Statement of Work (SOW)
iNEMI Sustainable Electronics TIG
Value Recovery from Used Electronics, Phase 2

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Basic Project Information

Background/Context
In the iNEMI project on Value Recovery from End-of-Use Electronics (Phase 1), the team developed options for best practices – collaborations, technologies, supply chains, and decisions by key stakeholders - that would increase the value recovered from end-of-use Hard Disk Drives (HDDs), as used electronic components, whether functioning or non-functioning and without compromising data security.

In the Phase 2 project proposed here, the team is seeking to develop and demonstrate design and resource management models whereby the value of a HDD could be maximized throughout its working life. This can be accomplished by extending the working life of the product by reuse as an intact drive through multiple pathways, by HDD manufacturing using extracted parts, by extraction of parts for higher value use than as feedstock for materials recovery, and finally for materials recovery alone. Phase 1 estimated that considering these scenarios as a series of decision points by collaborating stakeholders can increase the value of used HDDs by more than a factor of 10x compared to materials recovery by shredding, separation, and smelting. In Phase 2 we are seeking to challenge the current recycling paradigm by maximizing the recovered value of the HDDs themselves and their parts and materials that make up the HDD as described in the Phase 1 Project Report. Materials that cannot be recovered and repurposed for new product manufacture will have to be processed in a cost-effective, environmentally friendly manner.

In Phase 1, the team identified some existing technologies for “remanufacturing” intact, functioning HDDs as OEM branded and white label drives by using built-in “offline logical depopulation” firmware, erasing and replacing the security encryption key, and using proprietary testing and white labeling system. There are also opportunities to recover critical components such as the rare earth magnets and other critical components in a cost effective manner that they could be reused for manufacturing new HDDs.

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This will, however, take changes to HDD design, as well as effective collection and disassembly pathways that ensure that the components re-enter the manufacturing supply chain. In Phase 2 we will seek to realize those opportunities and create additional high value recovery processes and material streams as compared to current recovery efforts which focus on aluminum, ferrous metal, and gold recovery.

The purpose of the Phase 2 project is to create an economically sustainable process for value recovery and reuse of millions of HDD components and electronic grade raw materials from used HDDs. The team will seek to determine and document best design practices and process flows to maximize the value of recovered HDDs, parts and materials. In so doing we seek to establish a robust supply chain for processing used HDDs that results in a stream of components and raw materials that can be sustainably harvested, thus creating a robust circular economy model for HDDs.

To accomplish this goal it is essential that the goals and practices of various actors in the recovery system, particularly those who design/manufacture and those who use/discard the products, are aligned and complement each other to keep products flowing through the system. This must come about either through collaboration based on shared goals, or through properly structured incentives, or some combination of the two.

The project would build on the results of the Phase 1 and Metals Recycling projects by bringing together committed stakeholders in the HDD value recovery system to develop common goals for collaboration in implementing specific value recovery pathways that meet the needs of the stakeholders in a sustainable way.

**Scope of Work**

**Purpose of Project**

This fast-turn project will focus on collaboration in hard disk drive design, reuse, remanufacturing, and materials and component recovery that enables a robust, sustainable circular supply economy for hard disk drives. As articulated clearly by the Ellen MacArthur Foundation (Figure 1), the creation of a circular economy for any product requires a multi-stakeholder approach. From the users’ viewpoint, to be effective, the rationales, pathways and incentives must be compelling enough to convince users to channel their products into the value recovery stream. For HDDs in particular, data security concerns (and the legal and corporate liabilities associated with the release of confidential and sensitive data) frequently lead HDD users in the US to shred their HDDs, even if they are fully functional. One of the goals of the project is to engage with HDD users and all those in the value recovery supply chain to assess users’ data security concerns and obligations and best practices required to avoid shredding. The stakeholder groups in Figure 1, users, manufacturers, service providers, and parts manufacturers, and for others critical to value recovery of HDD (identified in Phase 1), must work together to analyze the capabilities of existing and new technologies and identify the gaps needed to “complete the circle.” The purpose of this project will be to take the next steps in developing a circular economy for HDDs.
Objectives/Goals:

1. Identify/Develop Criteria for encouraging the reuse/resale of used, functional HDDs for different user types that have different HDD use profiles and data security concerns. Starting with the NIST decision making guidelines, data sanitization options will be evaluated, including using firmware-based remanufacturing, physical data wiping, replacing the encryption key for self-encrypting drives (SED), as well as physical destruction/shredding, and the necessary conditions for choosing specific options. A set of examples will be used to demonstrate how these can be implemented for different user groups.

2. Identify/Develop Criteria for enabling reuse of HDD components – from HDD manufacturers’ point of view (design, materials, processes, economics, supply chain, corporate strategy for next generation devices and technologies), recycling/recovery supply chain point of view (collection efficiency, logistics, and economics), and HDD user/owners’ point of view (risks, incentives).

3. Identify/Develop Criteria for enabling reuse of magnets in non-HDD applications, including economics, technology availability, and secondary market dynamics.

4. Benchmark Current Reuse and Recovery Processes (quantitative: yield, efficiencies, economics, product availability and flows, collection efficiencies and pathways) and compare with emerging technologies and processes.

5. Identify Critical Leverage points affecting HDD value recovery/reuse.

Figure 1. Circular Economy schematic from the Ellen MacArthur Foundation showing some of the principles, necessary processes and the stakeholders responsible for them in creating an “optimal” solution. The principles suggest the dynamic nature of creating a circular economy: measuring system effectiveness over time may lead to system changes to minimize externalities and improve sustainability, vis-à-vis economics and environmental and societal impact. (https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram)
### IS / IS NOT Analysis

<table>
<thead>
<tr>
<th>This Project IS:</th>
<th>This Project IS NOT:</th>
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<tbody>
<tr>
<td>Focusing on value recovery of hard disk drives (HDDs)</td>
<td>Focusing on other IT electronics, except in so far as they contain HDDs</td>
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<td>Focusing on design guidelines and decision making criteria for HDD reuse, parts recovery, and metals recovery and their application</td>
<td>Developing standards or certifications</td>
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<td>Building supply chains for high volume value recovery of HDDs</td>
<td>Limited to existing pathways or stakeholder interactions</td>
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<td>Involving companies and stakeholders from across the electronics industry, not just HDD manufacturers or a limited number of stakeholder types</td>
<td>Repeat of existing work</td>
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<td>Investigating supply chain economic considerations to develop circular use of materials, components, products</td>
<td>Shredding and landfilling or waste to energy at end of life</td>
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<td>Identifying new materials recycling technologies being developed that might enable greater value recovery</td>
<td>Developing new metals recycling processes or end processes</td>
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<td>Performing product and supply chain analyses to determine where and how HDD are used and discarded by specific user groups and applying the decision points and agents/actors identified in Phase 1 to create different value recovery systems, pathways, and partnership</td>
<td>Developing commercialization plans for or promoting a particular recovery technology</td>
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<td>Engaging with R&amp;D community to discuss technology gaps for sustainable value recovery from end-of-use HDDs</td>
<td>Being proscriptive</td>
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<td>Testing the Ostrom socio-ecological framework for creating self-organizing, sustainable communities for HDDs</td>
<td>Creating new tools or assessment methods</td>
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<td>Showing options for value recovery to manufacturers, electronic recyclers and other economic and societal actors in the HDD supply chain</td>
<td>Judging effectiveness</td>
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<td>End outputs: Public report, implementation plans, iNEMI member-only recommendations for next steps (Phase 3+ or other)</td>
<td>Developing OEM-specific product design criteria</td>
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Business Impact
The industry will benefit from this collaborative effort without investing a huge sum of money and resources individually. The business impact could be substantial in the following areas.

A. Project Team
   • Experience gained in creating effective, specific collaborations to increase value recovery.

B. iNEMI Participation
   • Follow-on project could increase in membership for iNEMI and knowledge with the iNEMI membership

C. The Industry
   • Increase credibility of industry as agents for positive change

D. The Value Recovery Community, including the IT Asset Management and Recycling Industries
   • Provide insight regarding product and technology changes that are occurring and how they will impact value recovery operations and the creation of a circular economy for HDDs.

Participating Organizations (from Phase 1)

   Seagate
   Green Electronics Council
   Purdue University
   University of Limerick
   Oak Ridge National Laboratory
   Critical Materials Institute
   Teleplan
   University of Buffalo, State University of New York
   Geodis
   Idaho National Laboratory

Outcome of Project
The intended outcomes for the project are (1) the creation of new value recovery pathways for end-of-use HDDs, (2) the strengthening of existing pathways, in effectiveness, economic viability, and yield, (3) the identification of ways to change decision making processes and remove barriers to promote HDD and HDD component reuse, and (4) the establishment of new, stronger relationships among stakeholders with shared goals for increasing value recovery from EoU HDDs. The new value recovery pathways may include redesign of HDDs so that components may be reused, better education of and OEM-follow-through with users to enable firmware-based remanufacturing or encryption key resets to avoid the need for shredding, innovative technologies that reduce the cost for component recovery and materials recycling.

From a more long-term perspective, this iNEMI sponsored project proposes a highly collaborative prototype system for value recovery based on the Ostrom Framework for sustainable, self-management of common pool resources. The project would provide a case study for understanding what the term “best practices” mean for the stakeholders to create a circular economy, how trusted relationships can be built, and how information sharing can help the stakeholders identify new opportunities for EoU management of HDDs.

Previous Related Work

   • iNEMI Metals Recycling Project
   • e-Stewards, R2, WEEE-LABEX

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• STEP paper – what should be included in best practices of collection and processing in WEEE
• UNEP Resource Panel Reports, including “Metal Recycling: Opportunities, Limits, Infrastructure”
• Academic papers
• Best practices/interactions in asset management and the recycling/supply chain
• EU Best practice list for collection schemes (ERP)
• PACE recycling guidelines
• iNEMI Value Recovery from Used Electronics (Phase 1)

Prospective Participants from Different HDD Stakeholder Groups

We are soliciting participation from all the different stakeholder groups for value recovery from HDDs, including the following.

At least one representative from the following economic actors:

1. HDD manufacturers: Seagate, Western Digital, Toshiba
2. Large users of server and HDD storage systems
   a. Data centers
   b. Facebook
   c. Google
   d. Amazon
   e. others
   f. Data intensive companies and organizations, such as banking, finance, health care, federal and state governments, utilities, universities
3. IT asset management companies – large, medium, and small
4. Recycling supply chain, with different
   a. Collection schemes
   b. Pre-processing technologies
   c. Electronic scrap end-processing
5. Metals Recovery stakeholders/stakeholder groups and Makers or associated consortia
   a. Alcoa, Alcan, Umicore
   b. Cascade Asset Management
   c. Urban Mining
   d. R&D Institutes, such as NNMI
   e. Ferrous metal, aluminum and/or rare earth/magnet consortia
   f. Recycling associations
   g. Broker organizations
6. Academic and R&D Institutions
   a. Material flows, economic and supply chain analyses
   b. Innovative processes for value recovery along any pathway
7. Electronics Manufacturer – Consumer, Enterprise, Future looking
   a. Consumer electronics producer
   b. Enterprise electronics producer
8. Supply Chain for HDD
   a. Electronics: ICs, assemblies
   b. REE permanent magnet assemblies
   c. Others: disks, mechanical structures, housing
Project Plan

Schedule with Milestones

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<th>Task 1</th>
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Task 1: Identify Criteria for Enabling Reuse of used, functioning HDDs and of components from used, non-functioning HDDs
- Work with HDD users to assess specific decision making criteria for different user types
- Assess existing barriers and incentives for reuse with different user groups, particularly with respect to data security, and determine whether there are existing options that could be used to lower the barriers.
- Identify case studies/examples.

Task 2: Identify Criteria for Enabling Reuse of HDD components in HDD applications – both direct and indirect for metal components, disks, magnetics, motors, head, PWBs etc.
- Work with HDD manufacturers to assess the feasibility of reuse
- Work with recyclers and technology R&D organizations to determine whether the current technologies meet the needs determined by the HDD manufacturers

Task 3: Identify Criteria for Enabling Reuse of magnets in non-HDD applications
- Direct, indirect, raw materials for use in bonded magnets, materials recovery
- Identify high value engineering applications for recycling and reuse of aluminum and steel in HDD’s in non-HDD applications. Determine basic economic and engineering boundary conditions are requirements to achieve sustainable HDD metals recovery and remanufacture for high value engineering applications while maintaining net environmental benefit.

Task 4: Develop economic and logistics estimates for cases studies identified in Tasks 1-3.

Task 5: Summarize, Review Design principles for reuse in HDD and non-HDD applications

Task 6: Benchmark current reuse and recovery (direct, indirect) with stakeholder input

Task 7: Identify Leverage Points
- Materials Selection, Data Security, Material Recovery specialist, Data Center/Storage collaborative relationships, warranty repair/remanufacturing/resale, voluntary standards

Task 8: Identify/Map the supply chain and identify key gaps for developing a circular economy including each value recovery pathway for HDDs

Task 9: Socialize and publish findings

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**Project Monitoring Plans**

Ensure open lines of communication among participants.

Review all project requirements with participants before the project begins.

Project participants will meet bi-weekly to review various aspects of the project, complete tasks, and make plans for next phases of the project, if warranted.

Meeting minutes provided promptly through e-mail.

Follow-up with individuals and sub-groups on an as-needed basis.

Workshops and face-to-face meetings as determined by the project team.

Progress reports will be provided upon request for presentation at regularly scheduled iNEMI meetings (e.g., a short series of PowerPoint slides showing the work in progress at member council meetings).

Track and document approximate man-months per quarter per team member (this will require the active members of the team to provide estimates).

Track and document approximate number of people on the project per quarter (this can be tracked through iNEMI’s WebEx account).

**General and Administrative**