussions would be to examine the near term (i.e., next five years).

Dr. Hecht asked the participants to consider strategic events or opportunities that might present themselves in the next two years that would be influential and relevant. Businesses make many decisions, and it would be beneficial to examine those in relation to sustainable manufacturing by bringing business people together to discuss these issues. The Administration is looking for action items for the next two years.

6.2 The State and Future of Sustainable Electronics

Several expert participants, including Barbara Kyle from the Electronics TakeBack Coalition, Dr. Christian Hagelüken from Umicore and Dr. Bob Pfahl from iNEMI, presented an overview of their topics of expertise. The presentations were designed to stimulate thinking about specific challenges faced by the electronics community. The presentations and discussion were moderated by Mr. Rifer.

The Sustainable Electronics Vision Project
Barbara Kyle, National Coordinator, Electronics TakeBack Coalition

The Electronics TakeBack Coalition has begun to consider the traits of green electronics as well as metrics and standards that can be used to move toward sustainable electronics. The Coalition identified seven different categories of current electronics impacts. The first is hazards and harm to workers, communities, consumers and the environment as a result of toxic chemicals used during production and in the products themselves. Electronics production workers have high occupational exposures to carcinogens and reproductive toxicants (e.g., solvents, heavy metals, epoxy resins), leading to significantly elevated risks for several types of cancers. Women working in semiconductor fabrication have displayed increased rates of spontaneous abortion and birth defects. Growing concerns regarding the harmful health effects resulting from the production of electronic components have led to epidemiological studies in several countries. Another hazard identified is environmental exposures from discharges.

A second category of impacts identified by the Coalition is the destruction of communities and resources. Extreme pollution of resources destroys sustainable economies (e.g., fishing, farming), and permanently alters traditional lands. Physical effects may also occur downstream and downwind of production activities. A third category is wasted resources. Extraction and production, including chemical refining, consume large quantities of energy from nonrenewable sources and water that is not reclaimed. The fourth and fifth categories are wasteful inputs and wasteful outputs, respectively. Many processes use rare, virgin materials and are inefficient, creating large amounts of waste that is not easily recyclable. The sixth category of current impacts is "sweatshop" working conditions in developing nations where weak laws and enforcement do not protect workers. The final category is the industry's business model, which increases the severity of ICT-related problems because its primary metric is quarterly earnings. The products are designed to be obsolete so that they will be replaced with new products by the consumer. Product design focuses on product performance rather than life-cycle impacts.

The Coalition identified solutions to each of the following impact categories that provide a vision for sustainable electronics: (1) materials and processes cause no harm, including interim protections for workers until this goal is reached; (2) communities are enriched, with activities having a long-term positive impact; (3) natural resources (e.g., energy, water, air) are protected, and processes use low amounts of energy and water and recycle resources; (4) inputs are sustainable, and processes use renewable materials rather than critical minerals; (5) outputs are sustainable, with processes creating zero waste with maximum recycling; (6) working conditions are safe and fair, with decent wages and working hours and no child or slave labor; and (7) new business models prioritize sustainability and embrace life-cycle goals.

The Coalition next examined the broad solution categories across the lifecycles. Broad goals need to be applied to each life-cycle phase, including extraction, production, transportation and retail packaging, product use, and EoL. To determine how to apply the broad goals across each phase, more detailed goals were developed within each category. The Coalition realized the types of problems that needed to be addressed generally fell within three categories: (1) those that could be resolved through product design, (2) those related to sourcing, and (3) those that could be resolved by changing the process design. A color-coded goals matrix was developed as a result, which revealed the supply chain is a critical component of the solution. As a result, a color-coded goals matrix was developed, which revealed that the supply chain is a critical component of the solution.

The Coalition's priority focus is hazardous chemicals, which have the most impacts but receive the least amount of attention. There is inadequate testing before chemicals are placed into commerce, with the workplace and the environment acting as the testing ground. This issue has been complicated by the introduction of nanomaterials, which have been studied even less. Currently, the electronics industry is dealing with hazardous chemicals by phasing them out per the European Union's Restriction of Hazardous Substances (RoHS) Directive. Whether the replacements have been evaluated remains unclear. Because most work is focused on the list of known hazards, the industry has moved toward less-thoroughly evaluated chemicals. A proactive, precautionary approach that includes transparency is needed. Too much information is hidden behind proprietary claims. Efforts must go beyond list-based approaches with more OEM control over the supply chain. Better workplace monitoring as well as evaluation and tracking of health impacts must be instituted. Cross-industry efforts to find safer substitutes must be established.

Closing the Metals Loop: Recycling Opportunities and Challenges
Christian Hagelüken, Umicore

Global electronics sales continue to increase annually, thus increasing demand for technology metals. More than 40 percent of the global mine production of copper, tin, antimony, indium, ruthenium and rare earth elements is used annually for electronics production. Mobile phones and computers account for four percent of global mine production of gold and silver and 20 percent of palladium and cobalt. More than 60 percent of platinum group metals (PGMs) mine production is used in automobiles, which contain an increasing number of electronics. More than 80 percent of the rare earth elements, PGMs, gallium and indium that have ever been mined have been extracted during the last 30 years. Additionally, there has been a massive shift from geological to anthropogenic deposits (i.e., "urban mines") containing large amounts of technology metals. There is confusion regarding the various terms, however, the term "technology metals" is a descriptive term comprising most precious and special metals crucial to electronic products for technical functionality based on their unique properties.

There is consensus on the benefits of a circular economy. The system is complex, and activities in each phase of the lifecycle influence the other phases. As a result, a system-wide approach is necessary to reduce the generation of residues, collect and recycle residues, and improve metal yields via recycling. Although metal applications may change, the unique metal properties will not. Although recycling is crucial for modern society, recycling of most technology metals still lags behind other recycling rates. For example, precious metal recycling rates are below 15 percent. Urban mining "deposits" can be much richer than primary mining ores, however, the challenge is how to accumulate millions of EoL products into urban mines that are of an economically viable size. Recycling requires a chain rather than a single process. Again, a system approach is crucial, with the total efficiency determined by the weakest step in the chain. Therefore, the focus should be on the weakest steps.

The process begins with the product, and certain products are brought together with certain connections. Most products cannot go into metallurgical recovery and must be subdivided. Recovery of low concentrations of technology metals from complex products is another challenge; and smart recycling is needed because traditional mass-focused recycling is not appropriate. The focus should be on high-throughput, low-cost strategies and on trace elements and value. In some cases, higher costs are worthwhile if higher value can be recovered. Metals separation for final metallurgical recovery is a preprocessing challenge, since precious metals, precious steel and aluminum may be lost. Sometimes it is better to lose aluminum or plastics rather than precious metals. The majority of metals are lost if they are not removed prior to shredding. Shredding is a good solution for easy products, but for complex products, it needs to be combined with preprocessing. Rare earth elements, indium and cobalt-lithium recycling, however, do not fit within the process. Dedicated processes exist for certain components, but they require magnet removal. This highlights the importance of preprocessing and product design.

Dr. Hagelüken described Umicore's European plant, which is complex and costly to operate. The facility recovers 20 different metals via two processes, including a universal process and dedicated processes for battery recycling to recover cobalt. The driver is the value of precious metals; and sophisticated technology enables the co-recovery of these precious metals. Recycling is not as easy as it is sometimes portrayed. There are three challenges for metal recycling from complex products: (1) accessibility of relevant components and materials, (2) thermodynamic limits and difficult substance combinations for trace elements, and (3) severe deficits in closing the loop for consumer goods. Collection of consumer products with a high relevance for critical technology metals is poor, and once collected, a great deal of material escapes the system. Increased knowledge about material flows is necessary. For example, the overall life-cycle efficiency for the whole palladium chain is 80 to 90 percent for industrial applications and below 10 percent for electronics. The issue is collection and pretreatment. The industrial closed-loop system has built-in transparency compared to an open-loop system, which has high but avoidable losses.

OEMs need to use innovative business models to recycle products that have high relevance for critical metals. One vision is to create closed loops by OEM service subcontracting throughout the recycling chain. Although it is difficult for the manufacturer to control the chain, in this vision the OEM would recover precious metals from its own products. This standard already is in place for industry catalysts. There is a proposal for a mandatory certification scheme that emphasizes transparency, with the ultimate goal of ensuring high-quality recycling throughout the entire chain. To be successful, comprehensive collection is necessary, and the recycling chain must be set up in an optimal manner. It also is necessary to examine the system from two perspectives: material and product. When these aspects, including design and consumer awareness, come together, success is achievable. There also are a number of research requirements, some of which are less focused on technology but highly relevant (e.g., logistics, socioeconomics).

Producers and recyclers can work together on product development, manufacturing, sales and distribution, and recycling at EoL. The European Union and the United States can work together in the area of recycling by better understanding and monitoring EoL product and material flows as well as by aligning research on the recycling of complex products and residues. The two can collaborate to create a global framework for increased and higher quality recycling.

Discussion

Mr. Rifer noted that some tools to address particular issues (e.g., product design) already exist, but it is not clear what should be achieved with each tool. Standards development is a necessary outcome of this effort. How can the standards help accomplish goals?

Sustainable Electronics
Bob Pfahl, International Electronics Manufacturing Initiative

At a keynote address given 10 years ago, Dr. Pfahl presciently concluded that regulations and requirements were increasing faster than industry could respond effectively. He also noted that industry needed be more proactive in responding by developing solutions based on science and technology. He thought that these solutions needed be available in advance of new regulations and influence future regulations for more sustainable results. Dr. Pfahl predicted that sustainability would be a major undertaking for industry and society and that electronic solutions could help to empower people to live more sustainable lifestyles. By 2021, the primary focus should be on electronic products that empower sustainable lifestyles. It's also important to continue to reduce product energy use and increase product recycling and reuse; and expand the understanding of the ecological impacts on the world.

iNEMI's mission is to forecast and accelerate improvements in the electronics manufacturing industry for a sustainable future. The initiative has a strong research component and three major focus areas: miniaturization, the environment and medical electronics. Technology roadmaps are among its key deliverables. The 2011 iNEMI roadmap defines the needs during the next decade that are necessary for industry to continue to move forward and develop products and new technology. Approximately 600 participants from more than 300 companies in 18 countries across four continents participated in the process of developing the 2011 roadmap by working within 21 technology working groups. The Environmentally Sustainable Electronics Roadmap, issued biannually since 1996, is cross-cutting in that it provides feedback to 20 other roadmaps. In addition to trying to dispose of gold wire bond, iNEMI has been leading projects on lead-free reliability since 2000, as well as polyvinyl chloride alternatives and halogenated flame retardant-free high reliability since 2009. The initiative has also been developing LCA tools for ICT products since 2009. It has sponsored biannual environmental stakeholder forums since 2008. Several research proposals were identified as important during the forum held in 2010, including those focused on LCA. iNEMI, in partnership with other institutions and organizations, has used funding from the National Science Foundation to establish a global traineeship in sustainable electronics. This traineeeship will create a new integrative, collaborative model for graduate research and education that is needed to enable meaningful and measurable improvements in the global sustainability of electronics.

The goals of the 2012 forum, focused on progress in green electronics, and were created to: (1) engage a wide range of perspectives and inputs regarding the electronics industry and iNEMI's environmental focus, and (2) define critical incremental electronics industry- environmental focus and deliverables- for

2013 and beyond. There was a strong dialogue among research institutes, industry and NGOs. Two follow-up webinars were held to focus on the proposals developed at the forum.

In terms of industry impact studies, Dr. Pfahl provided a case study (cleaning of flux), that indicates the need for ongoing scientific and technical evaluation and multi-attribute value analysis. In addition to technology issues, economic, social, environmental and governance issues must be considered. Other problems that industry faces, including materials and their replacements, are better defined. Multi-stakeholder review and prioritization of the more than 400 substances on the International Chemical Secretariat (ChemSec) Substitute It Now (SIN) list are needed. The list must be evaluated for alternatives and their risk and reduced to a manageable level. There also is a need to identify and communicate best practices for recycling as well as to examine eco-design for recycling and sustainability that includes toxicity assessment and critical usage/application. Additionally, there is a need to define the measurable attributes of products that are truly recyclable/reusable.

In terms of next generation tools, transient input-output is needed for new material applications. Simplified LCA is needed for various segments and electronic materials. Also necessary is improved knowledge of user behavior and EoL scenarios. These requirements are cross-cutting and encompass several industries. To conclude his presentation, Dr. Pfahl reminded participants that electronic products are leading the journey to a sustainable world.

6.3. Consensus on Roadmap Themes

Following the presentations, Forum attendees discussed the themes that the group had developed during the previous sessions (see Appendix IV), and compared them with other sets of themes to develop the roadmap. There were multiple ways to divide the issues into themes, and the participants debated the merits of each method. The group chose to work on the seven themes developed by the Electronics TakeBack Coalition and presented by Dr. Kyle, including: Community Enrichment; Safe and Fair Working Conditions; Sustainable Inputs; Sustainable Outputs; Protection of Natural Resources (Energy, Water and Biodiversity); Materials and Processes Cause No Harm; and Business Models. The participants combined Sustainable Inputs and Sustainable Outputs into one group called “Resource Optimization,” which had been one of the themes from the previous sessions.

The attendees confirmed all of the topics that had been raised during the previous sessions were covered by these themes. They then broke into small groups of self-selected participants to produce a draft roadmap for each theme containing several related issues.

The group agreed on the following final list of roadmap themes:

1. Materials and Processes Cause No Harm
2. Resource Optimization
3. Energy, Water and Biodiversity
4. Enriching Communities
5. Safe and Fair Working Conditions
6. Business Models

Dr. Kyle briefly explained what each theme was designed to address. Materials and Processes Cause No Harm was focused on the toxicity and hazards of materials used in ICT products. Resource Optimization considered closed-loop systems with infinite recyclability and zero waste as outputs; as well as the use of virgin versus recycled content. The Energy, Water and Biodiversity theme included energy conservation, greenhouse gas reduction and the maximization of natural resources. The Enriching Communities theme involved the impacts on communities by each life-cycle stage of electronic products, including production, use and EoL, as well as applications of ICT. Safe and Fair Working Conditions considered the well-being of workers within the electronics industry. Business Models involved improving product longevity, modifying systems to be service-based, OEM transparency, how people interact with electronics during the use phase and so forth. Assessment tools (e.g., LCA), unintended consequences, how to motivate organizations to drive the greatest change possible, and the enabling role of ICT would be considered within all theme groups as cross-cutting issues.

6.4 Sustainable Electronics Roadmap Development

Participants divided into six groups to discuss the sustainability roadmap themes. Each group was given a timeline and instructed to identify five to seven issues related to each theme. For each issue, participants considered the key research questions, available resources, necessary standards, the role for regulation and stakeholder involvement. They also identified potential barriers and approaches that could be used to solve each issue; and considered how each issue is relevant to a sustainable society. Participants collaborated throughout the afternoon to develop a draft roadmap that indicated short-term (three to five-year) and long-term (2030) goals for each sustainability theme, including milestones for five-year intervals. The participants also built roadmap detail for the next three to five years, including immediate steps to be taken; upcoming events or publications to build from; additional events or forums useful for EPA to organize and any additional research recommendations for EPA; standards recommendations for GEC; and recommendations for other stakeholders. Ultimately, the draft roadmap would depict what a sustainable electronics system would look like in 2030.

7.0 Day 3 – October 18, 2012

7.1 Roadmap Reports

Participants came together in a plenary session to share the detailed roadmap themes that were developed in the small groups during the previous day. The groups each selected a representative to describe the theme they had addressed; the 2030 outcome; the list of issues and associated 2030 outcomes per issue; and some of the key highlights, milestones and recommendations. These presentations provided a chance for the entire group to reflect on, build and finish the roadmap. The draft Sustainable Electronics Roadmap developed by Forum participants is available as a companion document to this meeting summary.

Ms. Clarkson reviewed the day's agenda. She noted that many productive discussions had taken place during the conference, and expressed hope that these would continue long after the conference. In the interest of time management, however, today's goal was to summarize what had been discussed rather than raise new issues. She described the schedule: a brief time for each group to meet, a plenary session for group reports, final reflections and adjournment. She suggested that during the group session, each group should decide what to share in the plenary session and delegate presentation responsibilities. She asked groups to ensure that all of their thoughts, including feedback on the flip charts, are written down so that they can be captured in the draft roadmap.

During the plenary session, each group should provide a reminder of its theme and expected 2030 outcome; present the issues that were addressed; desired 2030 outcomes associated with those issues and steps needed to achieve those outcomes; and end with some of the key highlights and milestones of the group's discussions. Details will be captured in the conference summary. Ms. Clarkson advised groups to keep the reports concise to allow time for questions and discussion. The session wrap-up, will include discussion of next steps led by GEC, and EPA will offer concluding comments.

7.2 Materials and Processes Cause No Harm

Ms. Pamela Brody-Heine, the group's representative, stated that the theme was Materials and Processes Cause No Harm (i.e., toxics). She noted that the group did not attempt to constrain itself by reality and instead strove to think creatively. The group discussed six research questions on toxics in the ICT supply chain:

- What chemicals are in products?
- What chemicals are used in production?
- What chemicals are used in the extraction of virgin materials used to make electronic products?
- What chemicals are used in EoL processing?
- How can hazardous materials be eliminated across product lifecycles?
- What are the hazardous emissions to air, water and land from the ICT supply chain?

Ms. Brody-Heine stated the goal for research that would address the first question would be to develop an inventory of 100 percent of the chemical makeup of ICT products. An inventory available to product designers could be in the format of a computer-aided design (CAD) tool, which would be fully populated with chemical hazard data and manufacturer information. Ultimately, the goal of this analysis would be to use only biologically benign materials in products. Steps to achieve this goal would include: reaching an agreement among OEMs on the format for requesting this information from suppliers, committing to consistently requesting this information, gathering hazard information, and making the inventory data publicly available.

To determine what chemicals are being used in production, research would be starting later in the process. The steps to take would include: identifying processes used in production; determining what chemicals generally are used in those manufacturing processes (without being manufacturer-specific); identifying hot spots to target; and developing models of best practices, an activity in which the pharmaceutical industry is advanced. Pressure must come from the ICT industry to require chemical manufacturers to develop alternatives to hot spot hazards. As for product chemical composition, the end goal of this research would be an inventory of hazards and chemicals in production that would be verified and publicly available.

The group noted that information generally is available on the chemicals that are used in the extraction of materials, but needs to be made more accessible. Research is needed on what chemicals are used, their impacts, possible alternatives and sourcing from safe mines. Increased use of recovered materials should also be a priority. The end goal would be all virgin material sourced from mines that are certified as safe. For EoL processing, research is necessary on what chemicals are being used and what alternatives are available to those that are hazardous.

With respect to eliminating hazardous materials across the lifecycle of electronics products, the group focused on alternatives assessment. This would involve gathering hazard information on chemicals, identifying a list of “bad” and “good” chemicals, agreeing on a harmonized approach to alternatives assessment, and developing methods for comparing chemicals and materials. Because of the magnitude of the task, it would be practical to group chemicals when conducting alternatives assessments. The goal would be this process would become routine so that no chemical selection would be made without conducting an assessment, unless the chemical is already on the “good” list.

To eliminate emission of hazardous materials across product lifecycles, clean emissions standards need to be developed for water and land. An emissions certification system for mines and production facilities would need to be established.

Ms. Holly Elwood presented the group’s ideas of what could be implemented within the next three to five years. EPA could present developers of bromine-free flame retardants (BFRs), with a Presidential Green Chemistry Challenge award to draw public attention to these chemicals. The Agency also could launch education efforts, such as conferences for computer OEMs and NGOs about 1680.1 standard updates. EPA should market the .2 and .3 standards to federal purchasers and encourage them to purchase only those products that meet the standards. A roadmap is needed for next steps on creating new standards for products. EPA’s ORD and Office of Chemical Safety and Pollution Prevention (OCSPP), could help form a consortium to create the inventories of chemicals in ICT materials and processes. A first step to making a comprehensive list of “good” and “bad” chemicals would be to create a registry of preferred chemicals, perhaps starting with flame retardants. In this effort, it would be helpful if EPA’s Computational Toxicology Research (CompTox) tools were made publicly available. EPA could consider developing a “GreenStar” program similar to ENERGY STAR to educate consumers on the “greenness” of ICT products. In addition, the group suggested that members of voluntary trade organizations and not-for-profits, including iNEMI, the Electronics Working Group of the Sustainability Consortium, the Institute of Electrical and Electronics Engineers (IEEE), and the Comprehensive Approach for the Resource- and Energy-Efficiency (CARE) Electronics, could be briefed on the ideas that the group had developed. This could be accomplished, for example, through presentations at the Electronics Goes Green (EGG) and CARE conferences.

The group participants identified the pressing research questions that should be addressed:

- How can better test methods to verify what is in products be developed?
- How can better information on the fate and transformation of chemicals be obtained?
- What methods can be used to compare alternative chemicals not just on a chemical-to-chemical basis but by comparing chemicals to alternative materials?
- What are the best approaches to develop biologically benign materials?
- What options are available to source different materials?
- What is the best way to map the process chemistry used to develop ICT products?
- Where are the hazard hot spots in ICT manufacturing?
- What chemicals are used in these hot spots?
- What alternatives to these chemicals exist?
- Which processes result in which emissions?
- What is the best way to integrate alternative assessments into CAD tools?
- What chemicals and processes are used in materials recycling and recovery?
- How can the culture and "mindset" of the chemical industry be changed to be more supportive of the move toward green chemistry?

Discussion

A participant commented that process participles should be considered in the roadmap; and pointed out that the EICC is trying to address this issue. She asked where a repository of "white list" chemicals should be kept. She noted that EPA and industry take different approaches to green chemistry for products. A coordinated approach to phase out hazardous chemicals would be highly valuable.

Another participant asked how the activities of the Materials and Processes Cause No Harm Group could be related to those of other groups. Ms. Brody-Heine's response confirmed their ideas are in accordance with international efforts toward harmonization of sustainable approaches.

A participant pointed out that recycling can involve toxic chemicals as well. For example, cyanide is needed in gold leaching operations.

7.3 Resource Optimization

Mr. Rifer, the group representative, noted that the group members had very interesting discussions on outcomes that they plan to continue. He expressed the hope that other groups also would continue their work beyond the end of the conference. The group elected to change its theme from "Sustainable Resources" to "Sustainable Resource Optimization" or "Resource Optimization." The 2030 outcome that they considered was to have radically better closed-loop management of resources where it makes sense. This outcome was intended to capture sustainable inputs and outputs. The group expressed doubt that closed-loop management of resources was achievable by 2030, but believed that radical improvements toward that goal were possible. A number of terms related to the 2030 outcome must be defined: "radically better," "closed loop" and "where it makes sense." This last term requires a multidimensional definition. For example, would it make sense to transport plastic bottles from Nome, Alaska, to the continental United States for processing? The answer is probably not.

The key issues discussed by the group were: defining what makes sense for sustainable resource optimization; quantifying “radically better”; considering collection, product design and transparency of material flows; and optimizing system design and control.

The group recommended setting collection goals in terms of a given percentage of “arising” (i.e., waste generated) that should be recycled, processed and disposed of in landfills. Prioritized devices will need to be collected into responsibly managed channels. Work is needed on identifying which devices to prioritize.

Product design should be proactive, taking into account designing for disassembly, recovery and refurbishing. Incompatible materials should be avoided as long as this does not interfere with functionality. This is a condition that applies in general to sustainable resource optimization: functionality should not be sacrificed to create an ecologically friendly product. Products should be designed for tracking and detection, and mechanisms need to be established for tracking. Considering tradeoffs, products should be designed for less material use.

Transparency of material flows involves knowing the destination and volumes of all prioritized products. Monitoring should be standardized, and the parties responsible and accountable for this information should be identified. Tracing and tracking technology will be required for prioritized products. The absolute amounts and potential toxicity of product components will need to be determined. Questions that arose about transparency were:

- Who needs to know about transparency?
- To whom should this information be provided?
- What will be the technical and economic drivers, rules and incentives?

The group acknowledged that more data is needed about EoL processes: collection, preprocessing and recycling. A problem is that at each stage in the product lifecycle, there are losses of materials. The ability to optimize recovery at each step depends on the previous one; therefore, the entire system needs to be optimized. Currently, health and safety issues hold primacy over efficiency in the recycling chain and drive requirements of the initial provider. Instead, end users should establish the principles for preprocessing, sorting, triage and other activities involved in recycling.

Although defining “closed loop” was recognized as important, the group did not address it, partially in the interest of time.

Discussion

A participant asked for a time frame for establishing definitions. The group agreed that this was a short-term goal that could be accomplished in the next few years. It was recognized that it is valuable to have concrete goals and time frames that are thoughtfully defined. For establishing definitions and standards, the participants discussed the importance of including multiple disciplines and stakeholders from government, NGOs, industry and academia. The Zero Waste Alliance, though small, is such a multi-stakeholder organization that could help lead the effort to set definitions and standards. Dr. Carol Handwerker and Dr. Pfahl volunteered to ensure that the meeting’s 2030 sustainability goals are included in the iNEMI roadmap.

A participant pointed out that many of these activities take place overseas, where EPA has no jurisdiction or influence. It was recognized that it is unlikely that a single institution would be able to address all issues related to ICT sustainability.

In response to a participant's question, Mr. Rifer replied that the process by which his group planned to continue its work was to engage in further discussion via email. He will capture the ideas discussed, and the group will provide feedback to refine them. Another group member added that there was more detail to their deliberations that had not been included in the report back (e.g., research questions). This will need to be captured as well. To continue the work of all groups, participants are needed for their own expertise and to serve as mentors.

7.4 Energy, Water and Biodiversity

Dr. Eric Masanet explained that his group's task was the broad theme of Energy, Water and Biodiversity. The group focused on a few key aspirational goals for 2030. The overarching issue was the ability to understand all the applications of ICT and quantify the resulting benefits of all end uses of electronics. The broad goal for 2030 was to maximize such benefits of ICT deployment, which involves intermediary steps. The first specific outcome was to understand manufacturing and supply chain energy use and thereby achieve a zero net energy and/or carbon footprint. The group judged achieving a zero carbon footprint to be the more feasible goal. The second outcome was to attain zero net water use, which the group recognized would be location-specific. The biodiversity goal was for ICT to have no negative impact on biodiversity or improve it. The group found significant intersection among the issues of energy, water and biodiversity.

There are case studies that provide good data on maximizing the benefits of ICT in sectors such as manufacturing and buildings, but there is much that is not known about ICT benefits and how they change over time and space. For example, what are the benefits of email or digital downloads? The first step would be to inventory what data are available, what data are missing, and where new and existing applications are being deployed. The benefits of ICT use (e.g., energy efficiency) need to be promoted better. Barriers to moving beyond simple, cost-effective applications include the failure to take a life-cycle perspective.

The benefits of developing new markets and applications are poorly known. Research roadmaps are needed for developing quantitative tools and models to quantify benefits. Policy planning is necessary to overcome market barriers. Another challenge is that new ICT solutions might not be adopted because outcomes are not known. Secrecy within the industry can be problematic when attempting to demonstrate potential benefits of new products. The group concluded that verifying, tracking and documenting ICT benefits is a broad area with many opportunities.

The group found that a challenge for achieving a zero net energy and/or carbon footprint is the high degree of secrecy in the supply chain. For example, carbon footprint data are only available at a highly aggregated level. Development of energy performance indicators requires detailed data. This type of information is available for some industries (e.g., steel and cement manufacturing) but not at every step of the supply chain for industries as complex as electronics. An example of industry metrics for energy performance is ENERGY STAR, a joint program of EPA and the U.S. Department of Energy (DOE). If metrics could be established for energy use and performance, OEMs would be able to define standards, best practices and worst practices that would allow comparisons with other OEMs. Policy makers could devise incentives to achieve best practices. If companies minimize their energy demands, maximize their materials efficiency and embrace renewable energy sources, zero net carbon manufacturing might be achievable. Incentives based on metrics will be needed to achieve this goal.

Dr. Karsten Schischke suggested that LCA could provide a basis for developing carbon footprint models, although there are still gaps and uncertainties in such assessments. A footprint model for carbon would be a first step; later, water and other environmental impacts could be modeled. For water, data transparency is a problem. Indicators are needed on the manufacturing plant level to compare facilities. Once indicators are developed, targets can be set and the performance of the supply chain could be regulated. Standards for zero net water use will need to be appropriate to local conditions and linked to product design to be helpful.

Dr. Patrick Eagan noted that the 2030 outcome sought for biodiversity was for ICT to have zero effect on biodiversity or enhance current trends. Little work has been done on ICT's effects on biodiversity. Assessing such effects is challenging when extraction, manufacturing and product use occur in different locations. Biodiversity knowledge and metrics will need to be developed on a regional level. The variables that affect these metrics will need to be understood better. The group recognized that biodiversity is critical for sustainability and is a resource that cannot be recovered once lost. The hope is that by 2020, EPA will develop a way to link biodiversity and resource use. Water use, for example, is linked to biodiversity.

Discussion

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7.5 Enriching Communities

The three parts of the ICT lifecycle—extraction, production and EoL—each have significant impacts on the health, wealth and safety of local communities. Extraction often has destructive impacts on land and communities. Groups such as the Framework for Responsible Mining have formed to address these issues. A key step is to establish a procedure to guarantee that the free and informed consent of the community be obtained before opening a mine. The same approach could be applied to production and EoL. Siting of production facilities is an issue that is open to corporate abuse, with companies often pitting communities against one another to offer concessions such as tax breaks in return for the economic benefits of jobs and economic development. Increased transparency will bring greater public awareness of these issues at all parts of the supply chain. Currently, the EoL phase has received the most publicity, with camera crews reporting on conditions in waste locations. Extraction also has received attention, particularly around conflict minerals, but there are other issues, such as smelters.

The group discussed the need to develop models to bring together the formal and informal sectors. A workable business model is required to use current skills without destroying incentives. HP and other companies provide some examples, but experimentation is needed to develop relevant policy. Offering bounties that would be similar to bottle redemption fees was one suggestion. Metrics are necessary to measure the social impacts of ICT production throughout the supply chain. The long-term 2030 goal of addressing the social impacts of ICT production would be that no ICT materials are sourced from conflict areas and all are reasonably extracted. Research will define this goal further.

Discussion

A participant asked whether the group had considered incentivizing recycling and reuse of critical minerals to reduce the need for new mines. Mr. Ted Smith replied that this had not been discussed, but widespread awareness of critical mineral issues likely already is driving such efforts.

Another participant asked about enrichment of communities when considering internalization of costs. The participant's group had devised a model for considering enrichment of communities. Mr. Smith answered that this might be complicated to measure. For example, communities have offered tax benefits to manufacturers for plant siting and incurred both positive and negative economic effects that can be complex.

The issue of the enrichment of communities by the use phase of the product lifecycle was raised. Mr. Smith responded that this area already was receiving much attention.

Another participant mentioned the International Council on Mining and Metals, which is involved with extraction problems. The Council has multiple initiatives through which it is collecting information that combines the efforts of the formal and informal sectors.

7.6 Safe and Fair Working Conditions

Group leader Mr. Smith indicated that the group's discussions on health and safety standards were couched in terms of the recent recommendations put forth by the United Nations under its initiative on electronic waste codified in the Strategic Approach to International Chemicals Management (SAICM). These recommendations apply to the entire product lifecycle: design, midstream (production) and EoL. The desired 2030 outcome was for all ICT hardware to be manufactured in facilities with best-in-class health and environmental health standards, specifically no forced overtime, forced labor or child labor.

The participants suggested that an initial step toward achieving this goal was to increase consumer awareness by putting a "human face" on occupational and environmental health problems. Because most manufacturing occurs outside the United States, U.S. consumers are less aware of problems. NGOs have been instrumental in trying to increase consumer understanding. As a first step toward equalizing health and environmental standards globally, participants recognized that best-in-class standards need to be identified. Health standards for workers are orders of magnitude less protective than environmental standards.

Participants noted that increasing transparency will require improved monitoring of community health, workplace safety and emissions throughout the full supply chain. Efforts from other industries, such as the Fair Factories Clearinghouse from the apparel and footwear industries, can provide examples. Emissions disclosures should be required for the full supply chain. Comprehensive health and industrial hygiene monitoring is needed as is fair compensation for worker illness. Worker education and empowerment training are important so that workers understand the health implications of toxic exposures and availability of tools to protect their health.

In regard to social impacts, the group called for adopting ILO conventions on living wages, forced overtime, child labor and discrimination. Formation of the EICC was a major step forward for the electronics industry, but other vehicles are needed to advance implementation of the coalition's standards. EICC includes many brands and suppliers from the business sector but has no direct collaboration with government decision makers and NGOs. A major research effort will be required to develop meaningful indicators of the social impacts of implementing changes such as requiring living wages and banning child labor.

Participants identified other key research questions: establishing global best practices for health and safety safeguards for the whole supply chain, determining what new standards are called for, and identifying who should be involved in this effort. Assistance from global experts on specialized subjects will be needed. International institutions such as ILO and the World Health Organization (WHO), as well as the U.S. Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH), can offer their extensive expertise. Barriers in these efforts include lack of visibility and resources.

7.7 New Business Models

The group's theme was developing new business models to achieve the outcome of aligning business decisions with sustainability objectives. Mr. Jeff Eagan, the group leader, indicated that the group had suggested revising the desired outcome by removing the term "business" and instead set a goal of aligning all decisions through the supply chain with sustainability objectives. The six topics discussed were the following: enabling sustainability through broad application of ICT, internalizing all costs throughout the lifecycle, increasing product utilization with a lease model, researching consumer behavior related to sustainability, and aligning decisions within the informal sector to sustainability objectives.

The participants identified the 2030 outcome for using ICT as an enabler of sustainability as being smarter use of natural resources. The group struggled, however, to identify discrete steps to achieve that goal because of the broadness of the desired outcome. ICT could be used to improve medical care and motor efficiency. One suggestion was to award carbon credits directly to ICT providers for ICT applications that improve efficiency, such as coal-fired plants or the transportation sector.

The desired 2030 outcome of internalizing all costs throughout a product's lifecycle was to embed all external costs in the price of a product or service. The participants discussed extensively the methodology to achieve this goal. It was agreed that the process should proceed in a stepwise fashion to reduce political and economic shock. Each advance would be iterative, shaped by new data and science provided by previous steps. First, a model would be proposed and vetted. Businesses then would report within a prescribed scope, costs that had been internalized. From this information, the economic and political repercussions of voluntary, market-driven, or mandated standards could be assessed. The group discussed companies voluntarily reporting all costs that previously had been internalized. For example, a price tag might list both the market price and the "real" price, which would include all internalized costs.

To increase product utilization, the participants suggested a lease model with a goal of maximal utilization of all ICT products throughout their lifecycles. Rather than finding an application for ICT products that are not currently in use, the participants specified that the model should be meeting user needs with the minimum number of devices. A tiered ownership lease model was proposed that involved tiered pricing for new and used models over multiple generations. The zero tier—the EoL tier—could involve the informal sector.

The role of consumer research would be to change consumer behavior to align with sustainability goals. Smart phones, for example, could have an EoL "app" that informs users when a new device is available, provides instructions on how to recycle the device and identifies the three nearest recyclers. Users could transfer all phone data from the old to the new device on site. A key issue would be relieving consumer anxiety about relinquishing old devices. The participants agreed that multiple consumer intervention models could be tested to identify which one was the most effective.

The participants indicated that corporate governance and culture need to be adapted so that business and supply chain decisions become consistent with long-term sustainability. Business models could be changed by establishing research boards to set transparency goals. The emphasis should be on the long-term view. Motivation would be supplied by such boards and possibly, investment pressure.

The goal identified by participants for the informal sector was to empower the informal collection and disassembly sector. A micro licensing scheme could be implemented, and collection activities could be supported by providing personal protective equipment. Recycling activities should be the provenance of the formal sector, which has the capital and environmental controls to do it safely and well. Participants suggested providing device "bounties" in the developing world, which would be equivalent to bottle return deposits, to incentivize collection efforts.

Discussion

Regarding ICT as an enabler of sustainability, a participant proposed that hardware/software solutions should be pursued to maximize energy savings in the end application. There should be a mechanism, such as carbon credits, by which credit for these savings could be awarded to the manufacturer.

Instead of a leasing model, one participant suggested that products should become modular. A participant responded that a better alternative might be to make software- rather than hardware-driven upgrades. One approach to alleviate consumer reluctance to relinquish old devices would be to focus on continuity of the delivery of content.

A participant proposed that marketing would be necessary to change consumer psychology to accept leasing. There was some concern that if innovations were not dramatic enough between models, the leasing idea would not be viable. If cars are considered as an example, performance advances have not been dramatic enough to motivate intergenerational ownership among consumers. Institutional owners, however, have embraced the leasing option.

In addition, in the tiered model, a participant suggested that partnerships between localities and manufacturers should be fostered to directly involve the manufacturer in recycling.

7.8 Reflections and Adjournment

Ms. Clarkson indicated that proceedings from the conference will be distributed within the next few weeks. She asked for a contact person for each group to coordinate communication among the participants through an email directory. She thanked participants for their investments of time and effort in the process initiated at the Forum and for offering imaginative and far-reaching ideas, noting that much work remains to be done. She expressed gratitude to TJF for providing the conference venue.

On behalf of EPA, Dr. Sahle-Demessie thanked attendees for taking time from their schedules to participate in the conference. It was a critical and timely discussion. EPA would like to use the information and ideas provided by attendees to inform science policy and planning. Planning for the Forum began a year ago with the idea of organizing an electronics industry stakeholders' workshop. Much work went into brainstorming themes and ideas for the Forum, and he thanked TJF, especially Ms. Seidelman; the organizing team, including Drs. Anderson and Leazer, Mr. Rifer and the staff of GEC; and Forum for the Future. GEC was instrumental in helping draft the agenda and providing facilitation at the conference. He also thanked The Scientific Consulting Group, Inc., (SCG) for documenting the Forum's proceedings and providing logistical support. Dr. Sahle-Demessie reminded participants to send their reimbursement requests to SCG and complete the online process survey. He then wished conference attendees safe travel as they returned home.

Mr. Rifer added his thanks to the participants, acknowledging the efforts of Dr. Sahle-Demessie and EPA. The first forum was organized in 2008 by Mr. Omelchuck and former EPA Administrator Dr. Paul Anastas. GEC has been engaged in the standard development and implementation process and has met with great success due to the contributions of many of those who participated in that conference. He expressed hope that this Forum will be a watershed in developing and implementing standards and that attendees will catalyze the process by engaging stakeholders, facilitating communication among them and providing direction. An upcoming challenge will be refreshing the IEEE's 1680.1 computer standards.

The participants discussed mechanisms for continued communication among the attendees. Mr. Smith suggested a mechanism such as a drop box rather than email exchanges. Mr. Omelchuck offered access to GEC's collaboration website so that documents and work could be shared. The participants' goal is to complete a formal product from the Forum by the end of 2012. They expressed a desire to work together in the future to support EPA's efforts. The conference was adjourned.

Appendices

Appendix I

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Appendix II

Key Themes Developed—Sustainable Electronics Forum, Day 1

Building the Assessment Toolkit

From the scenarios work, we said: in 2030—everything has carbon metrics, carbon conservation is cool, systems for personal carbon trading and personal data, tools for real life-cycle analysis (LCA) evaluation.

- Developing a toolkit.
- Mechanism to allow group alternative assessment.
- Measuring benefits of information and communications technology (ICT) in society.
- Assessing toxicity of products.
- Assessing organizations—how well they do against toxics action.
- Public/transparent/validated.
- Build absolute requirements into Electronic Industry Citizenship Coalition (EICC).
- Agreed alternative assessment method.
- Full inventory of chemicals in products and processes.
- Measurement: develop metrics on goals of enhancements of metrics reports.
- Measurement: establish third-party verification of metrics reports.
- Measurement: develop methods of balance and trade-off for metrics.
- Need to demonstrate to the industry that chemical reduction processes improve their bottom line.
- For any action related to chemical use or substitution, a full LCA will need to be evaluated and understood.
- Transparency in LCA process is important—businesses must apply standard LCA methodology.
- Assessment methodology (life-cycle and chemical impact) needs to be developed; EPA should develop it.

Supply Chain Transparency

From the scenarios work, we said: in 2030—global trade regulations, global environmental health and safety standards, transparent reporting of supply chain toxics, sharing and tracking of resource use.

- Full inventory of materials in products.
- Material disclosure to support scientific assessment of impacts and opportunities.
- Disclose where materials came from in supply chain (particularly as affects biodiversity).
- Eco label to require living wage and benefit information and worker health and safety (H&S) data for ICT "manufacturing" employees (including mining, manufacture, End of Life [EoL]).
- Agree on Human Rights (HR) (locally adapted?) criteria. Evaluate/track HR performance. Contracts based on HR performance.
- Engagement across the supply chain:

- Consumer engagement.
- Educate consumers about significance of nonrenewable resources.
- Educate consumers about their influence and responsibility in sustainable electronics.
- Link supply chain operators such that they know their influence and interdependence with one another.

Resource Optimization

From the scenarios work, we said: in 2030—move towards lighter materials; more materials with lower energy impacts; big incentive for metals recycling; ICT is less material more versatile; long-living products with inbuilt recyclability and modularity.

- Exploration
  - Improve geological inventory with details about depth, concentrations, ore types, etc. (physical limits to availability).
  - Quantity of resources needed to get material (energy, water, land, etc.).
  - Define adverse effects (social, biodiversity).
  - Develop innovative exploration technology (minimal invasive, affordable, effective).
- Primary Extraction and Refining
  - Improve towards comprehensive recovery of constrained resources while minimizing adverse effects.
  - Improve recovery of historical mine/smelter waste.
- Manufacture
  - Consider nonrenewable resource issues when developing/designing product (including quantitative design tools).
  - Minimize and comprehensively recycle production waste.
  - Reduce material intensity in products and services.
  - Look for appropriate single-use system (SUS) initiatives, but consider adverse effects.
- Use
  - Avoid dilution (entropy) and dissolution.
- EoL
  - Create transparency about real EoL—flows, certification, accountability.
  - Design/improve entire recycling chain with its interactions and interfaces.
  - Develop improved recycling technology.
  - Minimize and recycle process residues.
  - Industrial symbiosis.
- Incentivise collection and recovery of waste streams.
- Develop infrastructure for 100 percent recovery of material.
- Eliminate toxic materials.
- Eliminate exposure to toxics.
- Tools do not currently factor in land use issues of new minerals.
- Closed-loop systems.
- Nonrenewable resources.

  - Different metals have an interdependence with fossil fuels.
  - Energy needs to supply minerals/metals.
  - Metal needs to generate energy.
- Change resource mix towards renewables.
- Redefine waste and maximize material recovery.
- Eliminate landfill of materials and products.
- Water metering and analysis for efficient end use.

Energy Efficiency

From the scenarios work, we said: in 2030—energy efficient infrastructure with long product life; electronics is simple, on when needed, micro-energy harvesting; infrastructure energy efficiency; energy efficiency of data centers and the cloud; centralized computing = less hardware demand = less waste.

- Energy efficient components/processes.
- Energy efficient system architecture and design.
- Smart power management.
- Potential of ICT as energy-efficient enabler.
- Information/tools to inform on systemic energy impact.

New Business Models

From the scenarios work, we said: in 2030—service models that include access for people at all income levels; shared ownership of energy intensive products; closed loop system to help build local; energy consuming part of IT is modular; open source; 100 percent software.

- Modularity.
- Product longevity.
- Long-termism—develop a financial model more attractive to consumers and service providers that shifts from planned obsolescence to providing tech solutions.
- Contracts based on sustainability performance.
- Build incentives for long product use, recycle and take back/collection.

Access to ICT

From the scenarios work, we said: in 2030—community building tools to provide societal connectivity and reinforce common global good; control versus empower; privacy?

- Industry-wide action to stop internet censorship.
- Increase investments to enable global access coverage to data connections by improved infrastructure and kiosks/devices.
- ICT can worsen HR through disparity in access.

    - Need to create devices and services for low income.
    - User interfaces for excluded groups.

Enabling Role of ICT

- ICT can enable renewable energy and reduce water use in power generation.
- Use ICT to support enhanced sustainable agricultural productivity.
- Use ICT to monitor global land use to encourage biodiversity.
- Enabling HR—communications (social media).
- Understanding valuable applications for SMART ICT.

How and Who

- Broad agreement to prohibit undeveloped land for manufacturing and recycling.
- Lobbying for carbon tax.
- Need a participatory, collaborative, credible institution that is a well-resourced technology expert to implement the research and action agenda.
- Participation governance for research and vehicle and action agenda for sustainable electronics that is credible, transparent and well-researched for the long term.
- Build common goals and understanding through an open process. NGO—Government—Industry. Business-to-Business.
- Water tax.
- Carbon tax.
- State and federal governments will base policy on scientific evidence. Evidence passes requirements for quality assurance, including uncertainty analysis.
- European Union has the responsibility to do more evidence-based policymaking because of international implications.
- International collaboration between governments to ensure consistency and leverage resources.

Appendix III
Agenda

Sustainable Electronics Forum

October 15-18, 2012

Sponsored by:

- The U.S. Environmental Protection Agency
- The Green Electronics Council
- The Johnson Foundation at Wingspread

Statement of Purpose:

To bring together forward thinkers in electronics design, manufacturing and recycling to develop a shared vision and roadmap for sustainable electronics of the future, and produce specific recommendations for research agendas, standards setting and voluntary manufacturer initiatives.

"If you want to go quickly, go alone. If you want to go far, go together."
- African Proverb.

Program

Monday
October 15, 2012

5:30 p.m.
Living Room—
Guest House

HOSPITALITY

6:30 p.m.
Wingspread

Welcome and Dinner

Lynn Broaddus
Director, Environment Program
The Johnson Foundation at Wingspread

8:00 p.m.
Living Room—
Guest House

EVENING HOSPITALITY

Tuesday
October 16, 2012

7:00-8:45 a.m.
Living Room—
Guest House

BREAKFAST

9:00 a.m.
Living Room—
The House

Welcome and Conference Objectives

Alan Hecht
Director of Sustainable Development
U.S. Environmental Protection Agency

Wayne Rifer
EPEAT® Director of Standards
Green Electronics Council

Susie Seidelman
Environment Program Associate
The Johnson Foundation at Wingspread

October 16, 2012

Helen Clarkson
Director
Forum for the Future

James Taplin
Principal Sustainability Advisor
Forum for the Future

Introductions and Overview of the Forum

a. Introductions from all participants
b. Overview of the process for the Forum

10:05 a.m. BREAK

10:15 a.m. Setting a Top-Level Vision

a. Future scenarios: What would sustainable electronics look like in the future?
b. Creating a vision and guiding principles for sustainable electronics.

12:15 p.m.
Wingspread
LUNCHEON

1:15 p.m.
Living Room—The House
PLENARY SESSION

The Sustainable Economy Framework and Implications for the Future of Electronics

Participants will consider the environmental barriers and social conditions of a sustainable economy and the implications for sustainable electronics.

3:15 p.m. BREAK

Tuesday Continued
October 16, 2012

3:25 p.m.

Roadmapping I

Participants will develop themes and headings to take forward for the roadmapping sessions.

Wrap-Up

We will review what has been achieved during the day and outline the objectives for Wednesday.

5:15 p.m. WORKSHOP CLOSES FOR THE DAY

5:30 p.m.
Wingspread
HOSPITALITY/TOUR OF WINGSPREAD (optional)

6:15 p.m. DINNER

7:45 p.m.
Living Room—Guest House
EVENING HOSPITALITY

Wednesday
October 17, 2012

7:00-8.45 a.m.
Living Room—Guest House
BREAKFAST

9:00 a.m.
Living Room—The House

Welcome and Reflections

Group discussion to reflect on insights from Day One.

Building From Today

The participants will build on the vision and roadmap developed, drawing on the trends and insights from today.

10:00 a.m. BREAK

Wednesday Continued

October 17, 2012

10:15 a.m.

Roadmapping II

The participants will develop measures of success and milestones for the roadmap.

12:45 p.m.
Wingspread

LUNCHEON

1:45 p.m.
Living Room—
The House

Diving into the Detail

The participants will hear from expert speakers on various topics, from resource recovery to standards development.

Wayne Rifer
Green Electronics Council

Barbara Kyle
Electronics TakeBack Coalition

Christian Hagelüken
Umicore

Bob Pfahl
iNEMI

3:15 p.m.

BREAK

3:30 p.m.

Roadmapping III

Participants will break into groups and continue to develop the goals and milestones outlined in the roadmap and vision, focusing in particular on research agendas, standards setting and voluntary manufacturer initiatives.

Wrap-Up

We will review what has been achieved during the day and outline the objectives for Thursday.

5:15 p.m.

WORKSHOP CLOSES FOR THE DAY

Wednesday Continued
October 17, 2012

5:30 p.m.
Wingspread
HOSPITALITY

6:00 p.m.
DINNER

7:30 p.m.
Living Room—
Guest House
EVENING HOSPITALITY

Thursday
October 18, 2012

7:00-8.45 a.m.
Living Room—
Guest House
BREAKFAST

9:00 a.m.
Living Room—
The House
Bringing the Roadmap Together

Participants will come together and share the roadmaps developed in the small groups with the wider group in a plenary session. This will be a chance for the wider group to reflect on, build and finish the roadmap.

10:30 a.m.
BREAK

10:45 a.m.
Bringing the Roadmap Together (cont.)

The plenary discussion continues.

Reflections and Wrap-Up

EPA and GEC will share reflections and outline the next steps.

12:00 noon
Living Room—
Guest House
BUFFET LUNCHEON

1:00 p.m.
CONFERENCE ADJOURNS

Departures from the Guest House.

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