2013 iNEMI
Environmentally Sustainable Electronics Roadmap

Bill Bader, CEO of iNEMI
Sustech 2013
August 1st, 2013

Advancing manufacturing technology
Agenda

iNEMI Overview

Technology Roadmap

Environmentally Sustainable Electronics; Methodology, History, Success Examples

Key Environmental Challenges form the 2013 Roadmap

Conclusions and Summary

Q & A, Discussion
International Electronics Manufacturing Initiative (iNEMI)

- Not for profit, highly efficient R&D consortia since 1994
  - Funded by Corporate memberships - Staffed globally in US, China & Ireland
- Membership includes 110 leading industry companies & organizations, representing a cross section of our electronics manufacturing industry & supply chain


We Accomplish This By:

- Being the recognized leader at projecting future technology needs for the global supply chain (iNEMI Technology Roadmap).
- Guiding and leveraging the strength of the consortium's industry leading international membership.
- Driving high impact collaborative R&D Results through constantly improving methodologies.
- Defining and implementing science based sustainable solutions in high impact areas including the environment and health care.
- Influencing and leveraging key government agencies and labs (iNEMI Research Priorities Document).

- iNEMI has currently 23 collaborative R&D projects and initiatives that address key technology gaps
- Projects typically have 10-20 member companies/institutions

www.inemi.org
The 2013 iNEMI Roadmap; Process and Scope
2011 Technology Working Groups (TWGs)

- **Modeling, Simulation, and Design**
- **Solid State Illumination**
- **Large Area, Flexible Electronics**
- **Semiconductor Technology**
- **Photovoltaics**
- **Ceramic Substrates**
- **Organic PCB**
- **Information Management Systems**
- **Connectors**
- **MEMS/Sensors**
- **Packaging & Component Substrates**
- **RF Components & Subsystems**
- **Passive Components**
- **Optoelectronics**
- **Test, Inspection & Measurement**
- **Thermal Management**
- **Mass Storage (Magnetic & Optical)**
- **Energy Storage & Conversion Systems**
- **Environmentally Conscious Electronics**

Red=Business  Green=Engineering  Purple=Manufacturing  Blue=Component & Subsystem
## Roadmap Development

**Product Sector Needs vs. Technology Evolution**

<table>
<thead>
<tr>
<th>Product Emulator Groups</th>
<th>TWGs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable / Consumer</td>
<td><strong>Environmentally Sustainable Electronics</strong></td>
</tr>
<tr>
<td>Office / Large Systems</td>
<td><strong>Business Processes</strong></td>
</tr>
<tr>
<td>Highend (e.g. netcom, server)</td>
<td><strong>Design Technologies</strong></td>
</tr>
<tr>
<td>Automotive</td>
<td><strong>Production Technologies</strong></td>
</tr>
<tr>
<td>Medical Products</td>
<td><strong>Packaging, Substrates, Displays, etc.</strong></td>
</tr>
<tr>
<td>Defense and Aerospace</td>
<td></td>
</tr>
</tbody>
</table>

**Design Technologies**
- Modeling, Thermal, etc.

**Manufacturing Technologies**
- Board Assembly, Test, etc.

**Business Processes**
- Product Lifecycle Information Mgmt.

**Comp./Subsyst. Technologies**
- Packaging, Substrates, Displays, etc.
Statistics for the 2013 Roadmap

• > 650 participants -- Big Thanks to All Contributors!!
• > 350 companies/organizations
• 18 countries from 4 continents
• 20 Technology Working Groups (TWGs)
• 6 Product Emulator Groups (PEGs)
• > 1900 pages of information
• Roadmaps the needs for 2013-2023
• Workshops held in Europe (Berlin, Germany), Asia (Hong Kong) North America (ECTC, San Diego, CA) in May 2012
• A Full Global Perspective

• Available to iNEMI members on 12/28/12 at: www.inemi.org
• Available to industry beginning April 4, 2013 at www.inemi.org
iNEMI Product Sector Forecast Growth
ELECTRONICS PRODUCTION
2009 - 2021

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
<th>2015</th>
<th>2021</th>
<th>CAAGR '09-'15</th>
<th>CAAGR '15-'21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computers and Office</td>
<td>$396</td>
<td>$433</td>
<td>$474</td>
<td>$500</td>
<td>$617</td>
<td>4.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Communications Infrastructure Equipment</td>
<td>$157</td>
<td>$174</td>
<td>$192</td>
<td>$213</td>
<td>$281</td>
<td>5.2%</td>
<td>4.7%</td>
</tr>
<tr>
<td>Consumer and Portable Electronics</td>
<td>$298</td>
<td>$319</td>
<td>$341</td>
<td>$400</td>
<td>$479</td>
<td>5.0%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Automotive Electronics</td>
<td>$105</td>
<td>$129</td>
<td>$158</td>
<td>$161</td>
<td>$237</td>
<td>7.4%</td>
<td>6.6%</td>
</tr>
<tr>
<td>Medical Electronics</td>
<td>$77</td>
<td>$85</td>
<td>$93</td>
<td>$103</td>
<td>$134</td>
<td>5.0%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Military and Aerospace Electronics</td>
<td>$118</td>
<td>$129</td>
<td>$140</td>
<td>$151</td>
<td>$189</td>
<td>4.2%</td>
<td>3.8%</td>
</tr>
<tr>
<td>Total Electronics Production</td>
<td>$1,242</td>
<td>$1,382</td>
<td>$1,541</td>
<td>$1,679</td>
<td>$2,171</td>
<td>5.2%</td>
<td>4.4%</td>
</tr>
</tbody>
</table>

Note: Total includes product categories not included in iNemi segmentation

Courtesy PrismarK Partners LLC
High Level Key Messages
Electronics Business Situation Analysis

- **Convergence**
  - Medical-Consumer
  - Automotive-Entertainment
  - Communication-Entertainment
    - Telecom-Datacom

- **Miniaturization and Thinner; Speed of Change Escalating**

- **Quality, reliability, cost still paramount**

- **Counterfeit Products a growing issue**

- **Infrastructure (Business Model) changes:**
  - Growth of “The Cloud”
  - Fabless Semiconductor Fabrication
  - EMS and ODM roles grow; R&D Challenges

- **Rare Earth and Conflict Materials**

- **Carbon foot print & Material Data Reporting Requirements**

- **Energy Storage & Usage Growing in Importance**
  - Rapid spread of Consumer electronics
  - Solid State Lighting
  - Electric and Hydrogen Vehicles
  - Opportunities for smart grid
Situation Analysis: Technology

• Consumers’ demand for thin multifunctional products has led to increased pressure on alternative high density packaging technologies.
  – 3D IC with TSV
  – SiP still key
    • Technology driver for small components, packaging, assembly processes and for high density substrates
  – Sensors and MEMs:
    • Exponential volume growth driven by portable products
    • Motion gesture sensors expanding use of 2D-axis & 3D-axis gyroscopes
    • Segment maturing, encouraging industry collaboration

• Semiconductor Scaling Limit Near
  – Definition of future requirements moving to “More than Moore”

• Product miniaturization and speed/voltage are challenging the movement to high reliability alternative materials
Strategic Concerns

• Restructuring from vertically integrated OEMs to multi-firm supply chains
  – Resulted in a disparity in R&D Needs vs. available resources

• Industry collaboration
  – Gain traction at University R&D centers, Industry consortia, “ad-hoc” cross-company R&D teams

• The mechanisms for cooperation throughout the supply chain must be strengthened.
  – Cooperation among OEMs, ODMs, EMS firms and component suppliers is needed to focus on the right technology and to find a way to deploy it in a timely manner

• Collaboration is iNEMI’s Strength; We play an important role
iNEMI Actions in Environmental Area

• The Environmental Leadership Steering Committee in place to set strategic direction

Bill Bader – iNEMI – Chair
Marc Benowitz – BOD Member
Jackie Adams
Todd Brady
Mary Liz Burns
Carol Handwerker
Joe Johnson
Nils Nissen
Scott O’Connell
Tom Okrasinski
Patrice Rollet
Tamim Sidiki
Joyce Taylor
Rob Taylor
iNEMI History & Actions in Environmental Area

- Roadmap of Environmental Conscious Electronics (since 1996)
- Established the Environmental Leadership Steering Committee to set strategic direction & priorities:
  - Issued iNEMI position papers on Product Carbon Foot printing and Definition of Low Halogen
  - Issued white paper on Timeline for Conversion of Notebook and desktops to HFR-Free and PVC free
  - Issued White Paper on Environmental Material Data Management & Reporting in Q4 2012
  - Issued White Paper on PVC Alternatives in Q4 2012
- Leading Projects on
  - Characterizing and improving Pb-free reliability - since 2000
  - Characterizing PVC alternatives & HFR-free high reliability - since 2009
  - Developing LCA tools for ICT products since 2010 – Two active well-led teams
- Defining Environmental Research Priorities
  - Six environmental research proposals webinars held in 2012; 2 YTD in 2013
- Organizing workshops
  - Electronics Goes Green 2012
A Winning Example of Joint iNEMI Research Initiated
Purdue University and Tuskegee University in close collaboration with Global Electronics Industry - iNEMI plus 5 members - and International Academic Partners - Fraunhofer IZM - Berlin, Shanghai Jiao Tong University, Tsinghua University – Beijing, Indian Institute of Management – Udaipur, Universidad EAFIT – Medellin Columbia

**Vision**

Create a new integrative, collaborative model for graduate research and education needed to enable *meaningful and measurable improvements in the global sustainability of electronics*.

Funded by NSF in June 2012
$3.2M for 28 two-year fellowships over 5 years
External Advisory Board and opportunities for collaboration with industry, NGOs, research institutions
Three Research Thrusts

1. Polymers from Nature for Construction & Disassembly
   - Natural Nanocomposites for Structural Applications in Casings and Boards,
   - Bio-based Lignin and Soy-based Resins for Circuit Board Construction
   - Biomimetic Marine-Derived Bioadhesives for Device Construction & Disassembly
   - Green Replacements for Brominated Flame Retardants

2. Sustainable Product Design and Manufacturing
   - Novel LCA Approach for Electronic Products
   - Electronic Product Manufacturing Process Characterization and Improvement
   - LCA-based Design of Electronics
   - Recycling and Reuse of Electronic Devices

3. System and Supply Chain Issues
   - Integrating Sustainability Indicators across the Supply Chain
   - Corporate Sustainability Behavior – Stakeholder Perception – Corporate Valuation
   - Consumer Behavior
   - System-wide Effects of Laws and Regulations
Learning & Result Examples of 2012 Completed Projects
HFR Free PCB Electrical and Material Performance & Supply Chain Readiness

- Eighteen company project of key laminators, OEM’s, ODM’s and Test Service providers
- Executed a comprehensive test suite on multiple materials from multiple suppliers, at multiple test facilities
- The test suite methodology developed enabled direct comparison of desired laminate properties
- Testing results are conclusive that the industry and the laminate providers are ready to make the transition to HFR Free materials for notebook and desktop applications
- Full spec sheets developed for usage at outgoing testing at laminate providers
  - Commitment received from all suppliers that outgoing laminate materials would be tested to conform with the iNEMI project team specifications
- Evaluation of industry capacity performed to ensure volume ramp readiness was in place.
ECO Impact Evaluator for ICT Equipment

- Simplified Building Block Tool Developed For Full Life Cycle Analysis of Product Carbon Footprint
  - Data bases assembled and tested
  - Algorithm’s for calculating impact of individual components
  - Full Life Cycle tool set for complete ICT boards and systems

- Model was tested and verified by multiple iNEMI members on multiple products.
  - Within 5% accuracy of complex commercial tools

- Discussions underway to put in place a long term sustainable ownership model
Environmentally Sustainable Electronics

Chairs:
Jackie Adams, IBM
Stephen Tisdale, Intel
# ESE Table of Contents

## Contents

- Environmentally Sustainable Electronics .......................... 1
  - Executive Summary ........................................... 1
- Situation Analysis .................................................. 4
  - Sustainability (Subsection) .................................... 10
  - Executive Summary ........................................... 10
- Introduction ......................................................... 10
- R&D and product development ...................................... 12
- Supply chain management (Logistics and Procurement) ........ 16
  - Manufacturing .................................................. 17
  - Facility management ........................................... 17
  - Human Resources ................................................ 17
  - Marketing/Sales .................................................. 18
- Critical Issues ...................................................... 22
- Technology and Business Needs ................................... 24
- Electronics as enabler to improve energy efficiency .......... 24
  - Consider the Green Sigma Coalition .......................... 28
  - Data availability, confidentiality and comparability .......... 28
- Gaps and Showstoppers ............................................. 28
  - Data for PCF/PWF/LCA ......................................... 29
- Privacy and data security issues ................................... 29
  - ICT as a driver to sustainability in other sectors too slow . 30
- Recommendations .................................................... 30
- Contributors ......................................................... 34
- Materials (Subsection) ............................................. 35
  - Introduction ...................................................... 35
- Situation Analysis ................................................... 35
  - Critical Issues .................................................... 37
- Technology and Business Needs .................................... 37
- Gaps and Showstoppers ............................................. 38
  - Recommendations ................................................ 39

## APPENDIX 1

- Eco Design (Subsection) .......................................... 49
  - Introduction ...................................................... 49
  - Situation Analysis .............................................. 49
  - Critical Issues .................................................... 50
  - Technology and Business Needs ................................. 50
  - Gaps and Showstopper .......................................... 51
  - Recommendations ............................................... 51
  - Energy (Subsection) .............................................. 53
  - Introduction ...................................................... 53
  - Situation Analysis .............................................. 57
  - Critical Issues .................................................... 61
  - Technology and Business Needs ................................. 62
  - Gaps and Showstoppers .......................................... 68
  - Recommendations ............................................... 69
  - Recycling (Subsection) .......................................... 70
  - Executive Summary .............................................. 70
  - Introduction ...................................................... 70
  - Situation Analysis .............................................. 70
  - Market Drivers .................................................... 74
  - Business/Technical Issues ....................................... 74
  - Roadmap of Quantified Key Attribute Needs .................. 75
  - Critical Issues (Prioritized) ................................... 75
  - Technology Needs ............................................... 75
  - Gaps and Showstoppers .......................................... 76
  - Recommendations ............................................... 76
  - Key Recommendations and Issues Raised in the Five Subsections ........................................... 76
  - Crosscutting Issues Affecting e-Waste and Energy .......... 78
  - Contributors ...................................................... 79
  - Glossary .......................................................... 80

## Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>iNEMI Environmentally Sustainable Electronics: Roadmap and Vision</td>
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## Figures

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<td>1</td>
<td>Global look at the exponential growth over time of Environmental regulations by country</td>
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</table>
To produce environmentally conscious electronics the ESE TIG must continue to keep pace with:

- Emerging material restrictions
- End-of-life requirements
- Energy efficiency requirements
- Holistic design requirements
- Sustainable business practices

To achieve these goals the ESE TIG has been divided into 5 groups:

- Materials
- Recycling
- Energy
- Design
- Sustainability
What Has Changed Since 2011?

- Global environmental regulations and standards continue developing at a rapid pace, particularly Energy & Waste

- “Old” major regulations are being revised (EU RoHS, EU WEEE, etc)

- Emerging sustainability issues – conflict minerals, rare earth metals, etc

- Continued opportunities for industry to develop collaborative solutions to meet future needs and reduce costs/complexity
Environmentally Conscious Electronics (ESE) Road Map Overview

Current Projects/Initiatives under or cross cutting to the ESE TIG

Projects
- Pb-Free Rework Optimization
- High-Reliability RoHS Task Force
- Component and Board Finish Reliability*
- Eco-Impact Evaluator Project
- Rare Earth Metals

Initiatives
- Create a quantifiable set of metrics and potentially a tool for measuring a product’s true recyclability and reuse. Eco design for recycling/sustainability including toxicity assessment and critical usage/application.
- Develop a stakeholder aligned methodology/stepwise approach to develop and assess new or alternative materials.
- Identify and communicate/share best known practices for recycling, for metals recovery, and for resource efficiency at EOL processing.
ESE Summary

• 2013 Key Issues
  – Growing issues that may impact other Technology Working Groups
    • Rare earth and conflict metals criticality
      – Reporting requirements on Conflict Minerals spelled out in Dodd-Frank Act
      – iNEMI team formed and defining critical actions/priorities on Rare Earth
    • Rapidly expanding list of restricted materials
    • Standards for carbon foot-printing/life cycle analysis data evolving
  – Highlighted issues that are cross cutting in the Roadmap
    • Energy efficiency standards being defined
    • Transition to lead free and low halogen in previously exempt sectors
    • Additional restricted materials
    • Standards for product data management
    • Eco-design standards
    • Automotive growth in electronics per vehicle is rapid.
Summary

• ESE TIG is divided into 5 areas, including Sustainability
• New proposed 2013 ECE gaps identified to-date:
  – Develop methodology for evaluation of alternative materials, emphasis on polymers and plasticizers
  – Technical qualification of HFR-free high-end connectors
  – Commercialization/viability of post-consumer recycled plastics
  – Address emerging materials issues: nanomaterials, rare earth metals
  – Identify water quality/scarcity issues
  – Increase visibility of global product energy efficiency regulations/standards (developed global matrix)
• Full Technical Plan (Gaps 1-5 Years) and Research Priorities (Gaps 5-10 years) to be published in September
• We encourage iNEMI member and non member participation
Concluding Thoughts

• New global environmental requirements continue to multiply – faster than industry can effectively respond
  – Opportunities to work alignment need to be captured and driven

• Industry needs to be more proactive in developing solutions that:
  – Are based on science and engineering, delivering value to customers
  – Are available in advance of new regulations
  – Can influence future regulations and stakeholder groups for more sustainable results

• Sustainability will be a major undertaking for industry as well as society

• Electronic solutions can help to empower people to live a more sustainable lifestyle

• iNEMI and its members are playing a significant role in preparing industry for these future needs
2013 Roadmap Pricing
(available April 4, 2013)

Full roadmap $3000*
(USB drive)

Single chapter $ 500
(PDF download)

Special pricing for research institutes, universities, gov’t agencies & non-profits

Full roadmap $ 500*
Chapter $ 100

* + $100 shipping outside North America
Summary

• INEMI has a strong history of driving environmental improvements globally
• Excellent new projects and focus as we move forward in 2013

Get Involved!!

Thank You

Merci   Gracias   Grazie   Danke Schon   Effaristo
Dank u Obrigado   Go raibh Maith agat.................
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