U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Sustainable Manufacturing Workshop

January 6th, 2016

Mark Johnson

Director

Advanced Manufacturing Office

www.manufacturing.energy.gov

Clean Energy and Manufacturing: Nexus of Opportunities

- Energy self-reliance
- Stable, diverse energy supply

- Competitiveness in clean energy
- Domestic jobs

- Clean air
- Climate change
- Health

<u>Clean Energy Manufacturing</u>

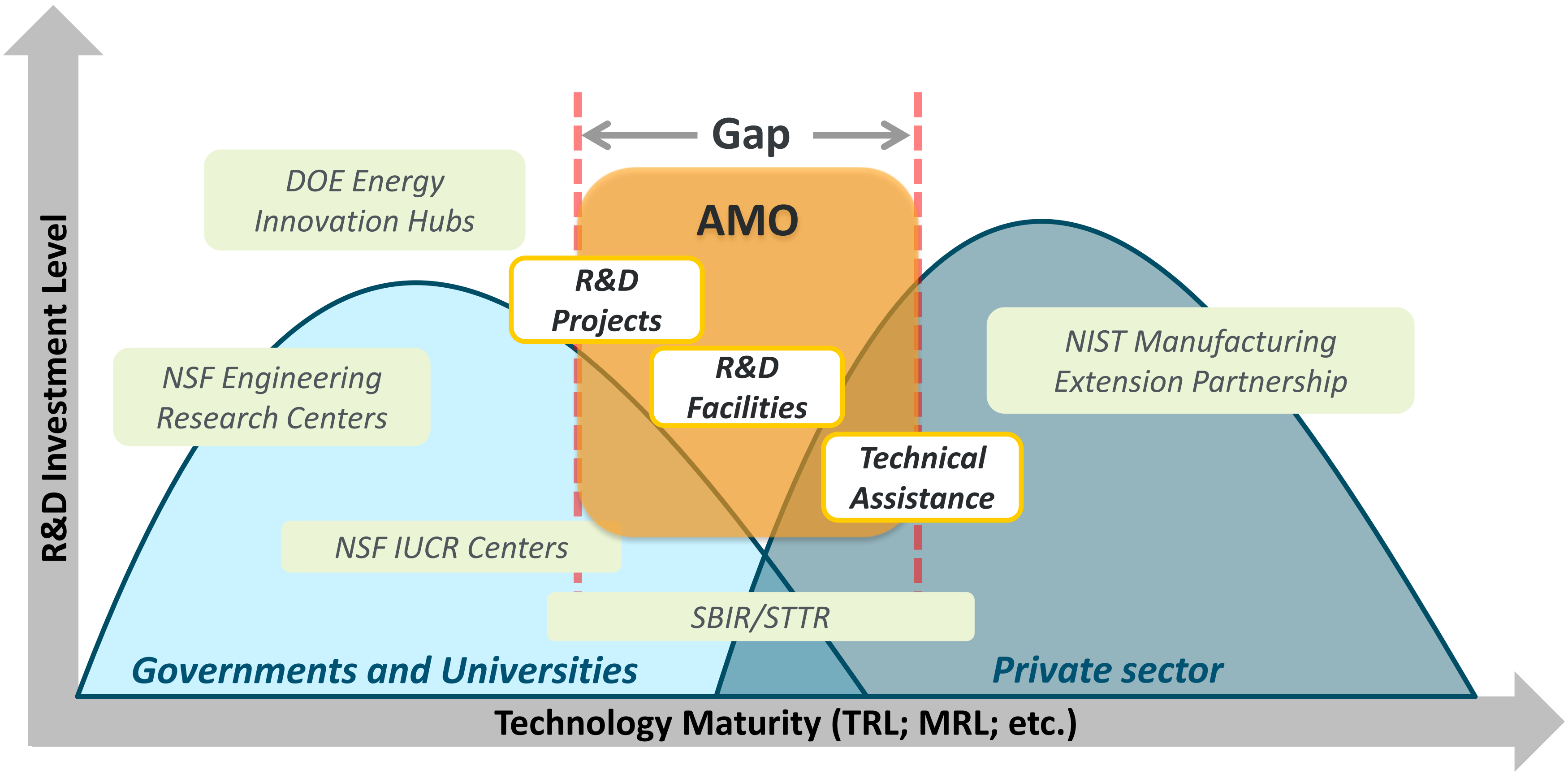
Making Products which Reduce Impact on Environment

<u>Advanced Manufacturing</u>

Making Products with Technology as Competitive Difference

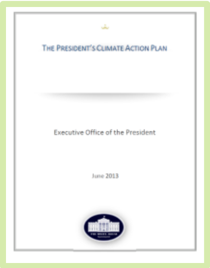
Bridging the Gap to Manufacturing

AMO: Advanced Manufacturing Office



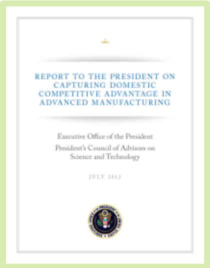
Concept → Proof of Concept → Lab scale development → Demonstration and scale-up → Product Commercialization

Advanced Manufacturing – Strategic Inputs



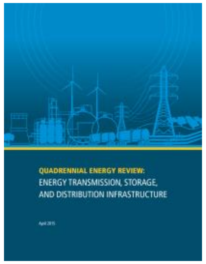
Climate Action Plan

(EOP / CEQ / OSTP 2014)



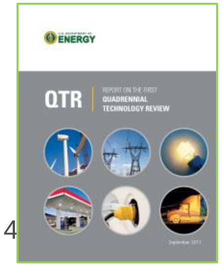
Advanced Manufacturing Partnership (AMP2.0)

(NEC / PCAST / OSTP 2014)



Quadrennial Energy Review

(DOE / EPSA 2015)



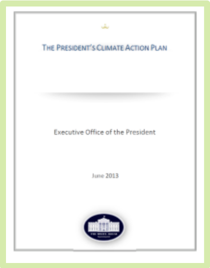
Quadrennial Technology Review

(DOE / Science and Technology 2015)

1) Broadly Applicable Efficiency Technologies for Energy Intensive and Energy Dependent Manufacturing

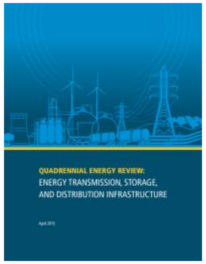
2) Platform Materials & Processes Technologies for Manufacturing Clean Energy Technologies

Advanced Manufacturing – Strategic Inputs

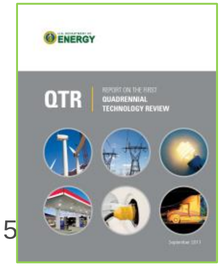


Climate Action Plan
(EOP / CEQ / OSTP 2014)

Advanced Manufacturing Partnership (AMP2.0)
(NEC / PCAST / OSTP 2014)



Quadrennial Energy Review
(DOE / EPSA 2015)

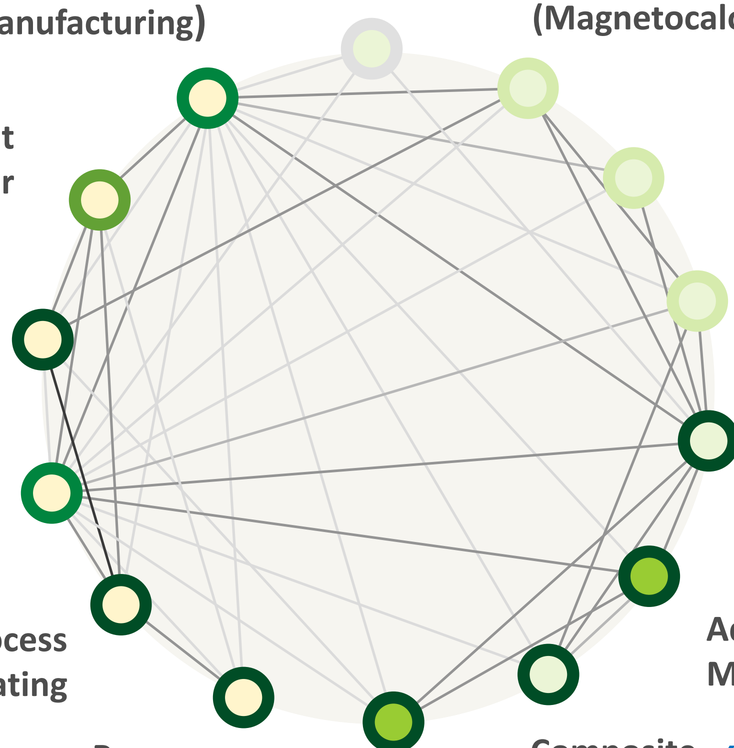


Quadrennial Technology Review
(DOE / Science and Technology 2015)

1) Broadly Applicable Efficiency Technologies for Energy Intensive and Energy Dependent Manufacturing

2) Platform Materials & Processes Technologies for Manufacturing Clean Energy Technologies

DOE QTR: Manufacturing Technology



Advanced Manufacturing Topical Priorities

Efficiency Technologies for Manufacturing Processes (Energy, CO_2)

(1) Advanced Sensors, Controls, Modeling and Platforms (HPC, Smart Manf.)
(2) Advanced Process Intensification
(3) Grid Integration of Manufacturing (CHP and DR)
(4) Sustainable Manufacturing (Water-Energy, New Fuels & Feedstocks)

Platform Materials & Technologies for Clean Energy Applications

(5) Advanced Materials Manufacturing
(incl: Extreme Mat'l., Conversion Mat'l, etc.)
(6) Critical Materials
(7) Advanced Composites & Lightweight Materials
(8) 3D Printing / Additive Manufacturing
(9) 2D Manufacturing / Roll-to-Roll Processes
(10) Wide Bandgap Power Electronics
(11) Next Generation Electric Machines (NGEM)

QTR Manufacturing Focus Areas Mapped to Advanced Manufacturing Topical Areas for Technology Development

Modalities of Support

Technology Assistance: (Dissemination of Knowledge)

Better Plants, ISO-50001 / SEP, Industrial Assessment Centers, Combined Heat and Power Tech Assistance Centers, Energy Management Tools & Training

Technology Development Facilities: (Innovation Consortia)

Critical Materials Hub, Manufacturing Demonstration Facility (Additive), Power America NNMI, IACMI NNMI, CyclotronRoad, HPC4Manufacturing

Technology Development Projects: (Individual R&D Projects)

Individual Projects Spanning AMO R&D Space - University, Small Business, Large Business and National Labs. Each a Project Partnership (Cooperative Agreement).

AMO Elements

Three partnership-based approaches to engage industry, academia, national labs, and state & local government:

1. **Technical Assistance**
2. **Research and Development Projects**
3. **Shared R&D Facilities** - affordable access to physical and virtual tools, and expertise, to foster innovation and adoption of promising technologies

Shared R&D Facilities & Consortia

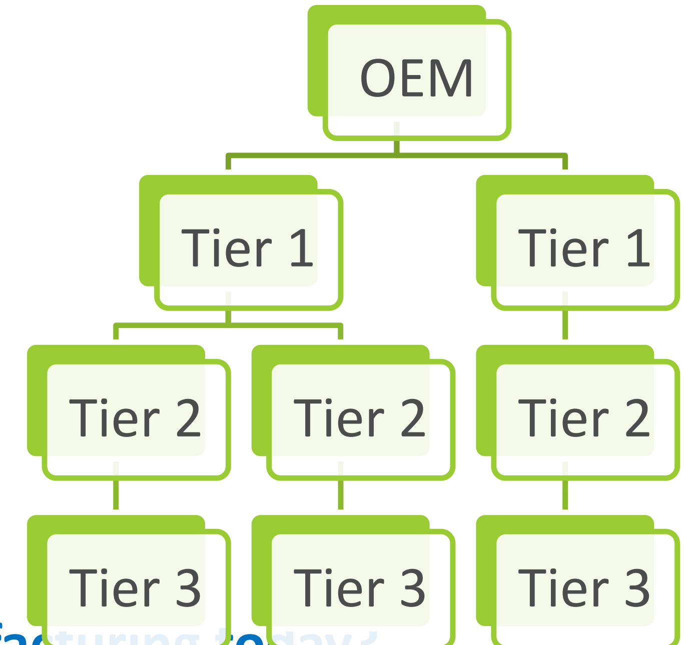
Address market disaggregation to rebuild the industrial commons

Then

Ford River Rouge Complex, 1920s

Photo: Library of Congress, Prints & Photographs Division, Detroit Publishing Company Collection, det 4a25915.

Now

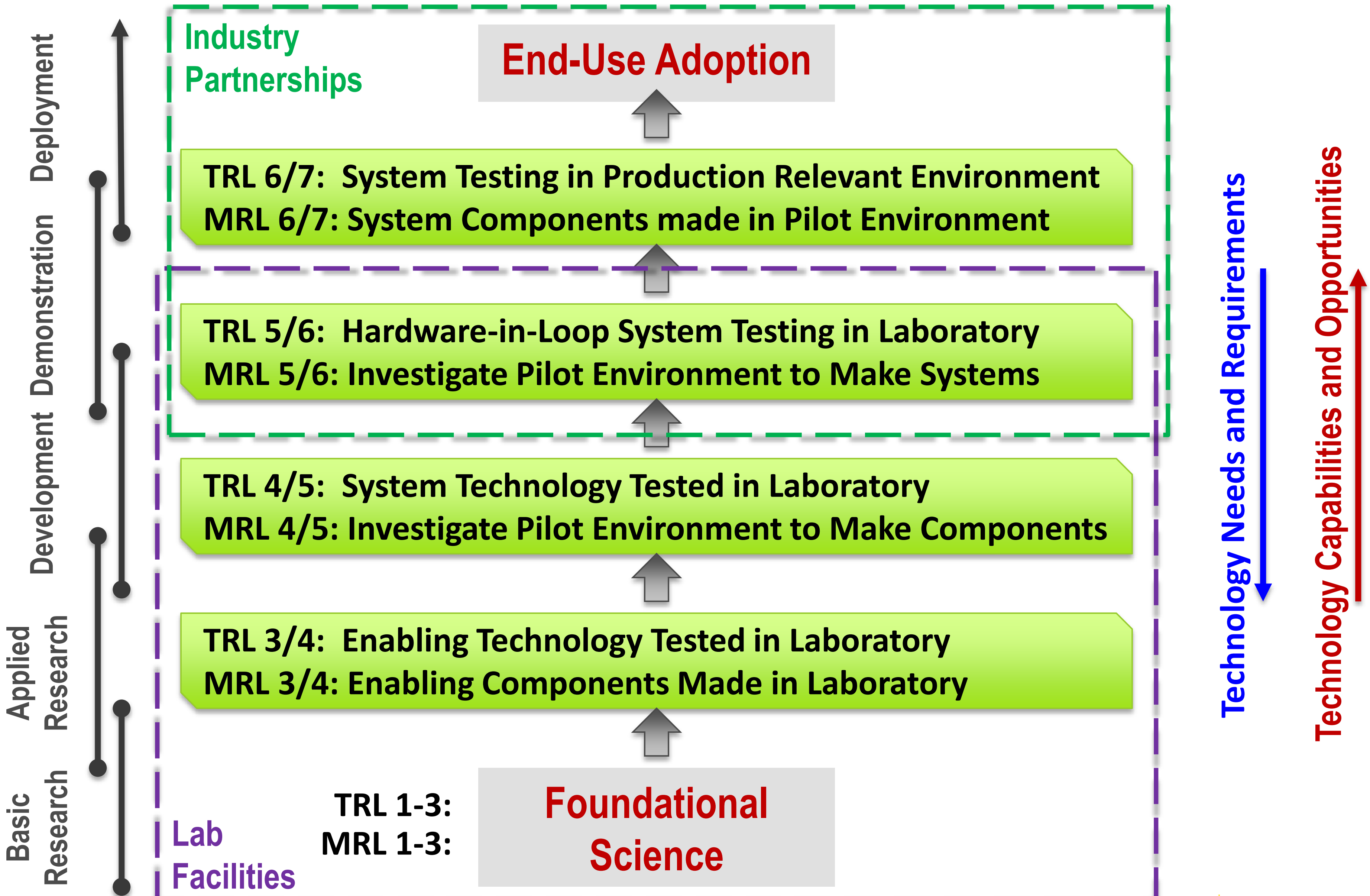


How could we get innovation into manufacturing today?

- RD&D Consortia based Eco-Systems

- Public-private partnership to scale

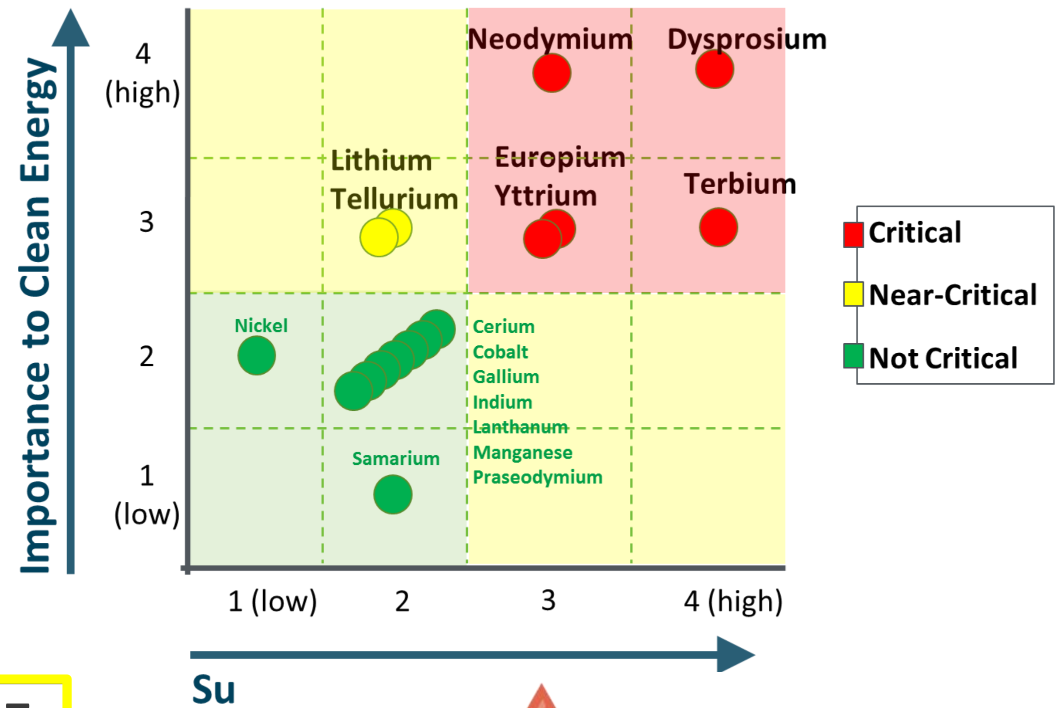
Manufacturing Technology Maturation



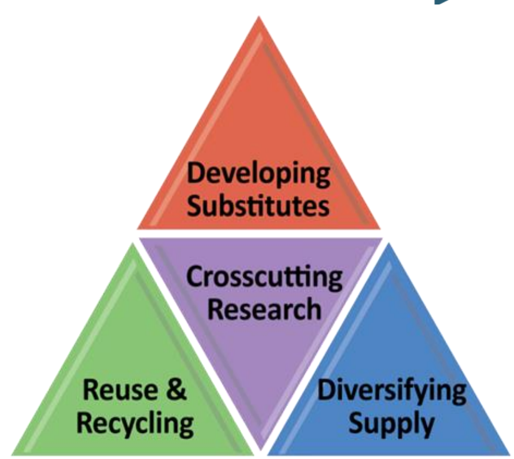
Critical Materials Institute

A DOE Energy Innovation Hub

- Consortium of 7 companies, 6 universities, and 4 national laboratories
- Led by Ames National Laboratory



	Dy	Eu	Nd	Tb	Y	Li	Te
Lighting		✓		✓	✓		
Vehicles	✓		✓			✓	
Solar PV							✓
Wind	✓		✓				



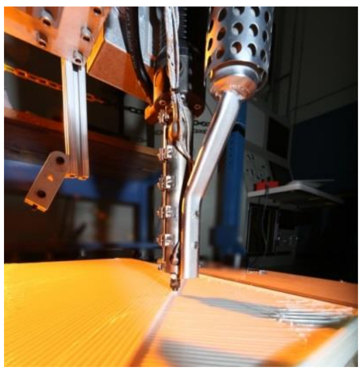
Critical Materials - as defined by U.S. Department of Energy, *Critical Materials Strategy*, 2011.

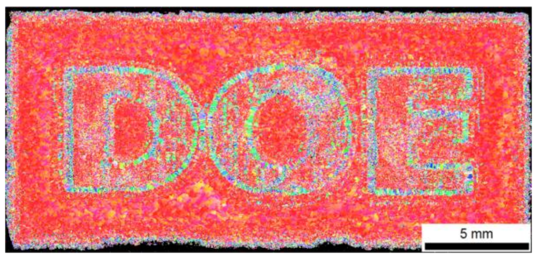
Manufacturing Demonstration Facility

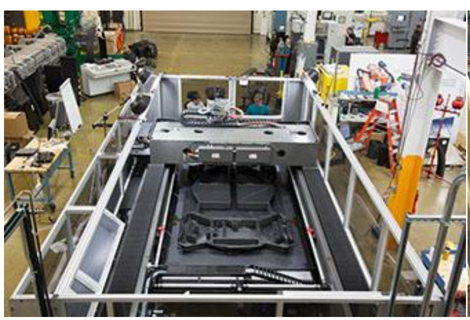
Supercomputing Capabilities

Spallation Neutron Source

America Makes







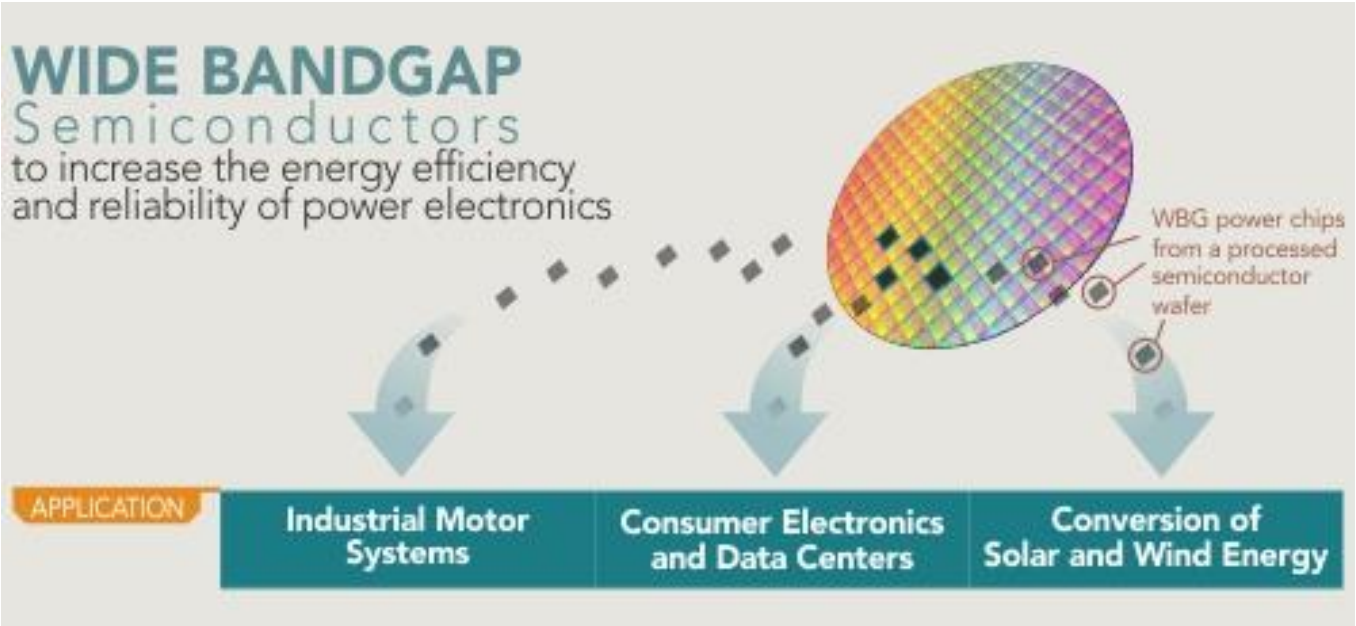
Additive Manufacturing

Arcam electron beam processing AM equipment

POM laser processing AM equipment

Program goal is to accelerate the manufacturing capability of a multitude of AM technologies utilizing various materials from metals to polymers to composites.

PowerAmerica:
Next Generation Power Electronics Manufacturing Institute



Institute Mission:
Develop advanced manufacturing processes that will enable large-scale production of wide bandgap semiconductors

- Higher temps, voltages, frequency, and power loads (compared to Silicon)
- Smaller, lighter, faster, and more reliable power electronic components
- $3.3 B market opportunity by 2020.[1]
- Opportunity to maintain U.S. technological lead in WBG

Poised to revolutionize the energy efficiency of electric power control and conversion

[1] Lux Research, 2012.

Institute for Advanced Composite Materials Innovation (IACMI)

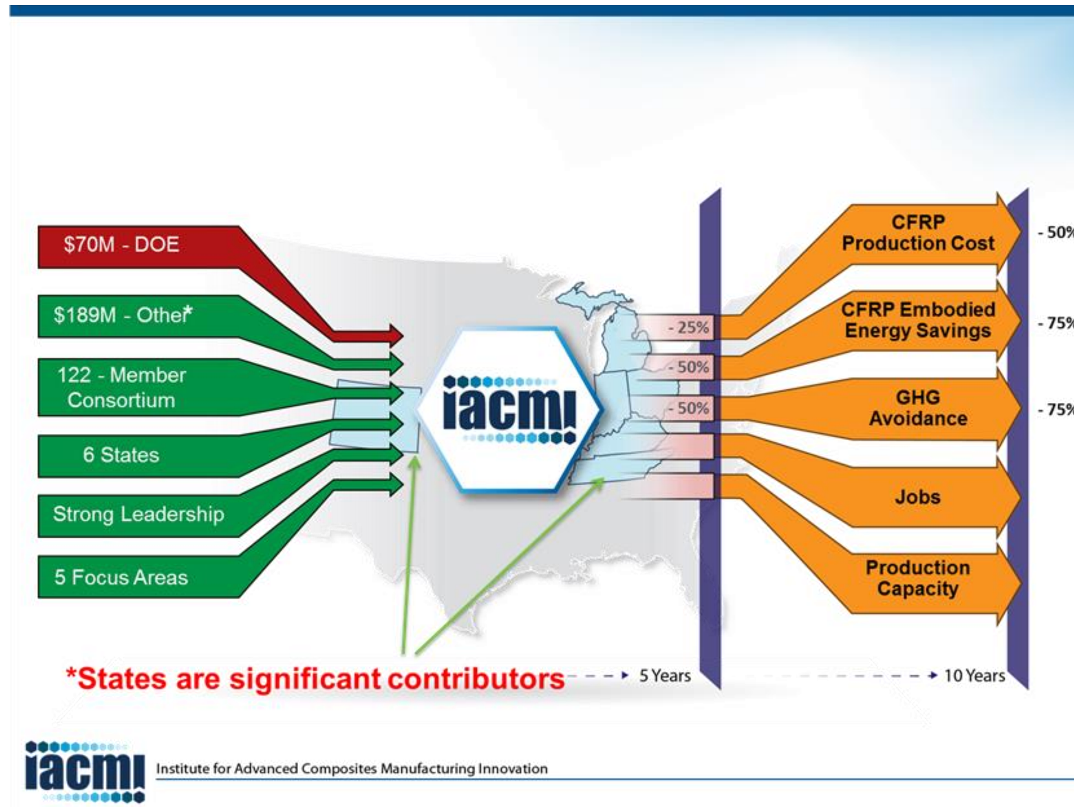
Objective

Develop and demonstrate innovative technologies that will, within 10 years, make advanced fiber-reinforced polymer composites at…

50% Lower Cost

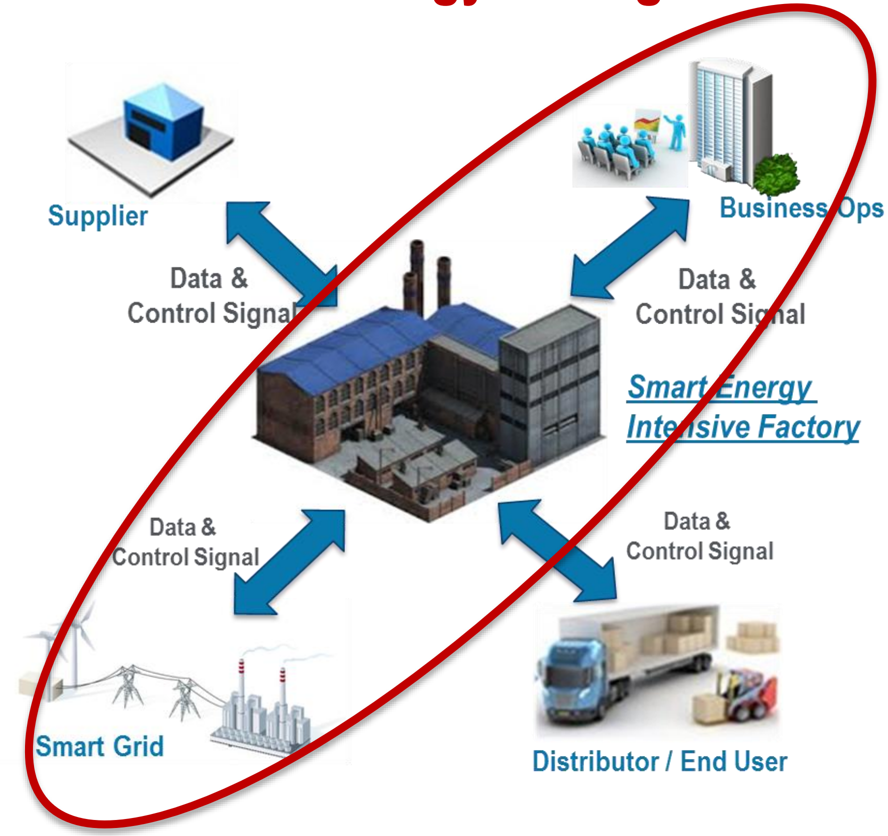
Using 75% Less Energy

And reuse or recycle >95% of the material



SMART Manufacturing: Advanced Controls, Sensors, Models & Platforms for Energy Applications

Focus on Real-Time For Energy Management



- Encompass machine-to-plant-to-enterprise real time sensing, instrumentation, monitoring, control, and optimization of energy **(>50% improvement in energy productivity)**
- Enable hardware, protocols and models for advanced industrial automation: requires a holistic view of data, information and models in manufacturing at Cost Parity (>**50% reduction in installation cost**)
- Significantly reduce energy consumption and GHG emissions & improve operating efficiency – (**15% Improvement in Energy Efficiency)**
- Increase productivity and competitiveness across all manufacturing sectors:

  Special Focus on Energy Intensive & Energy Dependent Manufacturing Processes

Leverage AMP 2.0 and QTR

National Network for Manufacturing Innovation (NNMI)

- **Network of distinct regional Institutes, each with different technology focus**
- **Public-Private Partnerships focused on TRL 4-7**
- **$70-100 million in federal funding, with minimum 1:1 cost share**
- **7 current DOE and DOD Institutes**
- **2 pending, 15 total by end of 2016**

National Network for Manufacturing Innovation (NNMI)

DOE Institutes

- PowerAmeica – Wide band gap power electronics
- IACMI—Advanced Composites
- (Pending)—Smart Manufacturing
- **Two new institutes in 2016—Topics TBD**

DOD Institutes

- AmericaMakes – Additive manufacturing
- DMDII—Digital Manufacturing
- LIFT—Lightweight metals
- AIM—Photonics
- FlexTech—Flexible Hybrid Electronics
- (Pending)—Revolutionary Fibers and Textiles

Topical Engagement with Industry

Advanced Materials	→	Materials in Extreme Conditions
	→	Sustainable Materials in Manufacturing
Process Intensification	→	Process Intensification (Chemical)
	→	Process Intensification (Thermal)
Roll-to-Roll Processing	→	Functional Membrane Structures
Advanced Sensors, Controls, Models, Platforms	→	Smart Manufacturing

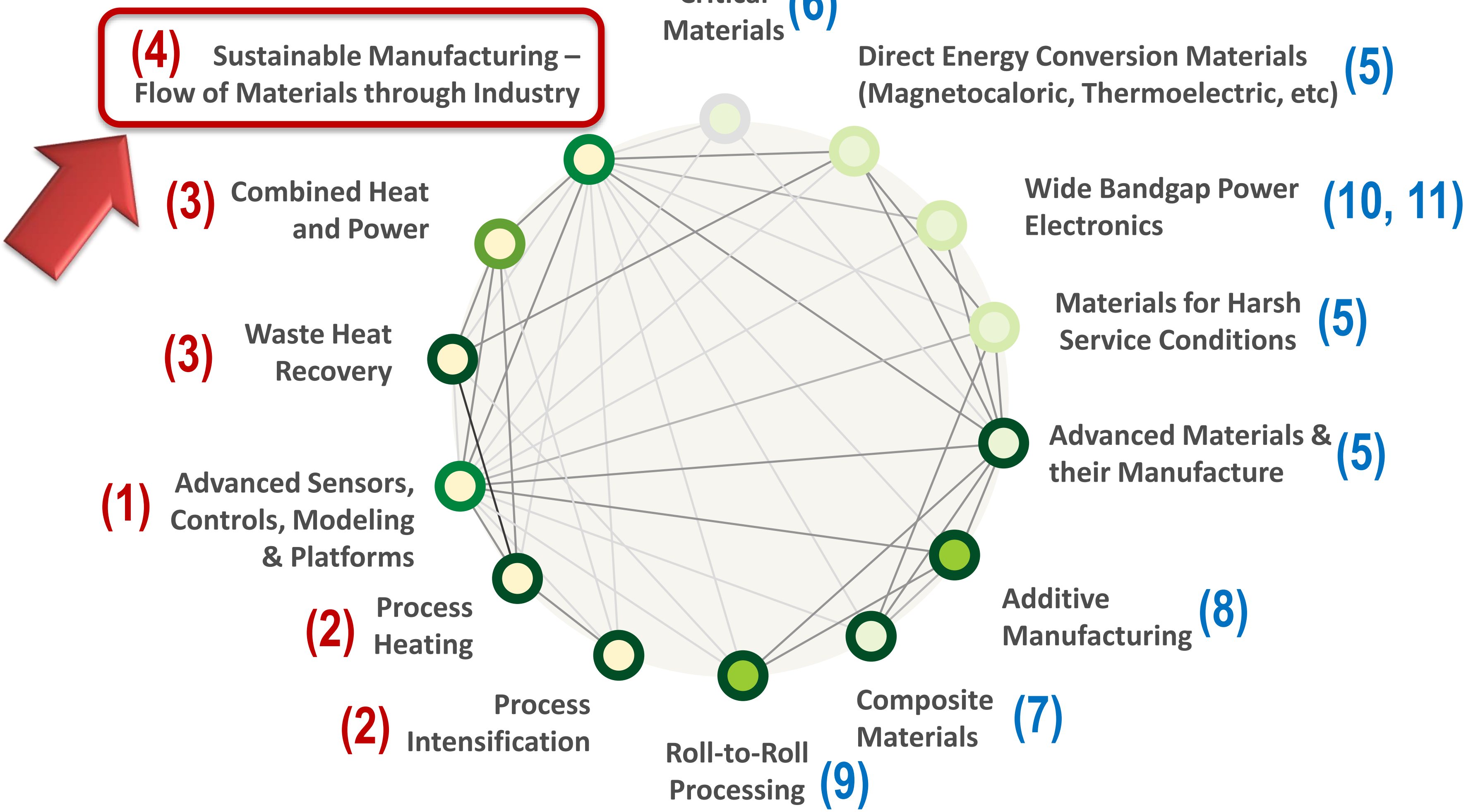
Developing R&D priorities

- **Will inform BOTH potential institute topic AND AMO's broader R&D portfolio**
- **Other workshops:**
  - Chemical Process Intensification (Oct. 2015)
  - Thermal Process Intensification (Oct. 2015)
  - Extreme Environment Materials (Nov. 2015)
  - High Value Roll-to-Roll Manufacturing (Dec. 2015)
  - Sustainable Manufacturing (Jan. 2016)

DOE QTR: Manufacturing Technology

Efficiency Technologies

Enabling Platform Technologies



Information & Data	Processes	Materials
Energy & Resource Management	Advanced Manufacturing Processes	Materials Development

Advanced Manufacturing Topical Priorities

Efficiency Technologies for Manufacturing Processes (Energy, CO_2)

(1) Advanced Sensors, Controls, Modeling and Platforms (HPC, Smart Manf.)
(2) Advanced Process Intensification
(3) Grid Integration of Manufacturing (CHP and DR)
(4) Sustainable Manufacturing (Water-Energy, New Fuels & Feedstocks)

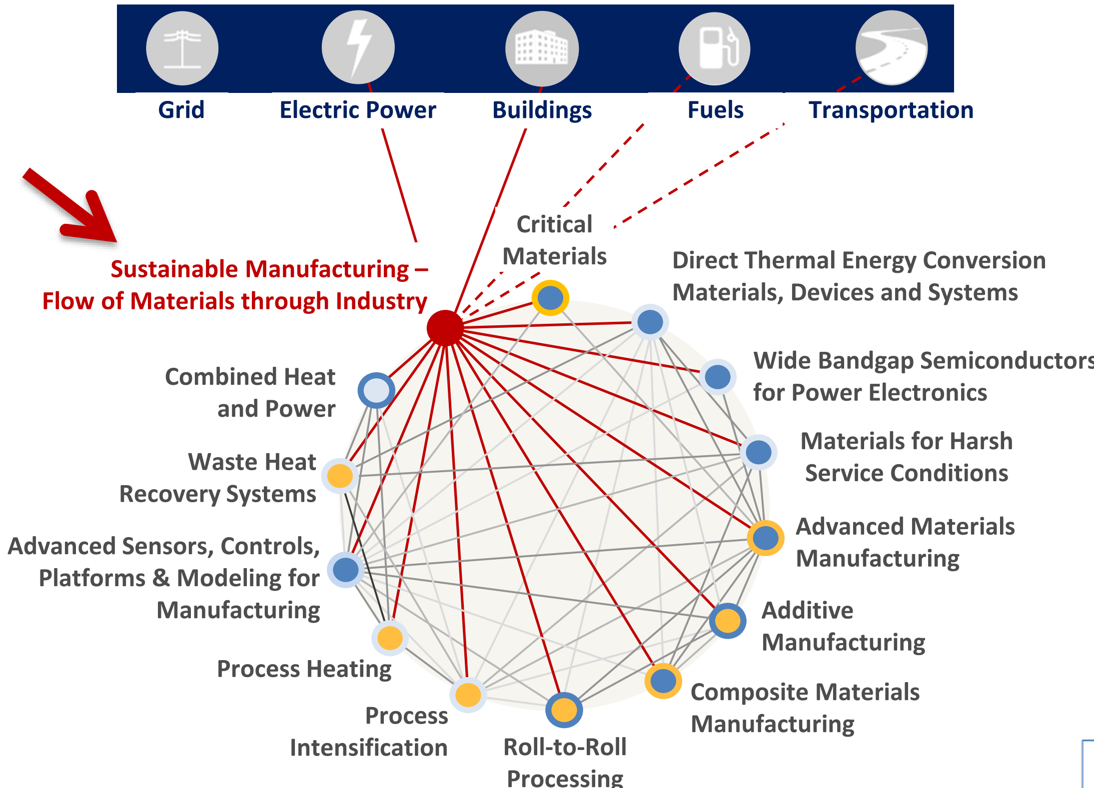
Platform Materials & Technologies for Clean Energy Applications

(5) Advanced Materials Manufacturing
(incl: Extreme Mat'l., Conversion Mat'l, etc.)
(6) Critical Materials
(7) Advanced Composites & Lightweight Materials
(8) 3D Printing / Additive Manufacturing
(9) 2D Manufacturing / Roll-to-Roll Processes
(10) Wide Bandgap Power Electronics
(11) Next Generation Electric Machines (NGEM)

QTR Manufacturing Focus Areas Mapped to Advanced Manufacturing Topical Areas for Technology Development

Sustainable Manufacturing

Connections to other QTR Chapters and Technology Assessments



Key Extra-Chapter Connections

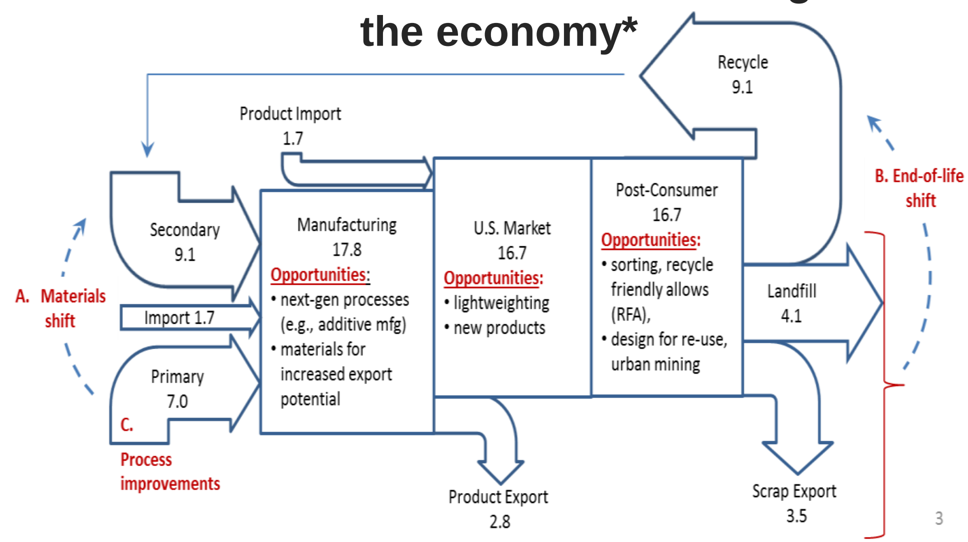
- **Electric Power:** *management of water & energy resources*
- **Buildings:** *recycling and materials substitution/minimization*

Ch. 6: Sustainable Manufacturing Technology Assessment

Scope

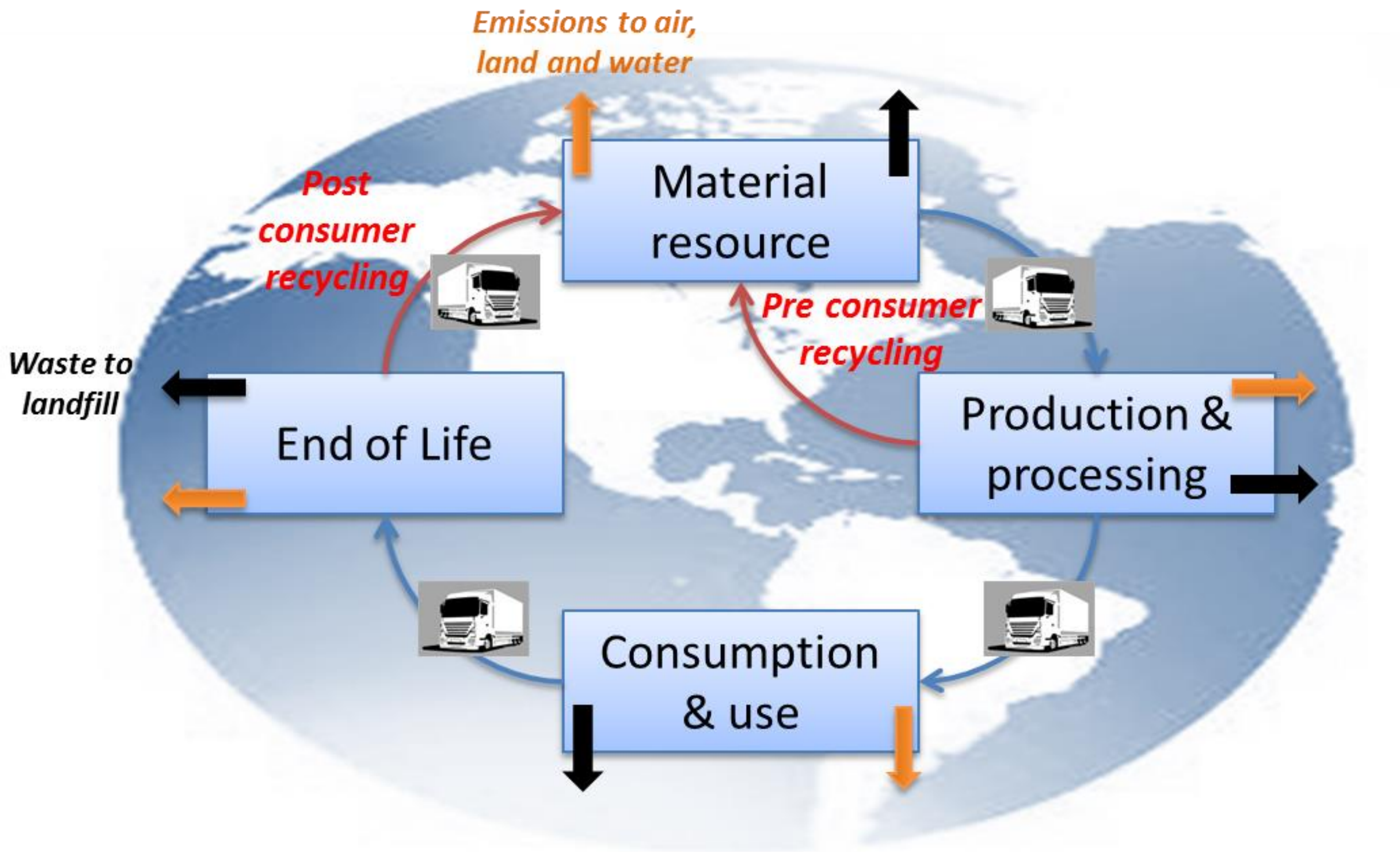
- Supply chain issues, from resource extraction to end of life (Life Cycle Analysis)
- Flow diagrams to demonstrate supply chain issues Material efficiency: mechanisms for reducing demand for materials (e.g., lightweighting, scrap reduction, increased material longevity)
- Design for Re-use / Recycling

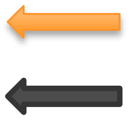
Aluminum material flows through the economy*



*Source: Internal analysis (DOE Advanced Manufacturing Office, 2013)

Circular Material Economy





Why Sustainable Manufacturing at the Department of Energy?

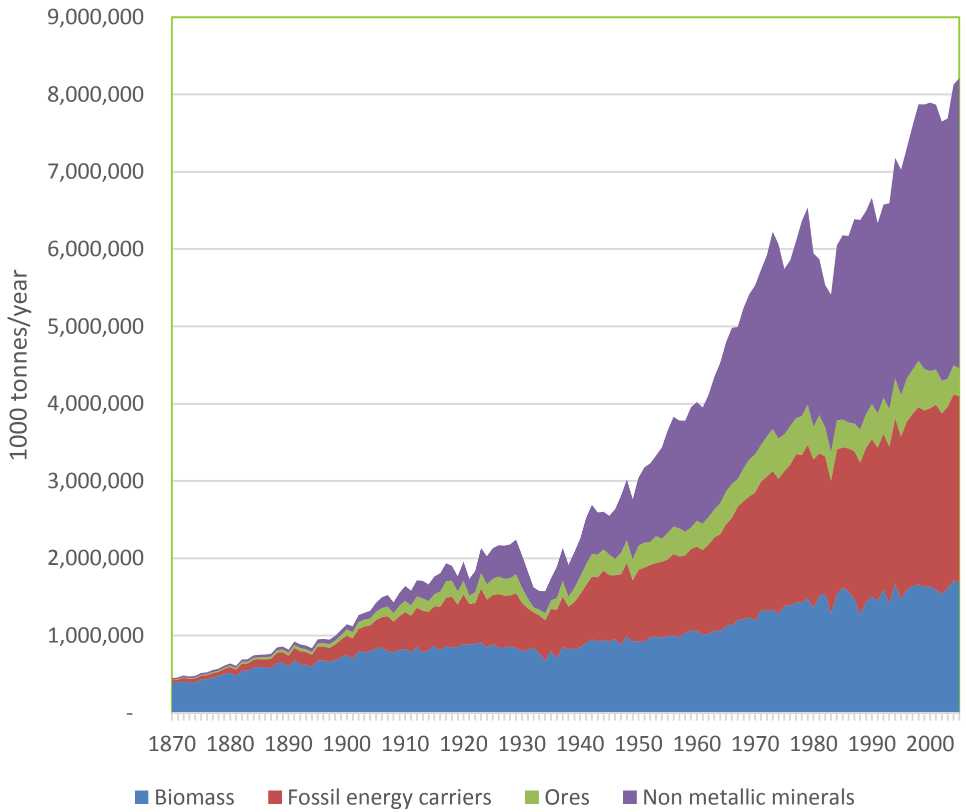
Motivation

- An efficient supply chain that has minimal negative environmental impacts can enhance the competiveness of the industrial sector
- As material consumption increases – we need to be more efficient with material, reduce emissions and waste to landfill, and reuse materials while optimizing their value and utility
- Significant energy is lost in inefficient system level processes – the entire supply chain must be engaged to uncover potential solutions

Opportunity

- Sustainable manufacturing technology development that improves energy-efficiency, reduces greenhouse gas emissions while improving the efficiency of material use throughout the manufacturing process. The focus could be:
  - Testing and demonstration of alternative feedstocks;
  - Reduction of waste throughout the manufacturing process;
  - Improve reuse and recycling of materials, water and energy within the manufacturing process and at the end of product life;
  - Validation and deployment of the tools, processes and technologies to enable sustainable design and assessment.

US Material Consumption & Imports Increasing

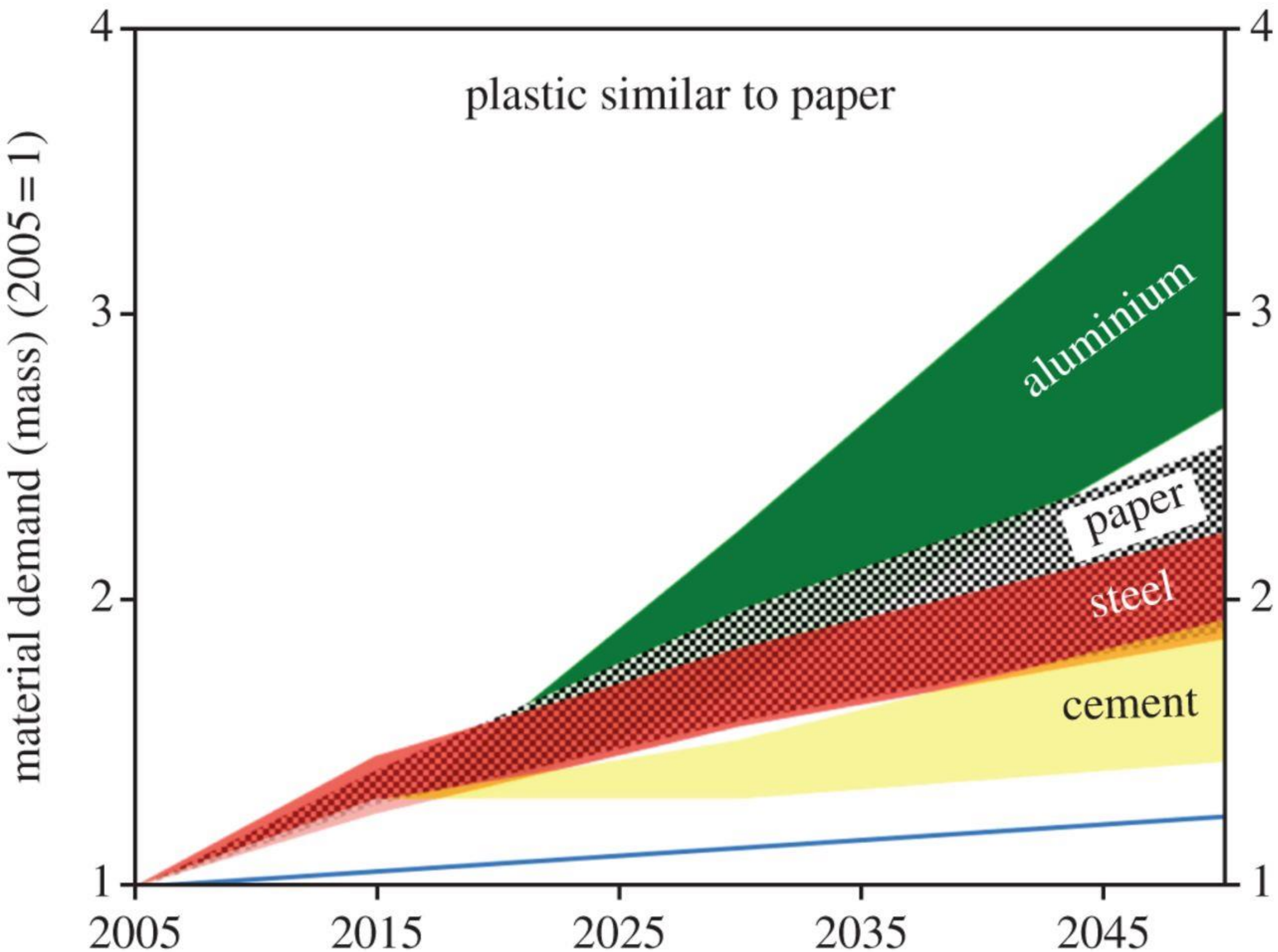


US Domestic Material Consumption
1870-2005

Year	Reliance on imports (%)
1950	3.3
1960	4.8
1970	6.0
1980	8.6
1990	9.1
2000	12.0
2005	13.7

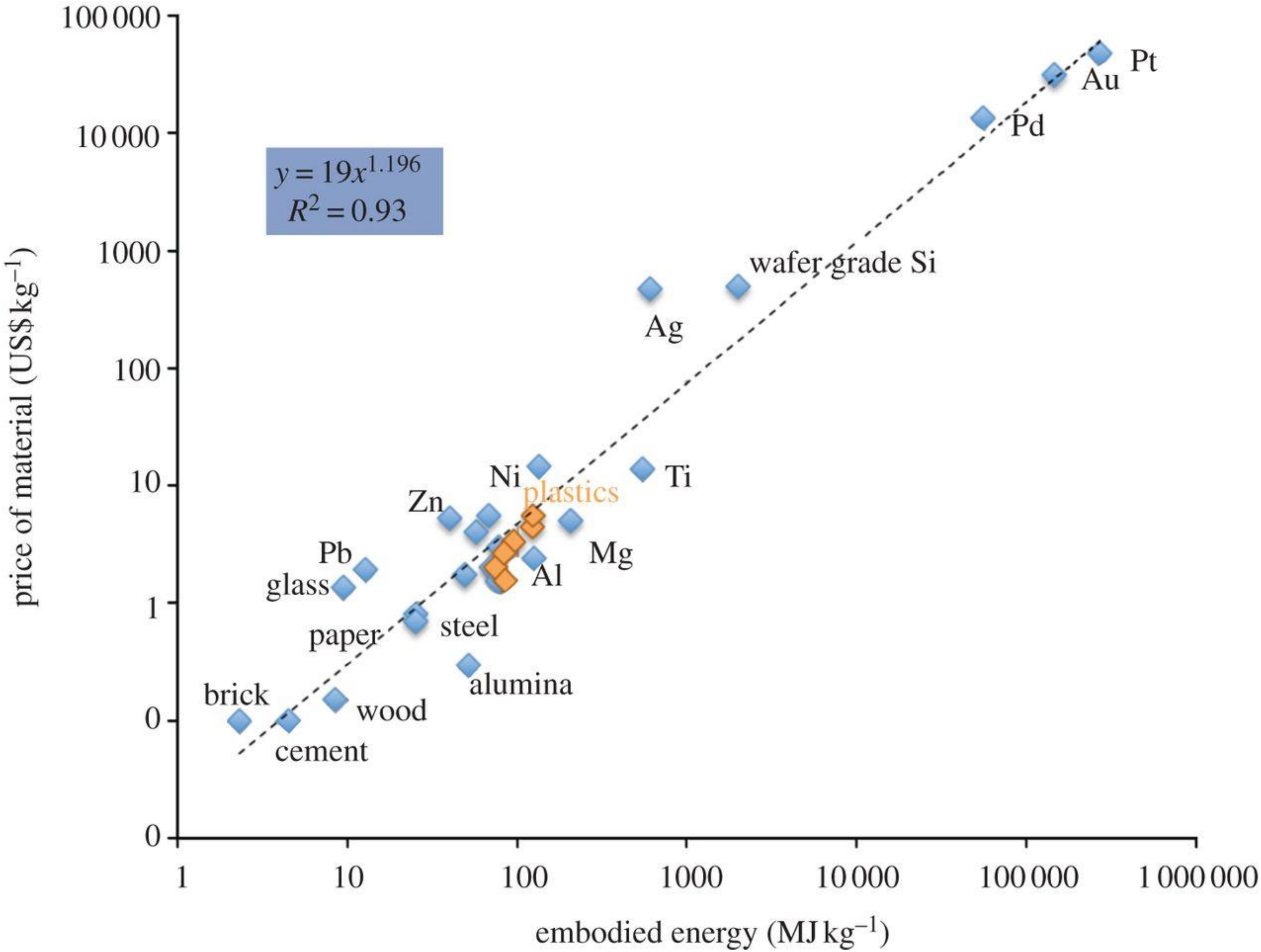
Gierlinger, S., Krausmann, F., 2012. The physical economy of the United States of America : Extraction, trade and consumption of materials from 1870 to 2005. Journal of Industrial Ecology 16(3), 365-377.

Demand for aluminum, paper, steel, plastic and cement is predicted to continue to increase thru 2045



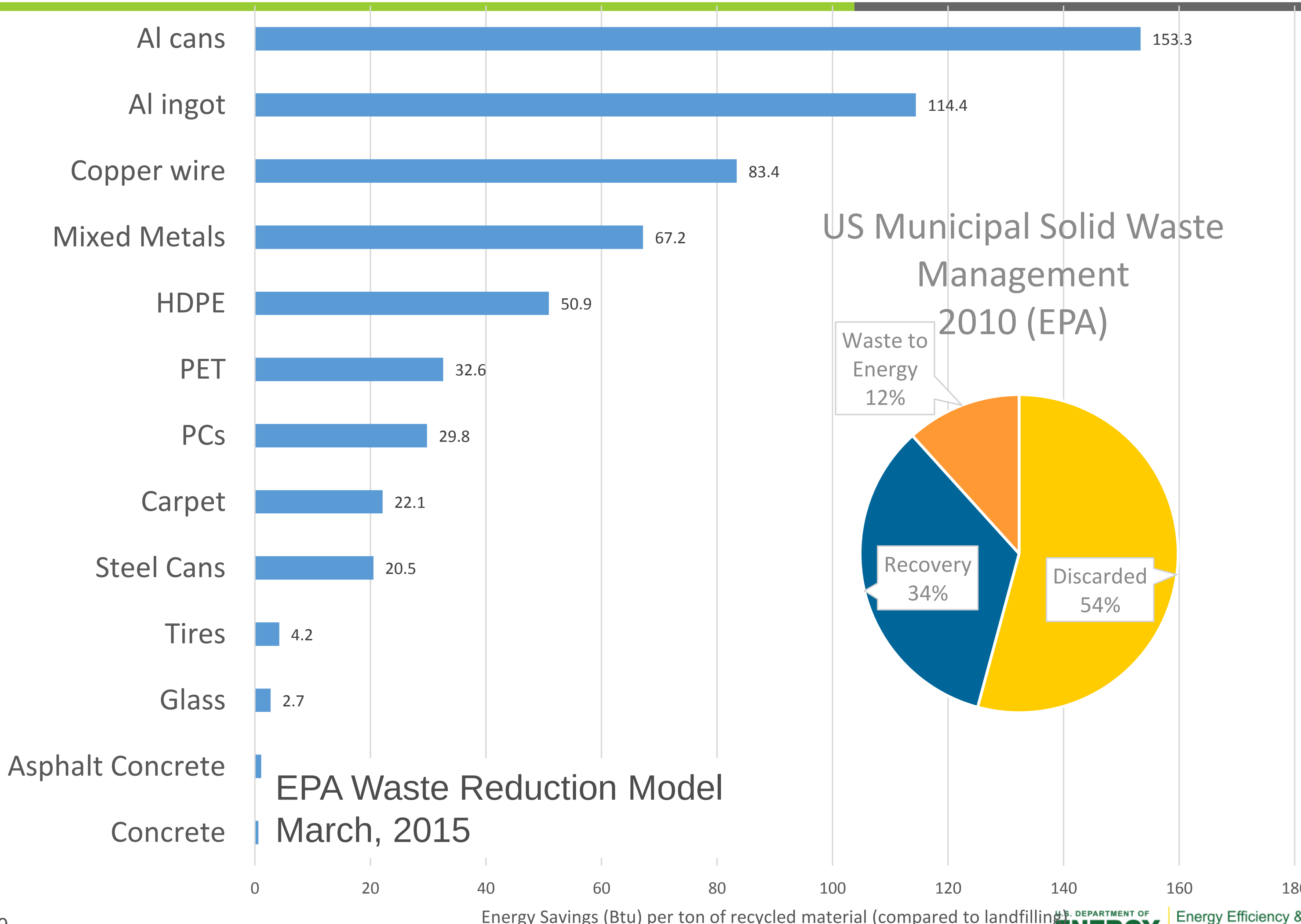
Gutowski, T., S. Sahni, J. Allwood, M. Ashby, and E. Worrell. 2013. The energy required to produce materials: constraints on energy-intensity improvements, parameters of demand. *Phil Trans R Soc A* 371: 20120003.

Price of materials and embodied energy of materials.

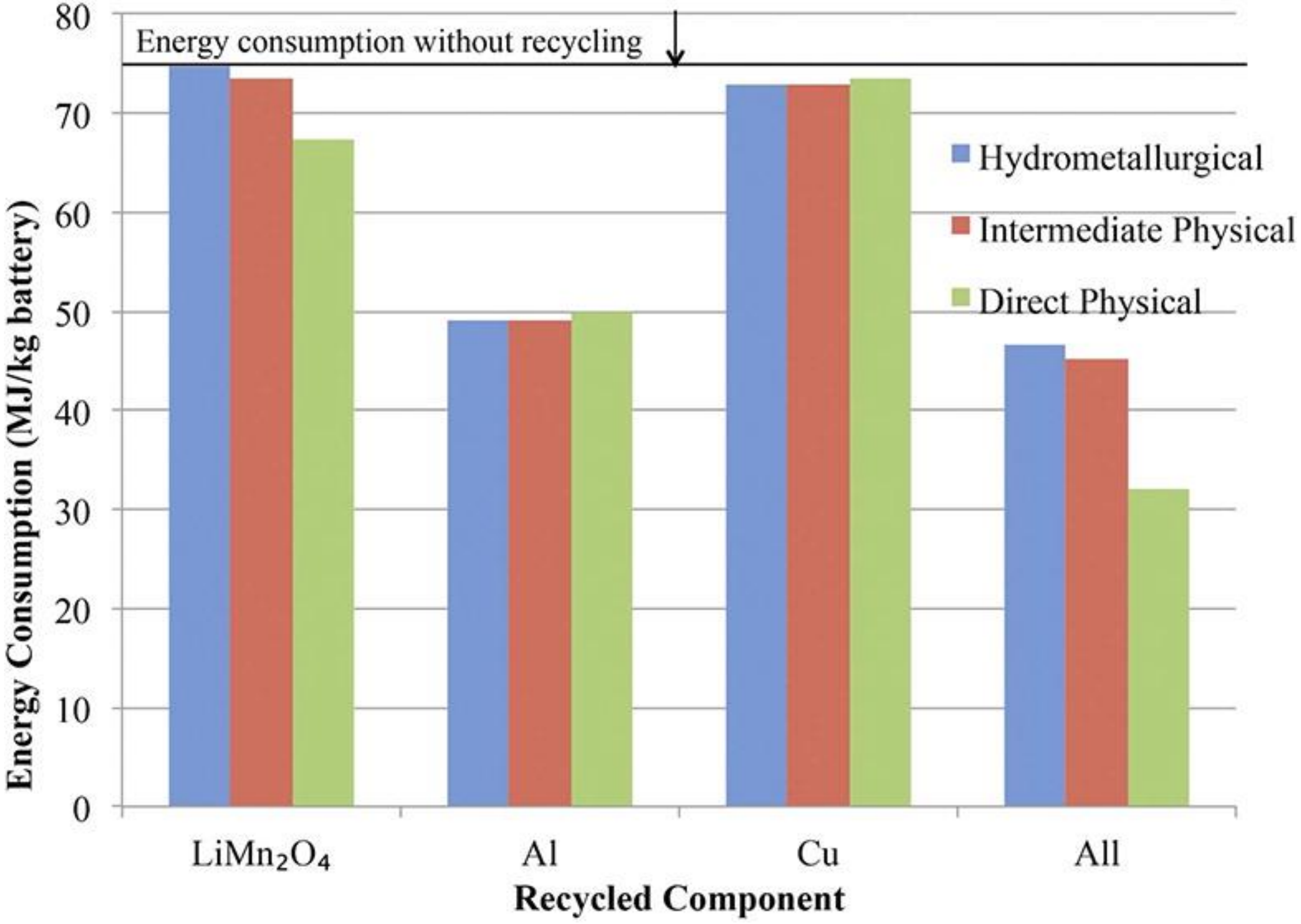


Timothy G. Gutowski et al. Phil. Trans. R. Soc. A 2013;371:20120003

Potential Energy Savings from Recycling



Analysis on Cradle-to-Gate Energy Consumption of Li-ion Batteries

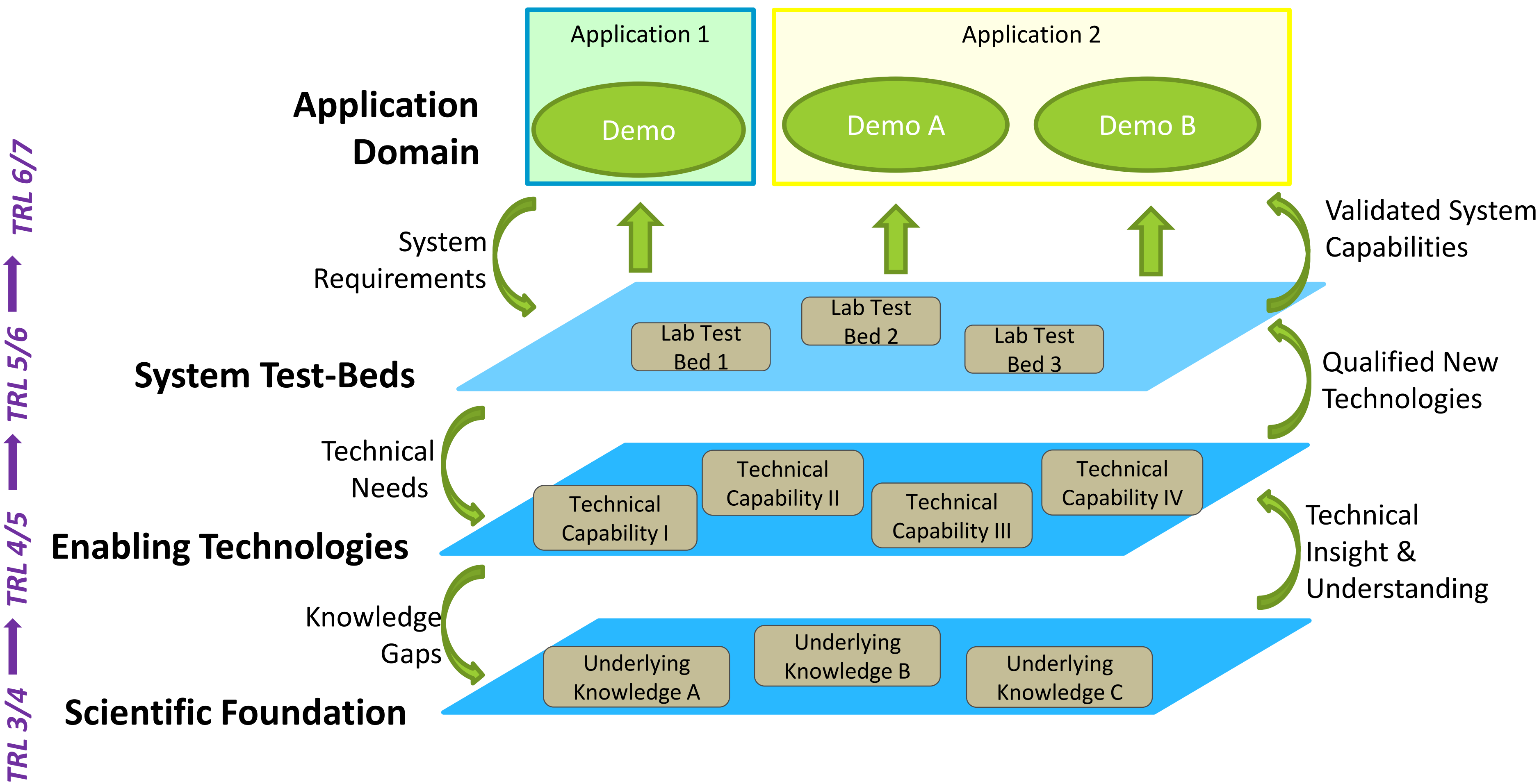


Published in: Jennifer B. Dunn; Linda Gaines; John Sullivan; Michael Q. Wang; *Environ. Sci. Technol.* **2012,** 46, 12704-12710.
DOI: 10.1021/es302420z

Workshop Purpose & Goals

- Purpose is to gather input from stakeholders on
  - Future opportunities and technical challenges facing development of transformative technologies, processes, and equipment for sustainable manufacturing
  - Input on performance metrics
  - Key problems to be addressed identified and quantified
  - Critical crosscutting barriers that, if successfully addressed, could enable step change impacts beyond the current state of the art
- Technology development should be focused on the gap between lab-scale development and deployment and scale-up
  - **QUANTITATIVE GOALS ARE NECESSARY**
- Specific goals include:
  - To identify high value opportunities and manufacturing challenges to improve energy efficiency, reduce material /water use, and enable increased recycle & reuse
  - To discuss promising technologies and manufacturing systems that increase sustainability in manufacturing at the unit operations, facility, and system level
  - To strategize how best to leverage R&D among the public sector, industry, and academia
  - To encourage discussion and networking among leaders in the field

Technical Challenge Hierarchy
Multi-Disciplinary Technology Translation



LIKE QUANTIFICATION OF POSSIBLE REQUIREMENTS, NEEDS & GAPS

Example Outcomes from Workshop

- What are ambitions and inspiring metrics for success?
  - Reducing possible waste / scrap by an order of magnitude while maintaining cost and energy use
  - Increasing reuse capacity by order of magnitude while maintaining throughput and cost
- What are the technical pathways needed to achieve this?
  - Technologies that enable low-cost reuse and recycling of multi-material products
  - Equipment that reuse manufacturing wastes (e.g., depolymerization)
- Where are the gaps?
  - Industry won't invest in new sustainable technologies / infrastructure
  - Novel processes have high capital cost limiting investment in scale-up

Workshop Structure: Breakout Sessions

- 5 Sessions
  - Developing and Using Alternative Feedstocks
  - Reduction of Waste in Manufacturing Processes
  - Sustainable Design and Decision-Making
  - End of Life Product Management
  - Materials, Water and Energy Management
- Staff will take real-time notes
- Results of each breakout session will be presented in a plenary session for each day

Types of information

- Be Specific
- Be Candid—Chatham House Rules (notes non-attributed)
- Give Quantifiable Metrics
  - What are the most important variables)?
  - For the most important variables, what are the game changer metrics for parameters like material usage, water consumption, cost, and energy consumption?
  - What are the actual numbers (e.g., 80% reduction, 100% recovery, etc.)?
- Provide High Level of Detail
  - What specific technologies are needed to meet these game changer metrics?
  - Why hasn't the private sector made more of these investments?
  - What specific form of public-private partnership would best accelerate sustainable manufacturing? What would be counterproductive?

Thank You!