iNEMI Project Value Recovery from End-of-Life Electronics - Phase 2

Co-Leads
Bill Olson (Seagate)
Carol Handwerker (Purdue)
Wayne Rifer (Green Electronics Council)

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Presenter: Wayne Rifer
Phase 1 Metals Recycling: Project Summary

Problem Statement

- Metals recovery from electronic product recycling is focused on high-volume, valuable metals that are easily recoverable.
- Current and future electronics will contain small quantities of resources available for recovery but are not currently recovered in today’s recycling infrastructure.

Purpose and Scope

Conduct an analysis of

- needs and readiness of current and future metals recovery, as it applies to consumer electronics, enterprise electronics and future ICT
- how the trend toward miniaturization, product dematerialization, and the introduction of new heterogeneous materials systems create new challenges with respect to materials supply, materials recovery, and electronics recycling
- how these interact to affect metals recycling now and in the foreseeable future

- Develop recommendations for a path forward
Key Findings from Metals Recycling Project: iNEMI Role

• Key role for iNEMI and its members to play in increasing metals recovery, while promoting sustainable electronics.
  – Focus on value recovery through Design for Sustainability.
  – Focus on innovative designs, business models, technologies, supply chains
  – Focus on community building

• Of particular importance is the ability of iNEMI to engage stakeholders across the life cycle of electronic products to examine new approaches to managing critical resources and increasing value recovery while protecting human health and safety and the environment.

• iNEMI Environmental Leadership: CMI, EGG 2016, E-Scrap,..
Community Building for Value Recovery: Path Forward

- Develop a voluntary, community-based solution involving adaptive governance systems to manage common pool resources (E. Ostrom - 2009 Nobel Prize in Economics)
  - Legislation is not practical or advantageous
  - Path forward is through a multi-stakeholder collaboration that articulates a vision and develops scenarios for enhancing value recovery of electronics and metal resources.

- First challenge is to identify a goal that can get us started
  - attract team members/stakeholders

- Second challenge for such a process is to develop a set of rules and tasks for interaction of institutions involving a mix of stakeholder types, business models, value systems, as identified by Ostrom.
Different Possible Foci of Phase 2

– **Component/Device Based Recovery**
  • Focus on a ubiquitous component or device and build a more comprehensive scope out of that, --- either an off line initiative plan OR standard iNEMI project.
  • What would provide the most useful rallying point for stakeholders?

– **Product Based Recovery**
  • What product would provide the most interest and need for industry?

– **Industry Based Recovery**
  • What Industry has the most need/benefit for metals recovery?

– **Requirements for EOL planning before ever going to market**
  • Develop requirements for industry around planning for EOL of a product before the product is released (to avoid issues at EOL like with CRTs)
  • Promote market access
• Suppliers of Materials (and components)
  – Identify products in our portfolio which promote, supply, or spec-in options to meet the industry’s recycling procedures and to understand recycling methods for future product development.

• IT/Electronics/Asset Management
  – Create and exploit multiple, commercially viable pathways for value recovery, including developing alternative supplies for metal resources
  – Increase market access through increased value recovery

• Collection/Aggregation/Recycler/Smelter
  – Create multiple pathways to increase value recovery for supply chain companies, organizations, and people, including examining new technologies & business models.

• Standards/Regulators
  – Develop options and strategies for initiatives that promote progress toward a circular economy through Ostrom-like initiatives (cooperative, industry-based, self governing solution sets).
### iNEMI Value Recovery Project: Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carol Handwerker – co-chair</td>
<td>Purdue</td>
</tr>
<tr>
<td>Wayne Rifer – co-chair</td>
<td>GEC</td>
</tr>
<tr>
<td>Bill Olson – co-chair</td>
<td>Seagate</td>
</tr>
<tr>
<td>Alice Lin; Jeffrey Lee</td>
<td>IST Group</td>
</tr>
<tr>
<td>Colin Fitzpatrick</td>
<td>University of Limerick</td>
</tr>
<tr>
<td>Gary Spencer</td>
<td>Geodis</td>
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<tr>
<td>Willie Cade</td>
<td>SUNY-Buffalo</td>
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<tr>
<td>Tim McIntyre</td>
<td>Oak Ridge National Labs</td>
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<tr>
<td>Alex King</td>
<td>Critical Material Institute</td>
</tr>
<tr>
<td>John Sutherland, Hongyue Jin</td>
<td>Purdue</td>
</tr>
<tr>
<td>Ardeshir Mashhadi, Mostafa Sabbaghi, Sara Behdad, Yosepho, Farzad Mehrpour</td>
<td>SUNY-Buffalo</td>
</tr>
<tr>
<td>Ian Lovell</td>
<td>Teleplan</td>
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<tr>
<td>Devin Imholte</td>
<td>Idaho National Lab</td>
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</tbody>
</table>
Value recovery in HDD...

• More than SHREDDING and metals recovery - currently dominated by either precious metals or commodity materials (i.e., Al, Fe, glass)

  ... We can challenge the paradigm...

Value in Reuse

• reuse of the HDD
• reuse of the magnets in HDDs in other products
• reuse of assemblies in HDDs
• helium recovery

  While addressing data security concerns.
Seagate President
– Make “Hard drives from hard drives”

Seagate and the Critical Materials Institute (CMI) have been discussing various approaches to value recovery:

• new technology for removing magnets from HDDs

• performing economic, environmental, and logistical analyses to examine the viability of various scenarios that can be applied to HDDs and other EoL electronics
Scope of Work

1. **Identify possible routes** to increase the value recovered from HDDs, from direct product reuse to metals recycling, for specific HDD product types, applications (server, data centers, portable, desktop, enterprise, telecom), and conditions at EoL.

2. **Develop a decision tree** to show the sequence of recovery choices being made from direct product reuse to metals recycling, including criteria being used to make the decisions and the handoffs required at each stage to realize value recovery.

3. **Identify the current barriers** to a safe, environmentally sustainable, economically feasible recovery system.

4. **Identify next steps** to demonstrate the feasibility of the system.
Project Priority

Fast Turn Project – Electronic Storage Media only, Hard Disk Drives

Circular Economy…get ahead of the regulators AND do the sustainable thing, i.e., the right thing

Communicate with the whole HDD stakeholder community, including standards (IEEE/NSF/EPEAT)

Self-managing
What is the relative market share for HDD applications?

Shipment of HDDs by Seagate

All numbers are in millions of units, data by the company.

- **Total**
- **2.5” & 3.5” HDD**
- **Non-computer**
- **Enterprise class**

Datacenters?

Source: anandtech, 2016
### Table 2 – Rare earth magnet applications and oxide requirements

<table>
<thead>
<tr>
<th>Applications</th>
<th>2010 yr</th>
<th>Magnet % of mix</th>
<th>Oxide, tons</th>
<th>2015 yr</th>
<th>Magnet % of mix</th>
<th>Oxide, tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motors, industrial, general auto, etc</td>
<td>25.5%</td>
<td>15,871</td>
<td>7,122</td>
<td>25.0%</td>
<td>24,316</td>
<td>10,912</td>
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<tr>
<td>HDD, CD, DVD</td>
<td>13.1%</td>
<td>8,140</td>
<td>4,196</td>
<td>14.4%</td>
<td>14,040</td>
<td>7,237</td>
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<tr>
<td>Electric Bicycles</td>
<td>9.1%</td>
<td>5,680</td>
<td>2,549</td>
<td>8.2%</td>
<td>7,955</td>
<td>3,570</td>
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<tr>
<td>Transducers, Loudspeakers</td>
<td>8.5%</td>
<td>5,290</td>
<td>2,727</td>
<td>6.5%</td>
<td>6,322</td>
<td>3,259</td>
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<tr>
<td>Unidentified and All Other</td>
<td>6.5%</td>
<td>4,046</td>
<td>1,995</td>
<td>6.0%</td>
<td>5,836</td>
<td>2,878</td>
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<tr>
<td>Magnetic Separation</td>
<td>5.0%</td>
<td>3,112</td>
<td>1,466</td>
<td>3.4%</td>
<td>3,307</td>
<td>1,553</td>
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<tr>
<td>MRI</td>
<td>4.0%</td>
<td>2,490</td>
<td>1,228</td>
<td>1.5%</td>
<td>1,459</td>
<td>720</td>
</tr>
<tr>
<td>Torque-coupled drives</td>
<td>4.0%</td>
<td>2,490</td>
<td>1,117</td>
<td>2.5%</td>
<td>2,432</td>
<td>1,091</td>
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<tr>
<td>Sensors</td>
<td>3.2%</td>
<td>1,992</td>
<td>982</td>
<td>1.5%</td>
<td>1,459</td>
<td>720</td>
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<tr>
<td>Hysteresis Clutch</td>
<td>3.0%</td>
<td>1,867</td>
<td>879</td>
<td>1.0%</td>
<td>973</td>
<td>400</td>
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<tr>
<td>Generators</td>
<td>3.0%</td>
<td>1,867</td>
<td>769</td>
<td>1.5%</td>
<td>1,459</td>
<td>687</td>
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<tr>
<td>Energy Storage Systems</td>
<td>2.4%</td>
<td>1,494</td>
<td>670</td>
<td>2.5%</td>
<td>2,432</td>
<td>1,091</td>
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<tr>
<td>Wind Power Generators</td>
<td>2.1%</td>
<td>1,300</td>
<td>583</td>
<td>10.1%</td>
<td>9,810</td>
<td>4,402</td>
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<tr>
<td>Air conditioning compressors and fans</td>
<td>2.0%</td>
<td>1,245</td>
<td>559</td>
<td>2.5%</td>
<td>2,432</td>
<td>1,091</td>
</tr>
<tr>
<td>Hybrid &amp; Electric Traction Drive</td>
<td>0.9%</td>
<td>570</td>
<td>214</td>
<td>6.3%</td>
<td>6,160</td>
<td>2,308</td>
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<tr>
<td>Total</td>
<td>7.7%</td>
<td>4,792</td>
<td>2,186</td>
<td>7.1%</td>
<td>6,906</td>
<td>3,113</td>
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</tbody>
</table>

REE requirement includes 80% oxide to metal, 97% metal alloying, and 80% magnet manufacturing material yields.

Constantinides, 2011
Current HDD Value Recovery Pathways

Start

Security Concerns

1. Security Category of data
2. Device remaining or leaving organization

Resale Value of HDD

2. Costs to Data Wipe, prepare for sale.
3. Barriers for entry.
4. Potential sale value in “White Label” process.

White Label Process Definition:
1. Alternate Sales Channel. Allows the sale of HDDs not otherwise eligible for resale to a Hard Drive remanufacturer. The Hard Drive Remanufacturer disassembles the hard drive and then reassembles the hard drive with new components. Result is a new hard drive ready for sale.
2. White Label sales should be considered as an alternative to shredding or destruction of hard drives.
3. The White Label process allows a full recovery of the component parts of the Hard Drive preserving components for commodity processing.

Commodity Pricing

1. Tradeoff of Labor versus Commodity Pricing
2. Overhead costs – space to perform tear down.
4. Barriers for entry.

End
NIST Risk Decision Matrix

Start

Security Categorization - Low

Leaving Organization Control?

No → Clear

Yes → Purge

Purge

Destroy

No → Security Categorization - Moderate

Reuse Media?

Yes → Clear

No → Leaving Organization Control?

Yes → Validate

Document → End

Source: NIST Special Publication 800-88 revision 1. Figure 4-1: Sanitization and Disposition Decision Flow, page 17.

Partial Definitions:

Clear – use software or hardware products to overwrite user addressable storage space on the media with non-sensitive data, using the standard read and write commands of the device.

Purge – Some methods of purge include overwrite, block erase and Cryptographic Erase, through the use of dedicated, standardized device sanitize commands that apply media-specific techniques to bypass the abstraction inherent in typical read and write commands.

Destroy – may render the Target Data infeasible to retrieve through the device interface and unable to be used for subsequent storage of data, the device is not considered destroyed unless Target Data retrieval is infeasible using state of the art laboratory techniques.

Security Categorization - Moderate

Security Categorization - High

Reuse Media?

Yes → Leaving Organization Control?

Yes → Destroy

No → No
Value Path Decision Making: Operations Perspective

Considerations when deciding the level to disassemble a HDD:
2. Technology – difficulty to separate components. Size of Screws, Number of Screws.
3. Commodity prices – Precious metals, etc.
4. Amount of recovery material – size of drive.
5. Manufacturer HDD – different assembly techniques.
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Value Path Decision Making: Operations Perspective

SMART Test Criteria:
1. Power On Hours – limit 40K hours – not required, but does relate to remaining life of HDD.
2. Reallocated Sector Count – limit to risk of organization and reuse methodology. Failure of HDD could result if remap sectors exceeded. 10 allowed has been seen. Refer to separate discussion.
3. Spin retry count – spin to start count. Indicates HDD failure. 1.2 count has been seen.
4. SATA downshift Count – or Runtime Block Count. Total number of data blocks with detected uncorrectable errors. Indicates potential failure of HDD.
Value Path Decision Making: Current Operations Perspective

Materials recovered:
1. Mixed Aluminum
2. Magnets
3. Mixed Stainless

Start

Receive undamaged HDD
Scan Model for Recovery decision into Floor Control System

Recovery decision?

Scrap

Run SMART test to verify functionality of Hard Drive

Reuse

Pass SMART Test?

Yes

No

Perform Data Wipe

Pass Data Wipe?

Yes

No

White Label Process only drive?

Yes

No

Segregate and process for White Label Sale

Segregate and process for resale or internal use

Hard drive contain large circuit card?

Yes

No

Hard Drive Carcass

Mixed Aluminum

Circuit Card Precious Metal

Sell at Commodity level

Shred Hard Drive to destroy data

End
**Task List**

**Task 1:** Review existing value recovery pathways for HDDs.
- Estimate sizes of various HDD markets by application and HDD type available for the value recovery feedstreams
- Identify the product(s) in each sector (consumer electronics, data centers, enterprise electronics) at EOL that contain HDDs and review disposition of HDDs when the products are identified as being “EoL”

**Task 2:** Develop list of possible value recovery streams and possible decision points.
- Routes through which equipment goes
  - Inputs
  - Outputs
  - Decision making criteria: general to specific, as available

**Task 3:** Review current state of HDD value recovery throughout the EoL supply chain.
**Task List**

**Task 4:** Develop high-level assessment of roles of the economic actors in the value recovery chain.

**Task 5:** Develop a more detailed decision tree for use along the supply chain on potential choices for value recovery and identify existing criteria, tests, and standards for decision making, including an estimate of the economics.

**Task 6:** Identify barriers to value recovery and opportunities for optimizing value.

**Task 7:** Develop recommendations for next steps. Write and issue public report.