Recycling, Reuse, Recovery and Remanufacturing Institute

R^4I

Workshop

Idaho National Laboratory

The Institute for Recycling, Recovery, Reuse, and Remanufacturing (R^4-I)

A National Institute for Innovation in Materials Efficiency with Regional Focal Points

New Products

Science → Manufacturing → Products

Moving from Science through Manufacturing to Products

Today's Agenda

Welcome and Introductions – Eric Peterson
Description of an Institute – Mike McIlwain
Overview of proposed Institute – Eric Peterson
Morning Leadoff Speakers discussing specific needs -
Charge for Breakout set #1 – Mike McIlwain
Morning Break
Breakout set#1

Lunch – On your own

Afternoon Leadoff Speakers discussing specific needs
Charge for Breakout set #2 – Mike McIlwain
Breakout set# 2
Afternoon Break
Summary of Days Activities/Recommendations – Discussion Leaders
Closeout – Eric Peterson

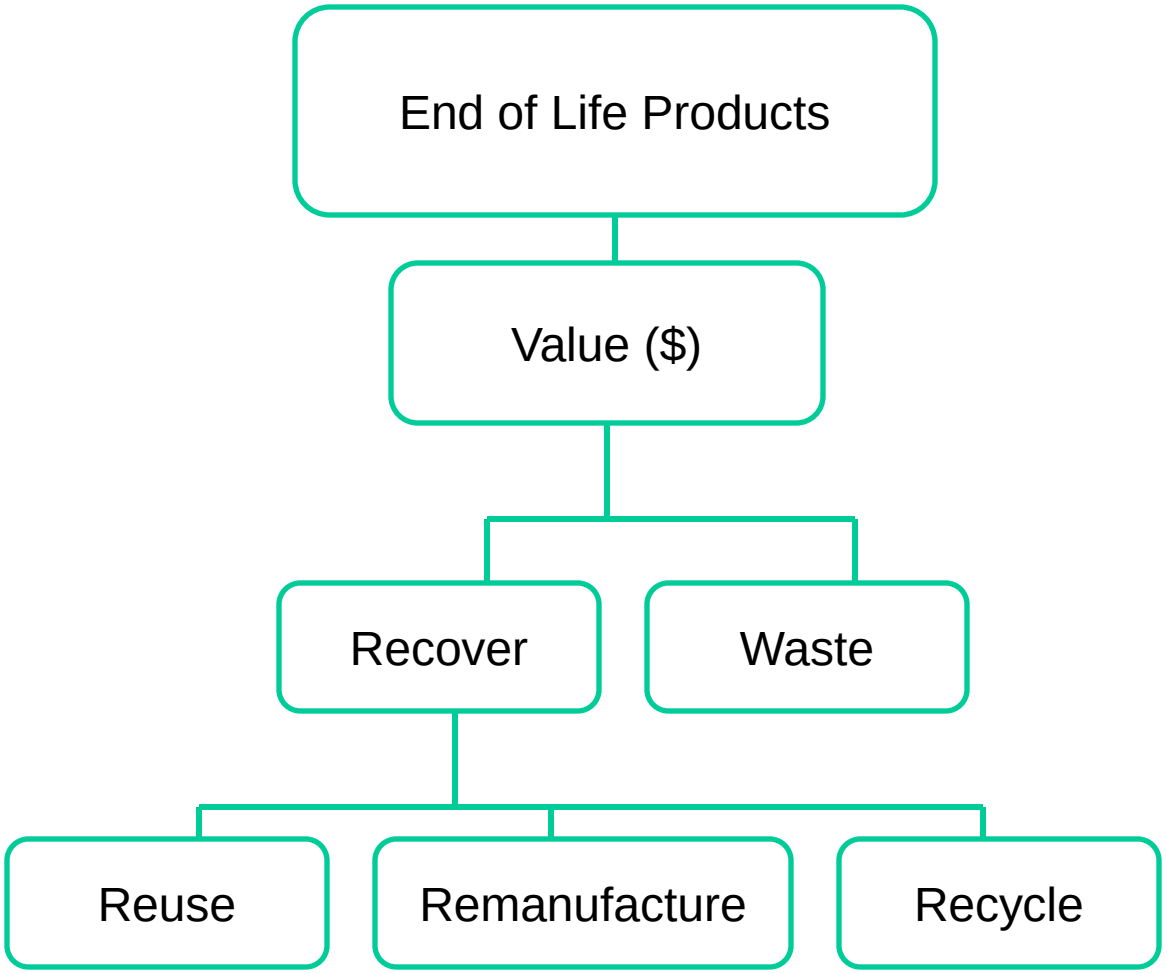
1) The Problem – High cost of commodity materials

- High cost of commodity materials – metals (REE, TM, PGM, Li, Te), petroleum
  - 1.2 million tons Plastics
  - 0.65 million tons copper
- Land fills are filling up
  - 28 – 35 million tons per year solid muncipal waste into landfills in England past 5 years – 5 - 6 yrs capacity remain in England
- Primary recovery is energy- and labor-intensive (frequently locked in technology from the last century or before)
- High environmental cost: water pollution, air pollution (35% of world methane produced, acid rain, metals, carbon) -- many unanticipated costs
- With limitations on the supply of some commodity materials – high prices
- Geo-political-military costs related to commodities in locations that are not friendly

Potential Approaches

- Government Policy development – helps provide driver
- Recovery approaches that are both energy efficient and practical
- Reuse, Repairing, Reconditioning – societal acceptance
- Remanufacturing – novel approaches and more of it
- Recycling – needs refinement and added drivers to implement
- Waste – landfills, construction materials, alternate applications

Recovery, Recycling, Reuse, and Remanufacturing



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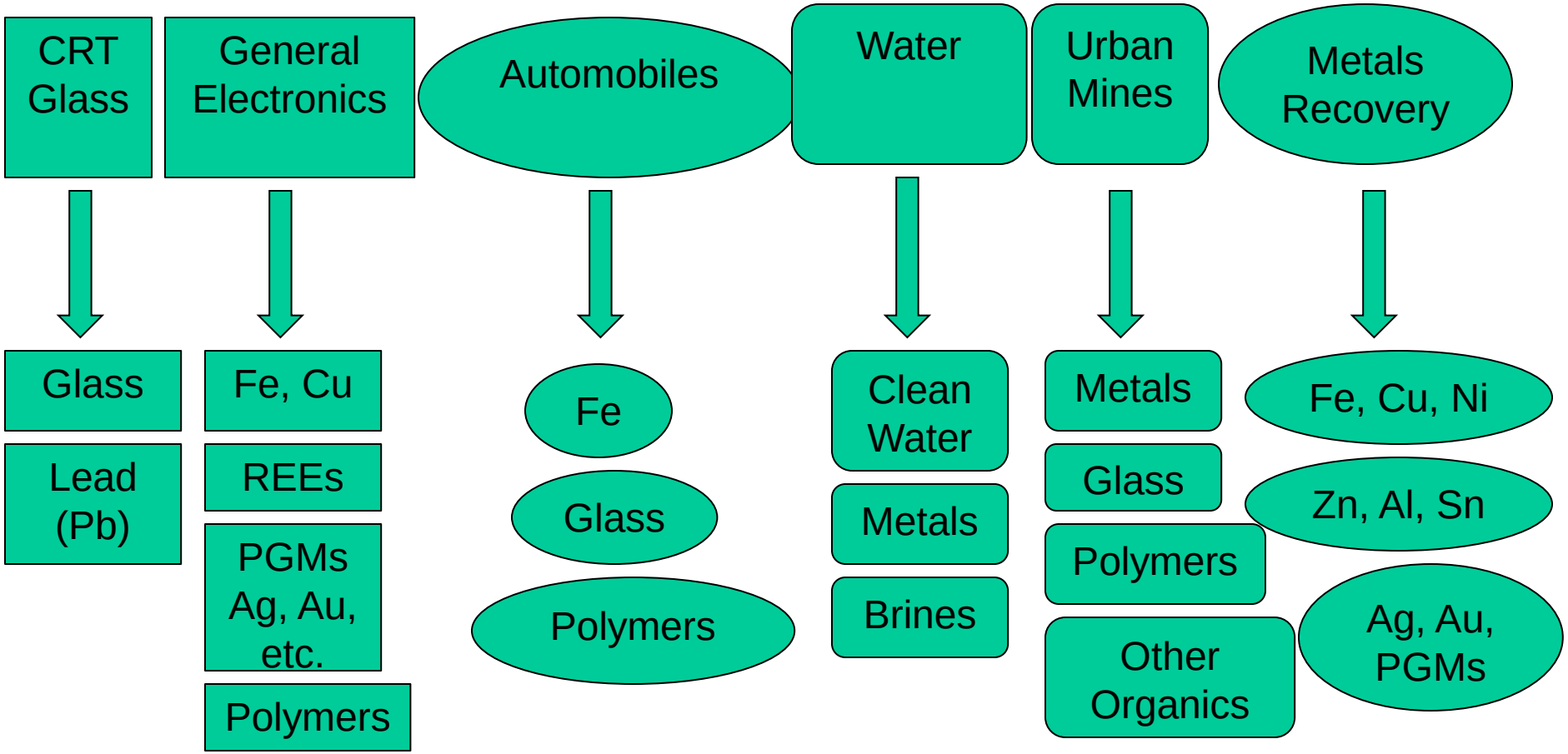
2) The Opportunity – next generation R^4 technologies

- Huge economic and environmental opportunities in innovation, development and deployment of R^4–I technologies with parallel policy development



2) Opportunity (con't)

- Next generation designs for Recycling, Recovery, Remanufacturing and Reuse
  - Reduced life-cycle energy consumption and greenhouse gases
  - Design for manufacturing and remanufacturing
  - Design for recycling
  - Development of lower-cost destruction/production pathways for commodity recovery and utilization
  - Enhanced economic competitiveness for U.S. manufacturing
  - Create a group of next-generation technologists specialized in the R^4 science and engineering disciplines
    - educational pathways in R^4 engineering/science – already started
  - Strengthened U.S. science and engineering vitality
  - Creation of high-paying jobs for Americans for spectrum of semi-skilled to skilled jobs
    - Consequence of improved economic competitiveness
- Summary - Can a compelling business case be made that includes incentives so that companies make money at this – or no one will do any of it!

Science → Manufacturing → Products

3) The Solution – Next generation R^4 technologies

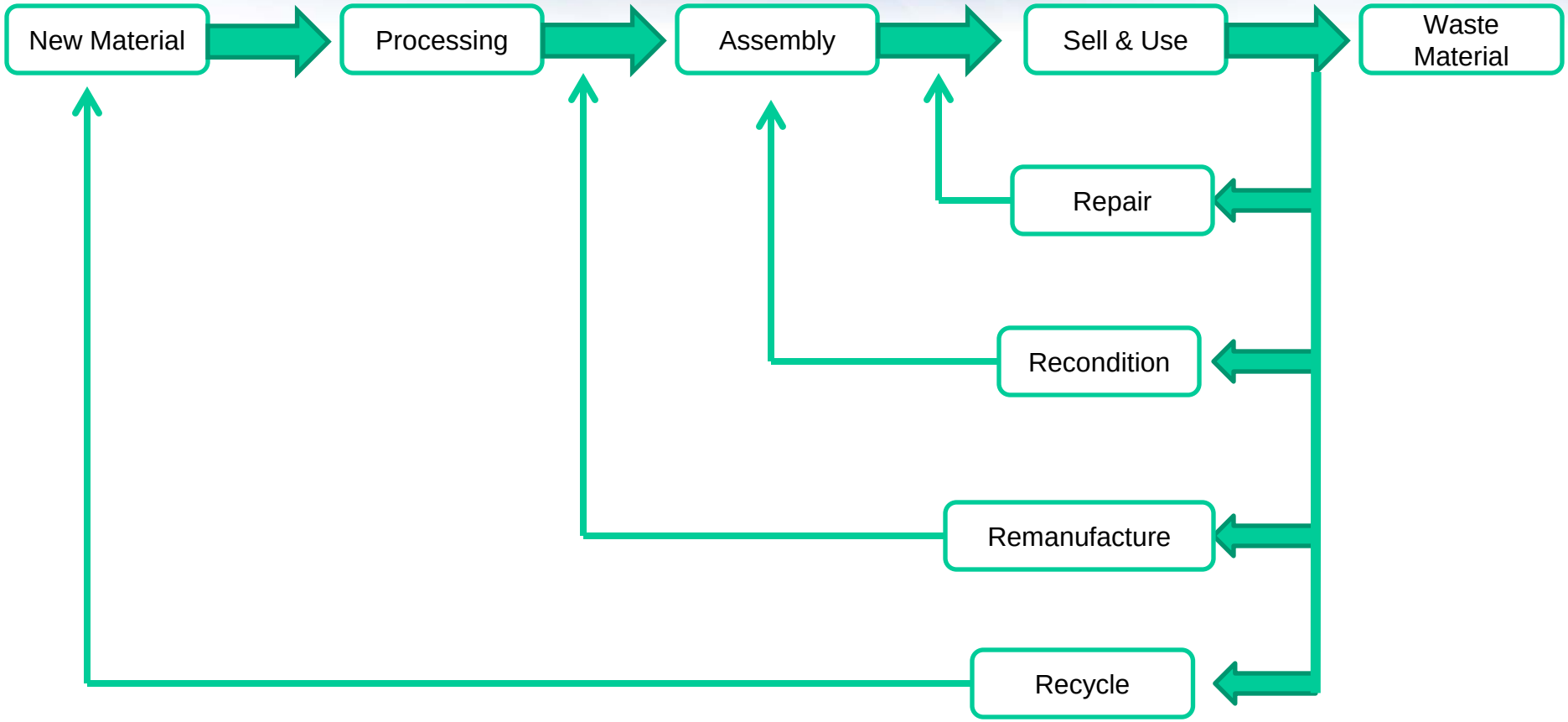
- Influencing Government policy – provides some basis for future
- Incentives are needed to further develop the markets…
- Material recovery: significant logistical challenge, to achieve appropriate commodity density, less energy than mining new elements
- Reuse: product design, economics, energy reduction, and cultural acceptance of product reuse
- Manufacturing for recycling and remanufacturing : achieving next-generation economic and environmental performance via product design compatible with recovery and recycling separations.
- Recycling
  - Energetically cheaper, conservation oriented, inherently sustainable, with far less air, water and land pollution.
  - a giant industrial separations problem
- Recycling separations: **crosscut** all manufacturing industries:
  - 4,500 trillion Btu/yr (22% of all in-plant energy use in U.S.)
  - innovations in separations enhance productivity and global competitiveness
  - key to reduced production cost, energy consumption, waste gen

4) The Approach –R^4I and the MDC

- **The Institute for Recycling, Recovery, Reuse, and Remanufacturing (R^4-I): A National Institute for Manufacturing Innovation with regional focal points (Nodes)**
  - critical economic and environmental evaluation of opportunities for commodity-bearing materials recovery, recycling separation processes, remanufacturing using recycled commodities, design for manufacturing and recyclability
  - target DOE EERE Advanced Manufacturing Office (AMO) sets goals for reductions in energy use (> TBtu/yr), emissions
  - Regional nodes leverage experience from centers of excellence that already exist – ie NIST Manufact. Engineering Partnerships
- **Manufacturing Demonstration Center (MDC) = $70M to $95M**
  - Sponsored by DOE-Energy Efficiency and Renewable Energy, Advanced Manufacturing Office (DOE-EERE-AMO)
  - Industrial Partnering required component for sustainability

One node could be Reuse and Remanufacturing…

Reuse & Remanufacturing Node



Possible Node Business Model

- Functions under Institute umbrella agreements
- Each Node has a focus – ie aluminum recycling
- Builds business through outreach to industrial partners
- Creates jobs by way of:
    - Education - universities, community colleges, etc.
    - R&D – specific needs driven technical development
    - Employment – increased skilled and semi-skilled jobs to operate systems that enhance productivity
- Shares lessons learned with other nodes and Institute partners
- Reports work through node to partners and on to Institute
- Provides support to industrial partners
- Each Node supports specific regional manufacturing needs

4.) The Institute for Recycling, Recovery, Reuse, and Remanufacturing (R^4-I): A National Institute for Manufacturing Innovation with regional focal points

R&D Affiliate/University/National Lab/Industry

Regional Clusters
Each has:
- Specific focus
- Industry
- Academics
-National Labs

One Lead Institution
-Multiple Customers

R&D Center/University/National Lab/Industry

Manufacturer/Industrial Partner

Sponsoring Agencies: **DOE-EERE**/NIST/DoD/DoL/NASA/**NSF**

4) A Suggested Program Approach

- 25% Recovery Methods/Systems
  - Economics / Strategic Analysis
    - Identify profitable commodity-containing waste streams
    - Identify recovery processes that are currently prohibitively expensive
  - Systems Analysis / Design / development
  - Socialization (Public Education)
    - R^4I will engage an unprecedented number of student participants
- 25% Recycling Technology
  - Economics
  - Strategic analysis
  - Systems Design/Development
  - Applications
    - Driven by stream value and process opportunity
  - Educational strategy
- 25% Reuse Methods
  - Economics
  - Strategic Analysis
  - Systems Analysis
  - Design/Development
  - Educational Outreach
  - Products
    - Polymers
    - Metals, etc.
- 25% Manufacturing for Recycling
  - Economics
  - Analysis
  - Implementation
  - Education Outreach

5) R^4 Barriers = R^4I targets of opportunity

- **U.S. social attitude toward recycling is indifference or negative**
  - *Hypothesis: attitudes can be quickly changed if there is economic motivation, particularly employment*
- **Need for U.S. manufacturing to redesign for R^4**
  - In particular: reduce high labor intensity currently needed for scrap recovery
- **Targets of opportunity:**
  - **Very modest changes in direction of US policy**
  - **Enhanced understanding of recovery processes and economics**
  - **Better reuse of materials and components – markets need to be more defined with stronger economics**
  - **Remanufactured products need to have broader acceptance**
  - **Recycling processes need to be more efficient with a *system* better established in US**

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7) Federal Agencies/Programs to Engage & Leverage

DOE – EERE – Advanced Manufacturing Office
NSF – CHE/ENG/DMR – SusChem Program
Commerce/NIST – National Manufacturing Initiative
- Manufacturing Extension Partnership
- Sustainable Manufacturing Initiative

DoD – Manufacturing Centers Program
- ManTech Program
- DARPA
- Connecting American Manufacturing

Labor – ????
NASA – Advanced Digital Materials and Manufacturing for Space Apps.
Interagency Initiatives
- Materials Genome
- National Robotics Initiative
- National Nanotechnology Initiative

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8) Who have we talked to so far?

INL – Mid-Level Management/ALD (Water) through Lab Director (Lab Summit)
ORNL – Mid-Level Management/ALD (Aluminum)
ANL - Mid-Level Management/ALD (Automobiles)
LLNL - Mid-Level Management/ALD (Electronics)
LBNL – Mid-Level Management (Electronics)
Ames – Lab Director Level (Metals)
PNNL – Mid Level Management/ALD (Metals and Systems)

DOE – EERE-AMO Golden Field Office – Encouraged to continue discussions with HQ Personnel, engage NSF, and start to gather partners

Colorado School of Mines:
Brajendra Mishra (Center for Recycling/Recovery/Reuse/Professor)
Doug Way (Professor)
John Speers (Associate VPR)
John Poate (VPR)

Industry – Universal Recycling Technology, Inc., Advanced Recovery, Inc., Inst. for Scrap Recycling, E-Waste Group, plus others

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9) Proposed Schedule

- Continue to flesh out concept with input from variety of sources
- Workshop – September, 2013, Denver, CO (Invited)
  - Industry
  - Academics
  - National Labs
- Use Workshop input to shape whitepaper(s) and proposal(s), October – February
- Brief Federal Agencies (DOE, NIST, NSF, DLA, EPA, NASA etc.), December, 2013, January – June 2014
- Continue to brief Congressional Delegations, December, 2013 – July 2014
- Prepare R^4-I Proposal(s):
  - submission to DOE-AMO by December 2013 (FY '14) (Aggressive)
  - submission to DOE-AMO in February 2014 (FY '15) (Less Aggressive)

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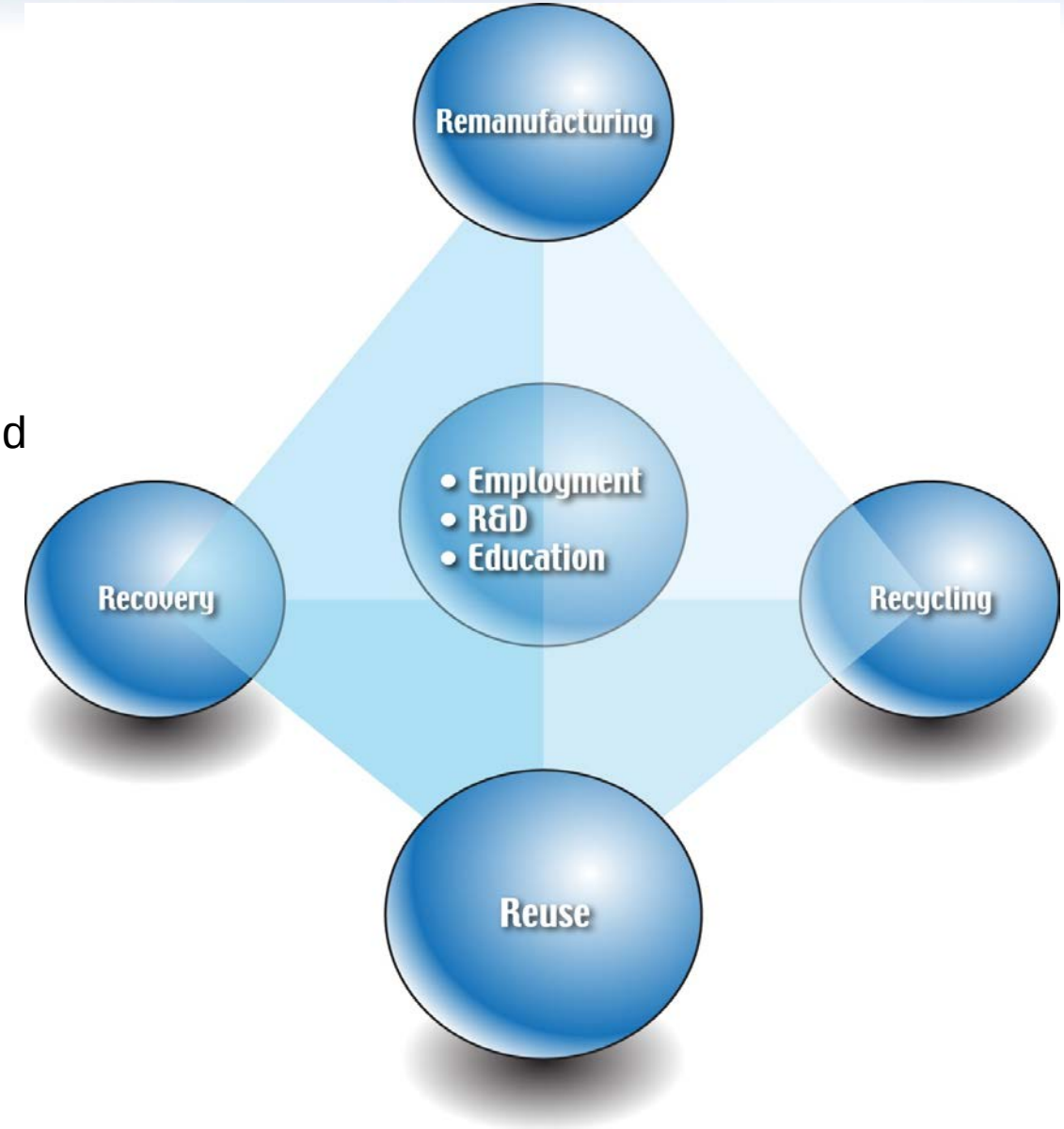
Summary

- This is an opportunity that we need to exploit NOW – if we do not do it now, someone else will….
- Jobs will be created (both skilled and semi-skilled)
- Novel designs for manufacturing and remanufacturing
- Designs for destruction
- Regionally focused – nationally effective nodes with unique capabilities
- Highly leveraged Federal and industrial support coupled with long term commitments
- Good understanding of materials and product lifecycles through life cycle analysis
- Set a lofty goal of up to 60% product/materials recovery

The Institute for Recovery Recycle, Reuse and Remanufacturing - Concept

4 Nodes
Multiple Centers
Multiple partners

One Goal:
Reduce impact on Earth and enhance peoples' welfare



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Outline

1) The Problem
2) Why Target Recycling?
3) Focus on Largest Recycling Streams
4) Some Recycling Separation Technologies of Interest
5) The Proposed Program
6) Opportunities
7) Barriers to Recycling and Recovery
8) Many Routes to Success
9) Routes to Success
10) The Proposed Institute
11) Federal Agencies to Engage
12) Who have we talked to so far?
13) Proposed Schedule
14) Next Steps

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2) Why Target Recycling?

- Recycling is a giant industrial separations problem
- Separation technologies **crosscut** all manufacturing industries:
  - 4,500 trillion Btu/yr (TBtu/yr)
  - 22% of all in-plant energy use in the United States.
  - innovations in separation technologies not only enhance productivity and global competitiveness of U.S. industries, but also are critical for achieving the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy's (DOE-EERE) industrial energy and waste reduction goals.
- The Institute will carefully evaluate opportunities for materials recycling and process development for recycling separation processes coupled with remanufacturing and manufacturing for recyclability for the DOE EERE Advanced Manufacturing Office (AMO) that will lead to substantial reductions in energy use (greater than one TBtu/yr) and emissions.

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6) Many Routes to Success
Many skill sets needed – Many Jobs Created

- Multiple R&D pathways for overcoming material-based barriers to low-energy intensity separation technology:
  - begin with an application-specific assessment of:
    - the working environment,
    - operating conditions,
    - failure modes,
    - performance requirements for economic insertion of new/ hybrid technologies into industrial applications.
- Followed by identification of metrics which define the targets for success:
  - Target metrics will be industrial application-specific and driven by :
    - the final economics of the separation materials/processes,
    - housings,
    - systems design (some applications will be driven by regulation).

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6) Case in point: recycling separation processes, continued

- Develop and Demonstrate Technological Alternatives, con't:
  - New membrane material manufacturing techniques to produce thinner, defect-free membrane surfaces (more anisotropic, multilayer, etc.) to:
    - enhance solution/diffusion-limited membranes
    - to produce more controllable membrane pore size for advanced filtrations
  - New or improving the existing sorbent materials that require less energy for product recovery and recycling
  - Novel solvent extraction materials (e.g., ionic liquids, super critical fluids)
  - developing separation process intensification concepts for new equipment designs that reduce size and capital costs
- Demonstrating in-service evaluation of new and/or advanced separation materials and systems

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6) Case in point: recycling separation processes, continued

- Identify opportunities to overcome material-based barriers to low-energy intensity separation:
  - application-specific assessments: current economic drivers, working environment, operating conditions, failure modes, economic performance for new/hybrid technologies
- Identify metrics
  - the final economics of the separation materials/processes,
  - Housings and systems design (including regulatory factors)
- Develop and Demonstrate Technological Alternatives:
  - new processes for enhanced selectivity, capacity, fouling resistance (e.g. surface/pore modification)
  - new materials/composites: thinner, defect-free membranes, mechanically strong, harsh-environment robust
  - New material fabrication techniques for membrane, solvent extraction and sorbent and hybrid systems

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Summary - Institute for Recovery, Remanufacturing, Recycling, and Reuse R^4-I Workshop – Current Status

Vision: The Institute will be the premiere industry-national laboratory-university collaborative dedicated to the sustainable stewardship of our Earth's resources.

- **Situation**: The US, EU, Japan, Canada, and others face restricted access to resource needs. One approach to filling part of the pipeline is to recover, remanufacture, reuse and recycle materials that are of value.
- **Challenge**: Other countries are making substantial investments in mining, materials processing, and manufacturing that threaten the US's, EU's and Japan's ability to manufacture products domestically.
- **Technical challenge**: Recovery, Remanufacturing, Recycling and Reuse, in the US is in its infancy, Japan, and EU are slightly further along, however each step of the process needs significant R&D throughout the world to enhance efficiency and further develop the US's capabilities.
- **Technical Solution**: Techno-economic analysis of processes for gathering materials, automation for remanufacturing, enhanced materials recovery for recycling, and new approaches to reuse technologies along with life cycle analysis and process development will provide solutions to efficient approaches within R^4-I

Institute for Recovery, Remanufacturing, Recycling, and Reuse Workshop – Current Status

- Institute will provide a focused program framework to promote collaboration between participants (Nat. Labs, Univ.s, and Industry) to rapidly de-risk emerging technologies, commercialize technology, and train the next generation of skilled and semiskilled workforce in systems and process development for enhanced materials life cycles(excluding rare earth metals).
- **Proposed Institute Team**: *National Labs:*INL, ORNL, Argonne, Livermore, Pacific Northwest, and Ames – all confirmed at ALD level; *Universities*: Colorado School of Mines, Purdue, CAES, Montana State University - all confirmed; Candidates: MIT, CalTech, Univ. of Mass, and Worcester Polytech Institute; *Industry:* Dupont, Dow Chem, Chevron, Shell, Universal Recycling Technology, Umicore, Waste Management, Advanced Recovery, Veolia, and many others.
- **Result**: Proposed $90 - 120M Federal investment over 5 years has potential to generate more than $220 B in sustainment and growth of the US GDP in less than 10 years.