



**THE CENTER FOR  
RESOURCE RECOVERY  
AND RECYCLING**

NSF Industry/University Cooperative Research Center

**Diran Apelian**

*Alcoa-Howmet Professor of Engineering  
Metal Processing Institute  
WPI – Worcester, MA USA*

# Academic Partners



Worcester Polytechnic  
Institute



Colorado School of Mines



KU Leuven



Center for Resource Recovery and Recycling

# CR<sup>3</sup> Team

## **Diran Apelian**

dapelian@wpi.edu

+1 508-831-5992 office

Metal Processing Institute

WPI, Worcester, MA 01609 USA



## **Brajendra Mishra**

bmishra@mines.edu

+1 303 273-3893 office

Metallurgical & Material Engineering

CSM, Golden, CO 80401 USA



## **Bart Blanpain**

bart.blanpain@mtm.kuleuven.be

+32 16 32 12 16 office

KU Leuven, Materials Engineering

B-3001 Leuven, Belgium



# 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

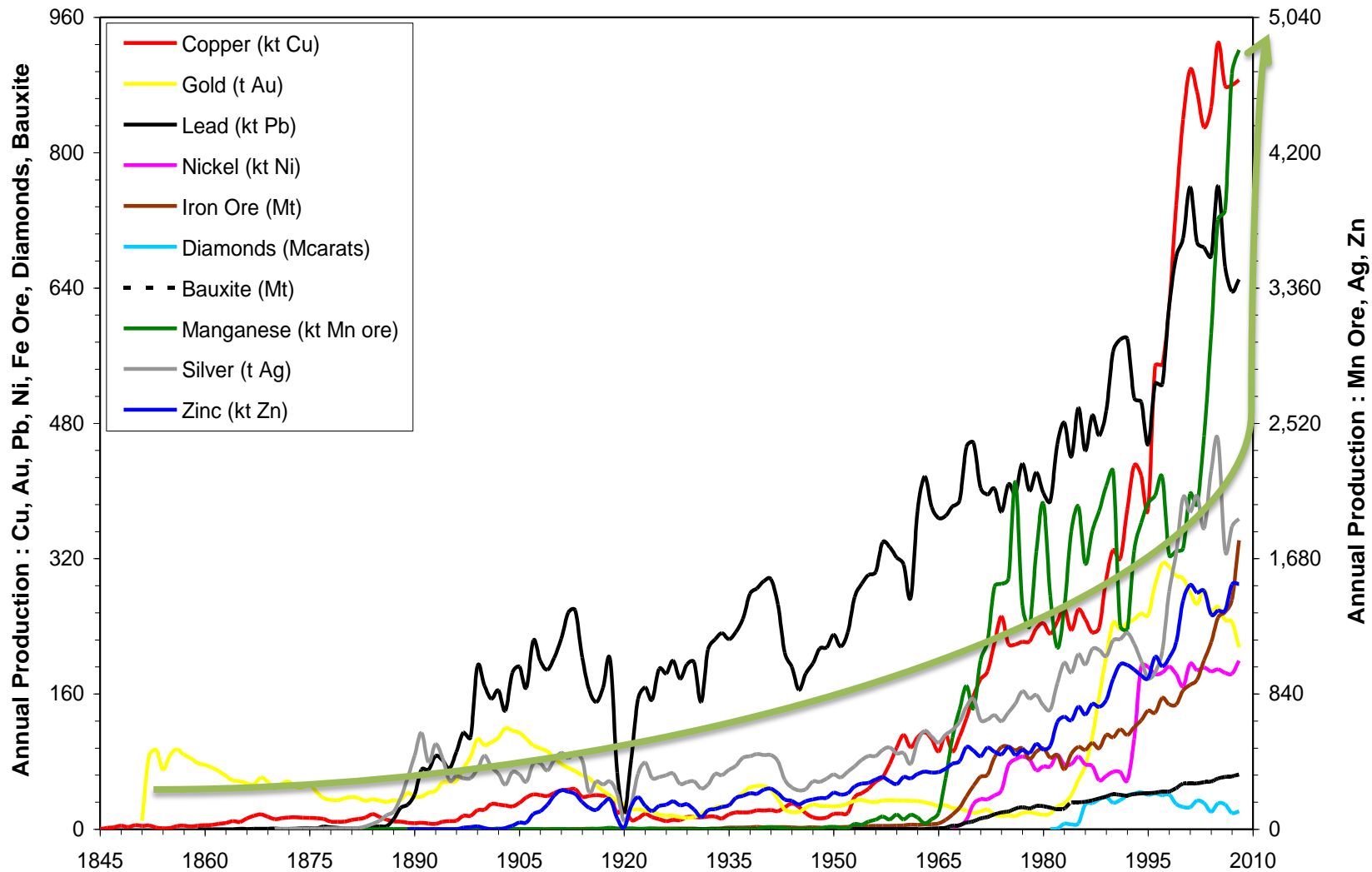
## KU Leuven

- Materials characterization
- High temperature Metallurgy
- Rare Earth Metals

# Outline

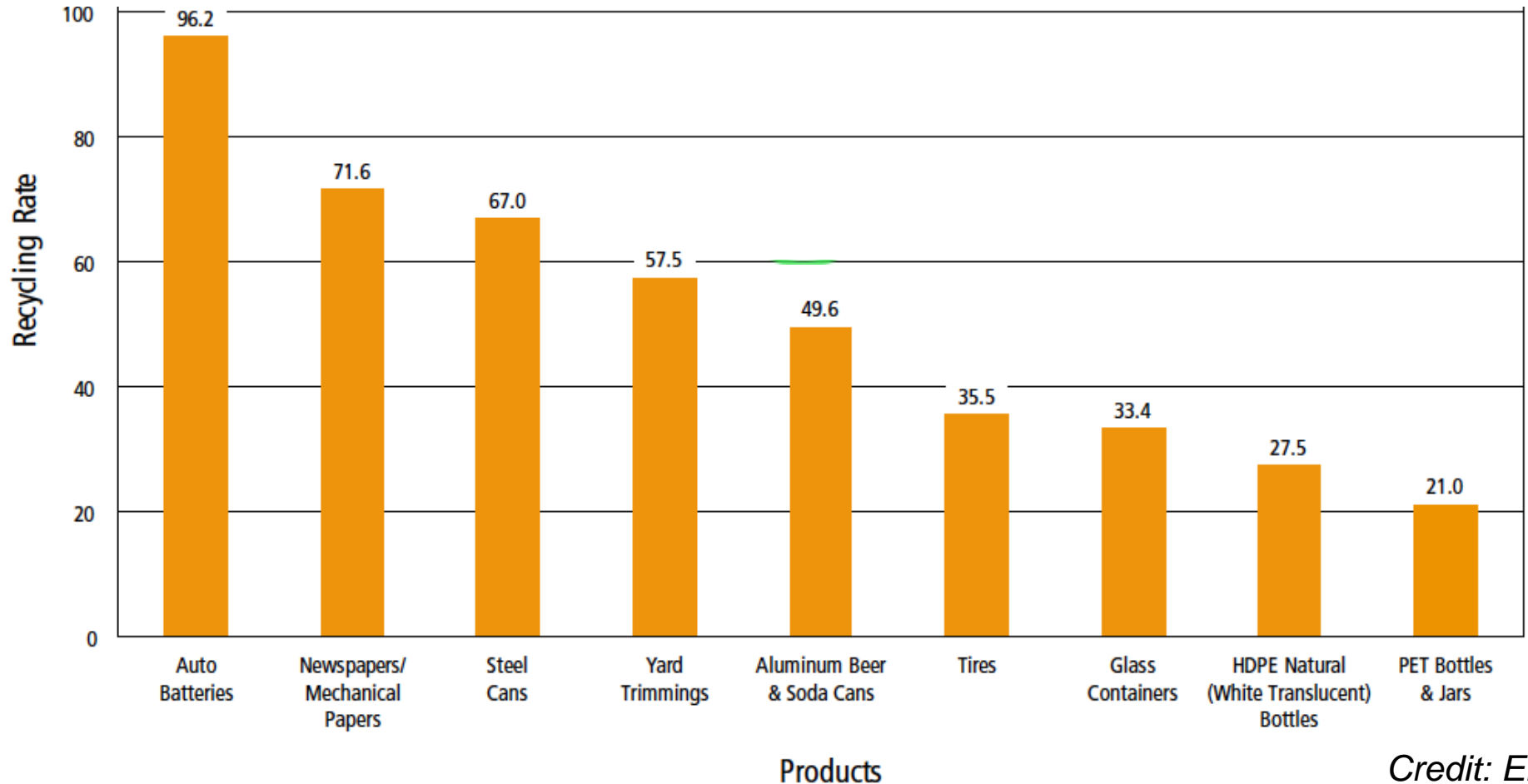
- ① What do we do at CR<sup>3</sup>?
- ① “Nucleation” issues with emerging areas
- ① Experience with “SBIR” members
- ① Recommendations

# Metal Production Trends



G. Mudd, 2009, Sustainability of Mining

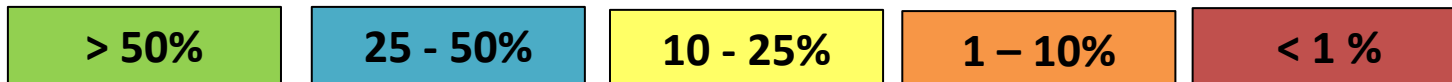
# 2010 Recycling Rates in the U.S.



# End-of-life Recycling Rates

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr



UNEP, 2010



# The Need for CR<sup>3</sup>

- 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 21<sup>st</sup> Century,
- Academia-Industry-Government need to work together to tackle these critical issues. CR<sup>3</sup> is the first center of its kind established to address these needs.

<b>Metal →</b> <b>Project Area ↓</b>	<b>Iron &amp; Steel</b>	<b>Pb, Zn, Cu, Ni, Co</b>	<b>Al, Li, Mg, Ti</b>	<b>Rare Earth</b>	<b>Ga, In, Te</b>	<b>Refractory Metals</b>	<b>General</b>
<b>Production Process Waste</b>							
<b>Post-Consumer Waste</b>							
<b>Instrument/Sensors/Controls</b>							
<b>Design for Recycling/Mfg for disassembly</b>							
<b>Trash to Treasure</b>							

**CR<sup>3</sup> RESEARCH  
 PORTFOLIO  
 METHODOLOGY**

# Outline

- ① What do we do at CR<sup>3</sup>?
- 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