THE CENTER FOR
RESOURCE RECOVERY AND RECYCLING

NSF Industry/University Cooperative Research Center

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Academic Partners

Worcester Polytechnic Institute

Colorado School of Mines

KU Leuven

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Expertise

**WPI**
- Metal Processing - Sortation and Recycling Technologies
- Electrochemistry – Li Ion Batteries
- Magnets; Rare Earth Metals; post consumer waste

**Colorado School of Mines**
- Kroll Institute for Extractive Metallurgy (Pyrometallurgy-Hydrometallurgy- Electrometallurgy)
- Mineral Processing
- Rare Earth Metals

**KU Leuven**
- Materials characterization
- High temperature Metallurgy
- Rare Earth Metals
Outline

① What do we do at CR³?

① “Nucleation” issues with emerging areas

① Experience with “SBIR” members

① Recommendations
Metal Production Trends

G. Mudd, 2009, Sustainability of Mining

Center for Resource Recovery and Recycling
2010 Recycling Rates in the U.S.

Credit: EPA

Center for Resource Recovery and Recycling
# End-of-life Recycling Rates

<table>
<thead>
<tr>
<th>Periodic Table</th>
<th>Recycling Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li Be</td>
<td>&gt; 50%</td>
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<tr>
<td>Na Mg</td>
<td>25 - 50%</td>
</tr>
<tr>
<td>K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr</td>
<td>10 - 25%</td>
</tr>
<tr>
<td>Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe</td>
<td>1 - 10%</td>
</tr>
<tr>
<td>Cs Ba Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn</td>
<td>&lt; 1 %</td>
</tr>
<tr>
<td>Fr Ra Rf Db Sg Bh Hs Mt Ds Rg Cn UutUuoUupUuhUusUuo</td>
<td>UNEP, 2010</td>
</tr>
</tbody>
</table>

Center for Resource Recovery and Recycling
The Need for CR$^3$

- Materials are not renewable. Technologies need to be developed for cost-effective recycling and recovery of resources,

- Design of components with end of life recovery/recycling needed to improve recovery/recycling rates,

- Both technological issues as well as policy issues need to be addressed for holistic sustainable solutions,

- Materials resource recovery and recycling is a critical need for sustainable development in the 21st Century,

- Academia-Industry-Government need to work together to tackle these critical issues. CR$^3$ is the first center of its kind established to address these needs.
<table>
<thead>
<tr>
<th>Metal →</th>
<th>Iron &amp; Steel</th>
<th>Pb, Zn, Cu, Ni, Co</th>
<th>Al, Li, Mg, Ti</th>
<th>Rare Earth</th>
<th>Ga, In, Te</th>
<th>Refractory Metals</th>
<th>General</th>
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</thead>
<tbody>
<tr>
<td>Project Area ↓</td>
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<tr>
<td>Production Process Waste</td>
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<tr>
<td>Post-Consumer Waste</td>
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<tr>
<td>Instrument/Sensors/Controls</td>
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<tr>
<td>Design for Recycling/Mfg for disassembly</td>
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<tr>
<td>Trash to Treasure</td>
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</tbody>
</table>

**CR³ RESEARCH PORTFOLIO METHODOLOGY**
Outline

① What do we do at CR$^3$?

① “Nucleation” issues with emerging areas

① Experience with “SBIR” members

① Recommendations
“SBIR” Members

1) ERCo
2) Infinium
3) Persimmon
4) wTe
“SBIR” Members

1) ERCo – FULL MEMBER 2014 and on
2) Infinium … Continuing
3) Persimmon… Continuing
4) wTe – Dropped out
Specific Recommendations

To I/UCRC Directors:

- Invest time in getting to know the company
- What are their needs?
- What can you do to make them successful?
- Reinforce Value Proposition with decision maker
- REUs, internships, joint proposals, etc.

To NSF

- Data Mining of SBIR grantees