Results from the 2004 iNEMI Environmentally Conscious Electronics (ECE) Roadmap

Dr. Mark Newton
Dell, Inc.
One Dell Way, MS 6630
Round Rock, TX 78682 USA

Joe Johnson
Microsoft
One Microsoft Way RedWest B/1188
Redmond, WA 98052 USA

Dr. Robert C. Pfahl, Jr.
International Electronics Manufacturing Initiative (iNEMI)
2214 Rock Hill Road, Suite 110
Herndon, VA 20170 USA

***Abstract*— The 2004 iNEMI Environmentally Conscious Electronics Roadmap was released to the public in February 2005. This paper outlines the roadmapping process used by the International Electronics Manufacturing Initiative to identify future research, development, and implementation needs to continue the growth of the world-wide electronics industry. It contains nineteen individual technology roadmaps covering all aspects of the global electronics industry and its supply chain. One of these nineteen roadmaps is the Environmentally Conscious Electronics (ECE) Roadmap. The output of this roadmapping process is used to establish projects to close gaps identified in the roadmap. The three generations of NEMI projects to eliminate Pb solder were developed to close identified environmental technology gaps from the 1998, 2000, and 2002 roadmaps.**

The 2004 ECE roadmap focuses on five key areas: design, energy, recycling, materials, and sustainability. Not only are the technical issues roadmapped in these five areas, but also the regulatory and business issues as well. This paper is the first detailed presentation of the technology and business gaps and research and development needs identified in the five key environmental areas. The paper discusses the findings and recommendations made by the roadmap participants. The paper concludes by discussing the future environmental challenges and recommendations made in the roadmap for the world-wide electronics industry over the next decade.

Keywords-environment, roadmap, sustainability, electronics

I. iNEMI ROADMAPPING PROCESS

iNEMI solicits input from industry experts representing all perspectives within the global electronics manufacturing supply chain to produce its roadmap. The biennial International Electronic Manufacturing Technology Roadmap[1]is over 1000 pages long and the 2004 roadmap was produced by over 470 individuals from over 220 industrial, government, and academic institutions through out the world, in cooperation with ITRS (International Technology Roadmaps for Semiconductors), IPC, IMAPS (International Microelectronics and Packaging Society), USDC (United States Display Consortium), INSIC (Information Storage Industry Consortium), IEEE CPMT, and OIDA (Optoelectronics Industry Development Association).

Efforts are organized into two areas: Product Emulator Groups (PEGs) and Technology Working Groups (TWGs). The PEGs, each chaired by someone from a major OEM in the specific sector covered, define the future technology needs of "virtual products" from seven areas: 1) consumer/portable, 2) office/large business systems, 3) automotive, 4) aerospace/defense, 5) netcom (network/datacom/telecom), 6) system-in-package (SIP) and 7) medical products (see Table 1). Each PEG chapter forecasts future product attributes, including cost and density drivers.

The TWGs forecast trends for numerous technology and infrastructure areas and contrast technology trends with anticipated product needs. Composed of experts from OEMs, EMS providers, suppliers, government agencies, universities and related consortia/trade associations, the TWGs predict the evolution of technology and/or business practices, identify gaps and "showstoppers" in the existing technology and/or infrastructure, and develop recommendations for their respective areas.

For each roadmapping cycle, iNEMI determines technology, infrastructure and business practice areas according to what is happening in industry and what changes are expected to have the greatest effect on electronics manufacturing.

In some cases, areas are influenced by other roadmaps, such as the International Technology Roadmap for Semiconductors (ITRS) or IPC's interconnect roadmap. In others, we are requested to cover a specific topic by another organization or a government group. In addition, iNEMI members, through our Technical Committee, help determine the technology and infrastructure issues on which the roadmap should focus.

The 2004 roadmap covers nineteen technology and business process topics including environmentally concious electronics (ECE). Addressing the shifts in each of these areas, along with the related technology gaps and business needs, benefits the entire electronics industry. By helping organizations focus resources on areas of greatest need, the roadmap improves technology development and deployment for greater productivity.

II. ECE SITUATION ANALYSIS

To remain competitive, the electronics industry must continue to keep pace with emerging:

- material restrictions,
- end-of life requirements,
- customer preferences for energy efficient products,
- holistic design requirements, and
- sustainable business practices.

The 2004 ECE roadmap focuses on five key areas: design, energy, recycling, materials, and sustainability and projects future industry trends and business needs for manufacturers. The major technical ECE challenges facing our industries are primarily associated with the imminent deadlines for compliance to international recycling and restricted material laws such as the European WEEE (Waste from Electrical and Electronic Equipment) and RoHS (Restriction on use of certain Hazardous Substances) directives, the Chinese "Management Methods", and US State initiatives such as California's SB20. In addition to the recycling requirements and material composition restrictions imposed by these regional directives, a strong push for reduced energy efficiency that has until now been satisfied by voluntary initiatives may become regulated as well. On the near horizon, holistic ECE design requirements, found today in voluntary ecolabels programs, are also being proposed as federal procurement criteria and potential legislation. Sustainable business practices, such as the disclosure of global warming substance release by manufacturers is now expected by socially conscious investor groups. Globalization of environmental legislative requirements is particularly problematic.

A. Design

"Design for the Environment" (DfE) principles have long been a goal of large electronic companies that sell in the global market. Such programs consider alternative technologies, materials and processes that conserve resources, reduce risks to human health, and decrease the overall impact to the environment. Incorporating environmental aspects early in the product design requires companies to obtain the raw data of purchased components and process materials and then use this data to evaluate and rank environmental concerns.

B. Materials

The electronics and electrical industry is facing a new trend of environmental regulation that focuses on the materials used in electronic and electrical equipment ("EEE") as opposed to the historical trend of focusing on the processes used to manufacture EEE. In addition to recent laws and regulations that have been enacted to ban or restrict the materials used in EEE, the industry is also facing voluntary or "market driven" initiatives that seek to encourage EEE producers to phase out or reduce the use of certain materials due to their actual or perceived environmental impact. These trends pose challenges as well as opportunities for members of the electronics and electrical industry.

C. Energy

Minimizing energy consumption is a major focus for electronic equipment manufacturers. Reducing energy consumption saves money on energy bills, reduces pollution by eliminating wasted energy, and helps prevent smog, acid rain, and climate change.

D. Recycling

Globally, the electronics industry is being forced to take responsibility for its products at the end of their useful life. The push for this responsibility stems from two public policy motivations: (1) the perception that electronic products pose a danger to the environment when disposed of in landfills and incinerators, and (2) the cost to recycle these products for local governments. Legislation has been proposed or enacted to impose design, use, and end-of-life management responsibilities on the electronic industry for its products throughout their entire lifecycles.

Whether in the form of higher prices being proposed in the US or having to take actual physical responsibility for their products at time of discard, as in Japan and Europe, end of life legislation will have an impact on the costs of business for manufacturers of electronic products.

E. Sustainability

The iNEMI Environmentally Conscious Electronics (ECE) TWG identified sustainability as a new topic of focus for the 2004 Roadmap. The concept of sustainability is being widely adopted and promoted by companies throughout the electronics supply chain as a core tenet and measure of performance of their business operations, largely in response to heightened interest by stakeholders in corporate social and environmental responsibility. Increasingly, companies are publishing what they refer to as sustainability reports, in place of traditional environmental reports, although the general nature and content of the reports has changed little, with the possible exception of additional emphasis on social considerations.

While "sustainability" is being treated as a stand-alone topic on the ECE TWG matrix, it is perhaps better viewed as cutting across all the existing ECE Roadmap topic areas – materials, energy, waste and design – both as an inherent reason for further examination of these and other areas, as well as a framework for measuring industry progress in meeting environmental and social goals.

III. ROADMAP OF QUANTIFIED KEY ATTRIBUTE NEEDS

Table 1 roadmaps the environmental issues which the core manufacturing technology roadmaps need to address in order to be compliant with major market requirements. Many of these requirements have been or are being addressed by iNEMI development projects which focus on developing the required materials and manufacturing process and also the business practices required to meet the RoHS/and WEEE regulations. Short product cycles have allow rapid introduction of alternative technology in new products once reliable and cost effective solutions have been established. Many major

electronic firms are currently in the midst of their conversion to Pb-free products.

TABLE 1 CROSSCUTTING TWG ISSUES WITH CORE MANUFACTURING TECHNOLOGY TWGS

Core Technology TWG	Environmental Needs	Time Frame
Board Assembly	•Improved Pb-free reliability for ceramic packages, backplanes, wave soldering	2004-5
Final Assembly	•RoHS-free EEE •Increase recycled content and recyclability •Alternatives to non-regulated Brominated Flame Retardants in cases	2004-6 2002-5 2002-4

Table 2 roadmaps the environmental issues that the component manufacturing technologies need to address.

TABLE 2 ROADMAP OF THE ENVIRONMENTAL ISSUES FOR THE COMPONENT MANUFACTURING TECHNOLOGIES

KEY COMPONENT TWG	ENVIRONMENTAL NEEDS	TIME FRAME
Packaging	•Pb-free lead finishes and BGA Balls •Pb-free C4 •High Temperature Reliability, esp. Ceramic BGA •Br-free mold compound	2004-5 2005-8 2004-5 2006-8
Interconnect Substrates-Organic	•Pb-free finish •Lower cost/enhance reliability of Br-free laminates	2004-5 2005-8
Interconnect Substrates-Ceramic	•Pb and other impurities	2004-8
Displays	•Alternatives to Hg in Lamps •Improved Energy Efficiency	2004-8 Ongoing
Mass Data Storage	•RoHS exemption for commercial data storage •Pb-free Magnetic and Optical drives for CE	2008 2004-5
Optoelectronics	High Temperature (235-265C) Compatibility	2004-5

It is critical to note that to remain competitive, global electronic firms will need to improve existing processes and develop, qualify, and introduce many new materials, components, and processes during 2005-8. Differences between product sectors are primarily driven by exemptions to RoHS and WEEE-type legislation.

Table 3 roadmaps the environmental issues affecting the crosscutting TWGs.

TABLE 3: CROSSCUTTING TWG ISSUES

Crosscutting TWG	Environmental Needs	Time Frame
Product Lifecycle Information Management	•Product Content Information Exchange standards •Supplier Declaration of Conformity and compliance verification standards •Product Recycling Verification documentation standards	2004-8 2004-6 2004-8
Modeling, Simulation, and Design Tools	•Practical and accurate DfE/LCA Tools to evaluate product life cycle impacts of manufacture, distribution, use, and end-of -life	2004-8
Thermal Management	•Improve Energy Efficiency •Increase Temperature Capability of Components for Assembly	Ongoing 2004-8
Test, Inspection & Measurement	•RoHS substance testing standards	2004-6

TABLE 2: STATUS OF MATERIALS USED IN ELECTRONIC APPLICATIONS IN KEY GLOBAL MARKETS

	Americas	Europe	Asia	Key
Pb	2007[1]	2006[2]	2006[3]	Red = is or likely to be restricted within 5 years (2009)
Cd	2007[1]	2006[2]	2006[3]	
Hg	2007[1]	2006[2]	2006[3]	
Cr (VI)	2007[1]	2006[2]	2006[3]	
PBBs	2007[1]	2006[2]	2006[3]	
Penta BDEs	2007[1]	2006[2]	2006[3]	
Octa BDEs	2007[1]	2006[2]	2006[3]	
Deca BDEs	2007[4]	2006[5]	2006[6]	Yellow = voluntary restriction or requirement not likely to be in effect within 5 years (but probably will later)
TBBPA				Green = no restrictions on the horizon

[1] California SB 20 contains a "RoHS" provision for covered TV and computer displays. This provision bans the use of heavy metals in covered displays sold in California by July 1, 2007. Some northeast US states have banned the use of mercury in certain applications used in electronic products (e.g., mercury switches). Although the use of mercury in lamps is not currently banned in any state, regulatory pressures have been established that discourage its use in such applications.

[2] EU RoHS directive bans on Pb, Cd, Cr, Hg and PBB & PBDO flame retardants beginning 2006 (select exemptions exist)

[3] China has proposed a "RoHS Directive" that is modeled on the EU RoHS Directive. It is expected to be enacted in 2005, and would restrict the same materials as the EU RoHS Directive by 2006.

[4] Although no US states have banned the use of deca BDEs in electronics, past legislation has proposed such a ban. Furthermore, if the EU concludes that deca BDE is covered by the RoHS Directive, US states may decide to cover deca BDE as well.

[5] The EU has recently completed a risk assessment which determined that deca-BDE should be outside of the scope of the EU RoHS Directive. A final decision should be made by the end of 2004.

[6] China is modeling the restricted materials it restricts in its Management Methods after the EU RoHS. If the EU decides to restrict deca BDE, China could adopt the similar restrictions

IV. Strategic Issues.

To minimize supply chain chaos and reduce the need to manufacture region-specific products it is critical that emerging international requirements of a given topic do not substantially differ in scope. Harmonization through international standardization is essential.

The area of Corporate Social Responsibility (CSR) is being driven by multiple factors, including globalization of the world economy, the failure of firms to effectively police themselves and the ability of the Internet to provide almost instant access to information. With environment as one of the pillars of CSR, there will be increasing need to demonstrate that a firm is actively responding to environmental issues on more than an ad-hoc basis.

V. Identified Gaps.

Several major gaps need to be addressed in the five focus areas:

A. Design:

1) Qualification of acceptable replacements for hazardous substances
2) Automated data management systems for materials declarations
3) Product compliance verification testing
4) LCA / SLCA tools
5) Diverse labeling requirements
6) WEEE compliance verification process

B. Materials:

1) Pb-free for high reliability requirement applications
2) Cd and Pb-free PVC cables
3) REACH risk assessment for chemical emissions

C. Energy:

1) Cost efficient methods to improve the energy efficiency of power supplies
2) Enabled power management of IT equipment
3) Recycling
4) Compliance to diverse regional Recycling requirements in Europe (WEEE), the US (CA SB 20 etc.) and Asia

D. Sustainability:

1) Definition of Sustainability
2) Standard Sustainability Indicators and Reporting protocol for EEE

VI. Recommendations.

The ECE Roadmap makes a number of recommendations to the industry in each of the five focus areas. The following paragraphs outline these recommendations.

A. Design:

1) Designers need a comprehensive and standardized framework or "quick reference" system to determine the status of a given substance with respect to its environmental classifications in such categories as regulatory restriction, EU risk phrases, persistent organic pollutants (POP), persistent, bioaccumulative, toxic (PBT) materials, etc. to facilitate material selection and materials management.
2) Product performance and compliance standards should be available to ensure common interpretation and execution of design objectives driven by public policy.
3) In terms of the sheer volume of environmental information that must now be maintained and managed for product communications to users and recyclers, technologies like radio frequency identification tags could be explored for environmental data repositories on the products themselves.

B. Materials:

1) Need for development and implementation of good scientific methodologies to assess true environmental impacts of materials and potential trade-offs of alternatives.
2) Need to assess the technical viability of alternatives to Cd, Hg, CrVI, PBB, and PBDEs with the same rigor that has been used to identify alternatives to Pb.
3) Need for industry to be more involved in policy making on material restrictions so that policy makers understand trade-offs inherent in material substitution.

C. Energy:

1) Develop cost-effective, energy efficient power supplies.
2) Assist in better educating consumers on the advantages of enabling the power saving features of their IT products.

D. Recycling:

1) Support of research and development to create a sustainable infrastructure and reliable recycled materials market for use in new products.
2) Industry wide communication and cooperation on a global basis regarding recycling challenges.

E. Sustainability

1) Develop a common, meaningful, straightforward definition of sustainability that is relevant to the electronic industry and its supply chain, can be applied quantitatively at the business level, can be easily communicated to stakeholders, can be used to set targets, and that encourages an integrated, lifecycle sustainability strategy.
2) Efficient, standardized methods for data exchange of environmental metrics and attributes must be developed and implemented. These metrics should be synergistic with Environmental Management System (EMS) methodologies and ultimately linked to the concept of environmental sustainability.

3) There is an urgent need to develop and standardize tools and definitions for Design for Environment (DfE), Life Cycle Assessment (LCA) and Life cycle impact (e.g., consider tradeoff of reducing Hg use in LCD product vs. Hg reduction through reduced energy consumption over CRTs).

4) A Coherent Framework for Sustainability Reporting by the Electronics Sector. The industry should identify one existing common reporting framework (e.g., GRI) that best meets the necessary attributes for the electronics industry, and develop modifications to address identified gaps (such as a sector-specific supplement). A Sector Supplement for the GRI reporting guidelines may be one possibility.

VII. CONCLUSIONS.

The global electronics industry is in the midst of responding to the enormous impact that the EU RoHS and WEEE directives are having on the materials and processes that the industry uses, and the way the industry transmits information through the supply chain. However, the roadmap points out that there are several new issues that the industry needs to address including sustainability and energy efficiency. CMOS device technology will become less energy efficient due to increasing leakage currents as we approach the limits of scalability over the next decade. Increased emphasis will be required on energy at the systems level to meet this technical and environmental challenge.

REFERENCES

[1] iNEMI Technology Roadmaps, 2004 Edition,Herndon, VA