U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Driving Reuse, Recycling, and More Efficient Use of Critical Materials

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manufacturing.energy.gov

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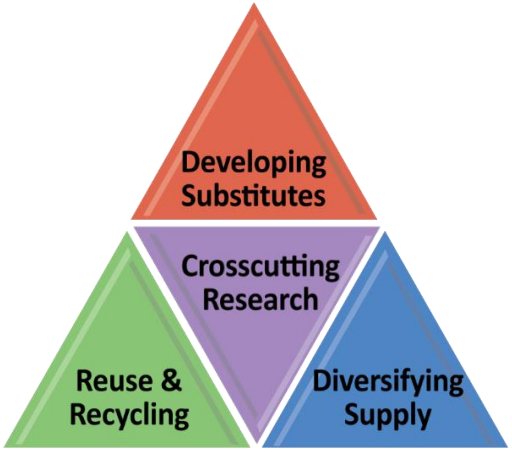
Critical Materials Institute – an Energy Innovation Hub

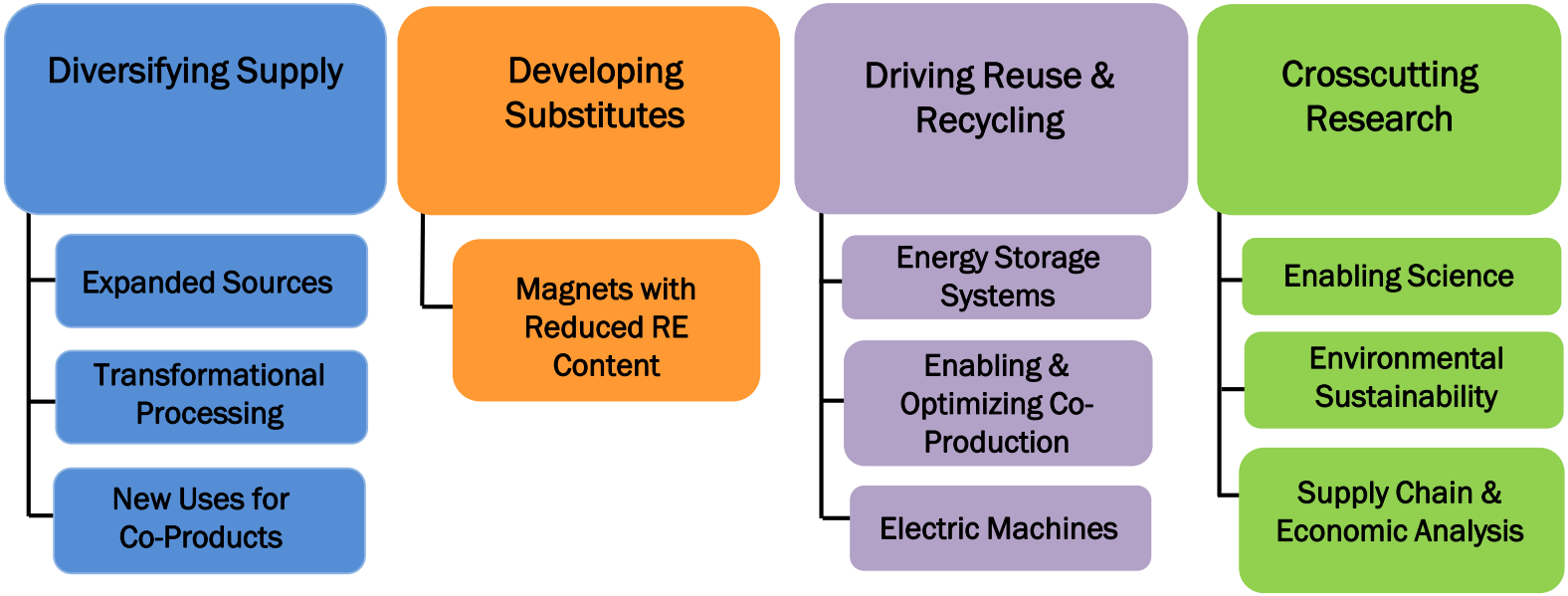
CMI | Accelerating Energy Innovations

Critical Materials Institute



- Focused on advancing cost-effective separation, processing, and substitution of critical materials, to support U.S.-based supply chains for high-value add technologies that rely on these materials (magnets, aerospace components, lasers, etc.).
- CMI has filed 129 invention disclosures, filed 50+ patent applications, received 12 patents, and licensed 9 technologies to industry.

Critical Materials Institute – an Energy Innovation Hub



Al-Ce Alloys
Low RE Phosphors
Low RE Magnets
Printable magnets
Strengthened SmCo magnets

Rigid ligands
Improved MSX

Mining & Concentration → Extraction & Refining → Chemical & Metallurgical Processing → Refining & Alloying → Recycling → Fabrication → Part Manufacturing → Sub-Assembly Manufacturing → System Integration

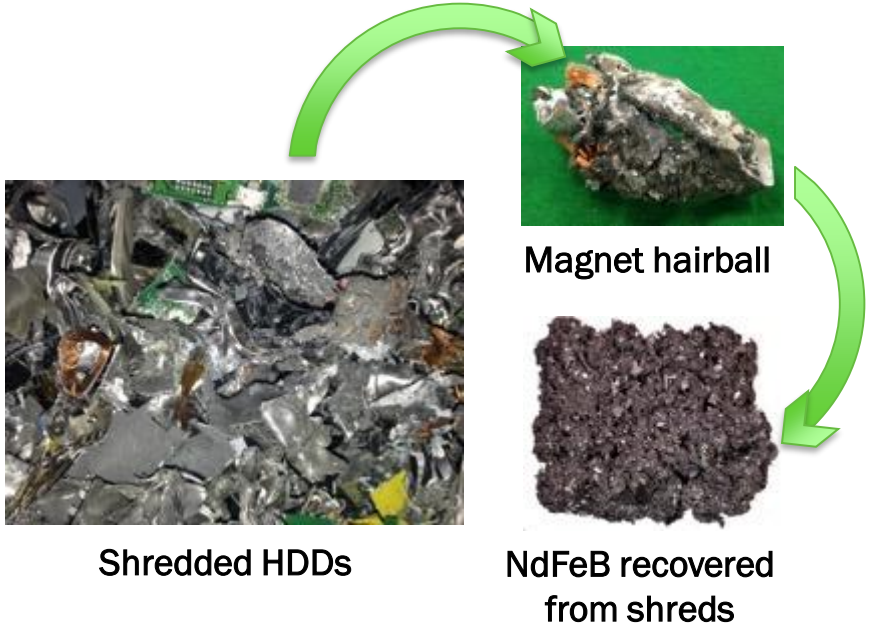
Improved beneficiation
Li from Brine

Molten salt
Ionic Liquids
Synthetic Graphite

Acid-free
E-RECOV
Automated disassembly

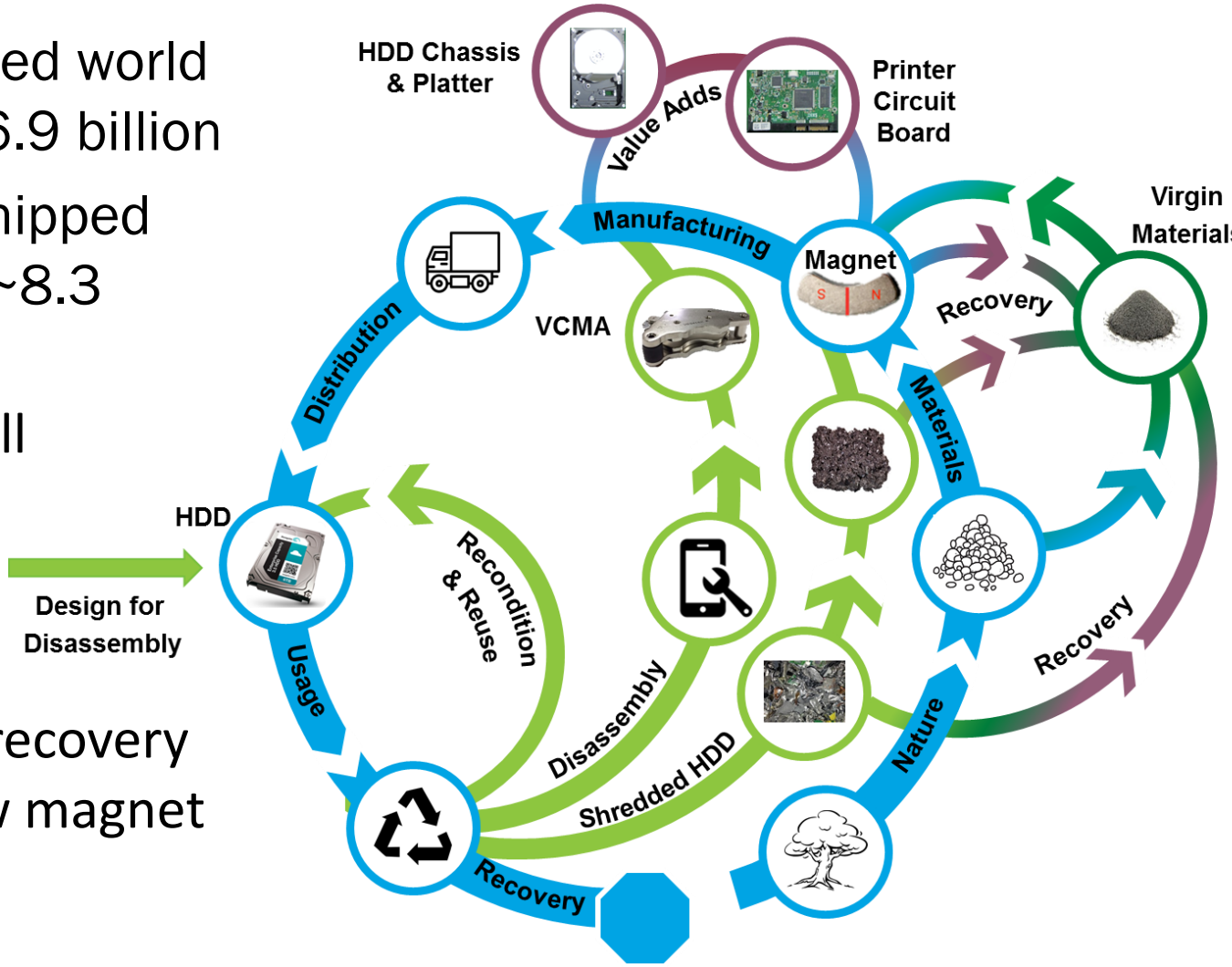
Opportunity – Hard Disk Drives

- Hard disk drive (HDD) components include **Dy/Tb**-containing **Nd**FeB magnets
- Nd, Pr, Dy, Tb are *critical* rare earth elements
- Majority of HDDs are shredded at end-of-life
- NdFeB recovery from shredded material is technically feasible but not economic



Circular Economy

- Total HDDs shipped world wide to date = ~6.9 billion
- Total projected shipped through 2020 = ~8.3 billion
- Recycled HDDs will generate > 500 metric tones of NdFeB per year
- High throughput recovery can stimulate new magnet reuse industry



Acid-free Dissolution Process for Electronic Waste

Achievement

- Best acid-free chemical solution ($CuSO_4$) for preferential HDD-magnet dissolution at room temperature and varying solution concentrations has been selected

Significance and impact

- Chemicals with highest hydrolytic stability and REE leaching selectivity for magnet dissolution from e-wastes (<4% of REE) are required for the efficient recycling (Figs. 1 and 2)

Details and next steps

- Other parts of HDDs (e.g. PCBs, ceramic or Al bases, etc.) are non-reactive with copper sulfate solution at recycling conditions
- Different Cu-based based solutions were tested, leading to $CuSO_4$ being selected
- Next step is to determine the efficiency of the process including as a function of temperature

Figure 1: Images of: iron(III) hydroxide (as hydrolysis product, left) and resulted unreacted HDD parts (right) after reaction with copper(II) chloride

Figure 2: Image of some parts of shredded hard disk drives after acid-free dissolution reaction

High Performance Magnets from Scrap Materials

Achievement

- High performance Nd-Fe-B-based magnet, with 14.2 kOe coercivity, was made using rare earths elements recovered from the acid-free dissolution recycling process.

Significance and impact

- Demonstrates ability to reinsert recycled rare earths into magnet supply chain.
- Rare earth oxides were recovered from shredded HDDs and swarfs- indicates that the acid-free process can be applied to mixed rare earth recycling feedstock.
- Acid-free dissolution process is efficient and environmentally safer than acid-based processes.

Details and next steps

- Recovered >99.5% pure rare earth oxide was used to produce a rare earth metal ingot.
- Ingot was alloyed with iron and boron to make magnet material.
- Alloy is used to make sintered magnets.

SBIR/STTR Opportunity

Critical Materials Supply Chain Enabling Research SBIR subtopic provides the opportunity to strengthen the domestic critical materials supply chain by supporting small business R&D.

- **Reduction of Critical Materials in Energy Technologies:** Responsive proposals to this area of interest should seek to significantly reduce critical materials content in energy technologies. Refer to the full subtopic description for complete details on suggested critical material and energy technologies. Proposals that either target reduction of critical materials in batteries, or propose a system to completely substitute for critical material dependent technology will be considered non-responsive.
- **Energy Efficient Manufacturing of Critical Materials:** Reducing energy consumption through investment in advanced processes and technologies can enable domestic supply chain manufacturing competitiveness. Proposals in this area of interest are encouraged to increase energy efficiency by targeting reduction of energy intensity of processing and manufacturing of critical materials or critical components for energy technologies.

AMO Webinar Dec. 12, 2-3pm

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