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

Public-Private Partnerships Using Shared R&D Facilities

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Broad Topical Areas

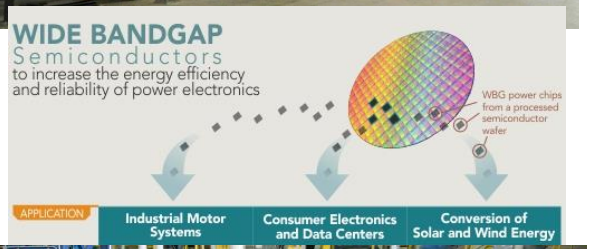
- ***Platform Materials and Technologies for Energy Applications***
  - Advanced Materials Manufacturing (Mat'l Genome, Nanomaterials, etc.)
  - Critical Materials
  - Advanced Composites & Lightweight Materials
  - 3D Printing / Additive Manufacturing
  - 2D Manufacturing / Roll-to-Roll Processes
  - Wide Bandgap Power Electronics
  - Next Generation Electric Machines
- ***Efficiency in Manufacturing Processes (Energy, CO_2)***
  - Advanced Sensors, Controls, HPC Modeling and Platforms (i.e., Smart Manufacturing)
  - Advanced Chemical Process Intensification
  - Grid Integration of Manufacturing (incl. Combined Heat and Power)
  - Sustainable Manufacturing (Water, New Fuels & Energy)
- ***Emergent Topics in Manufacturing***

AMO Supported R&D Facilities

- Critical Materials Institute: a DOE Energy Innovation Hub at Ames National Laboratory
- Manufacturing Demonstration Facility at Oak Ridge National Laboratory
- America Makes, an interagency National Additive Manufacturing Innovation Institute, led by DOD
- Power America: Next Generation Power Electronics Manufacturing Innovation Institute, led by North Carolina State University
- Institute for Advanced Composites Manufacturing Innovation, in negotiation with team led by the University of Tennessee
- Smart Manufacturing: Sensors, Controls, Platforms, and Models for Manufacturing, Funding Opportunity Announcement released September 16 ,2015

CMI Accelerating Energy Innovations

Critical Materials Institute

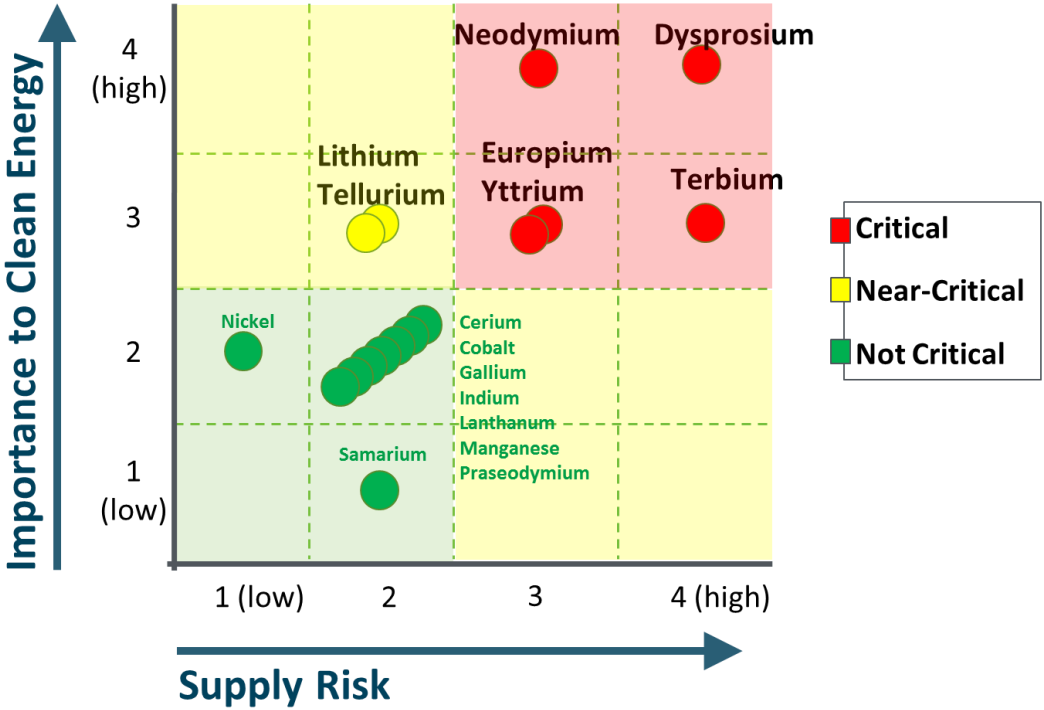


CMI Accelerating Energy Innovations

Critical Materials Institute

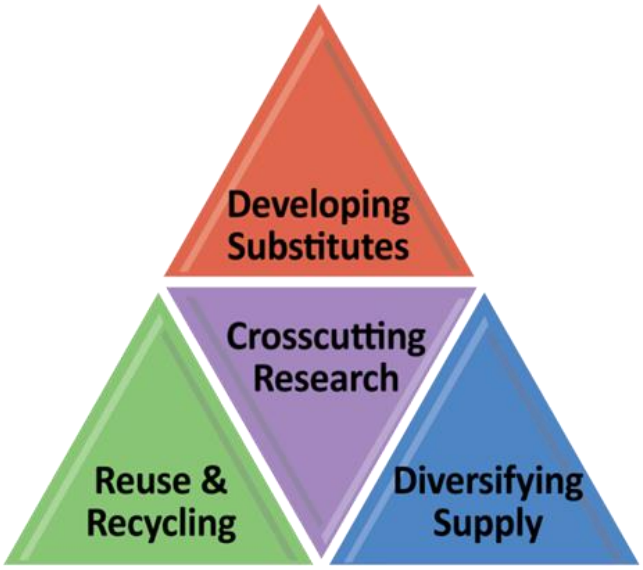
A DOE Energy Innovation Hub

- 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

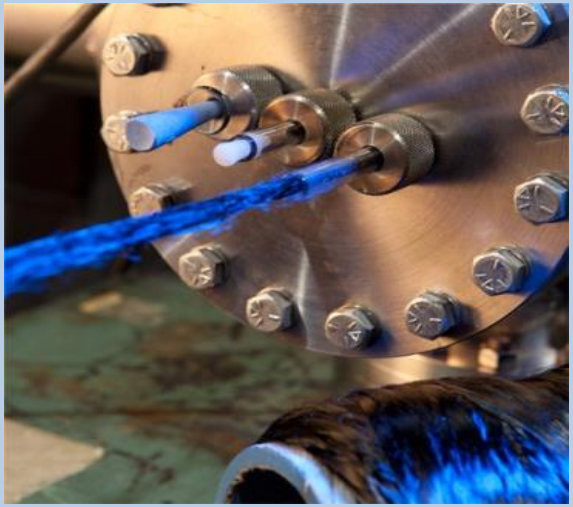
Additive Manufacturing

Arcam electron beam processing AM equipment

POM laser processing AM equipment

Carbon Fiber

Exit end of Microwave Assisted Plasma (MAP) process, jointly developed by ORNL and Dow



PowerAmerica

Next Generation Power Electronics Manufacturing Innovation Institute

Developing advanced manufacturing processes to enable cost-competitive, large-scale production of *wide bandgap* semiconductor-based power electronics, which allow electronic systems to be *smaller, faster* and more *efficient* than power electronics made from silicon.

- **Wide Band Gap Semiconductors for Power Electronics**
  - **Silicon Carbide: 1200 V, 1700V, 10 KV Diodes and MOSFETs**
  - **Gallium Nitride: 600-900 V**

***Goal:* Achieve cost parity with Silicon in 5 years**

- **Advantages**
  - **Operate at Higher Temperatures**
  - **Block Higher Voltages**
  - **Switch Faster with less losses**
  - **Smaller Passive components**
  - **Potentially More Reliable**
  - **Substantial System-Level Benefits**

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Institute for Advanced Composite Materials Innovation

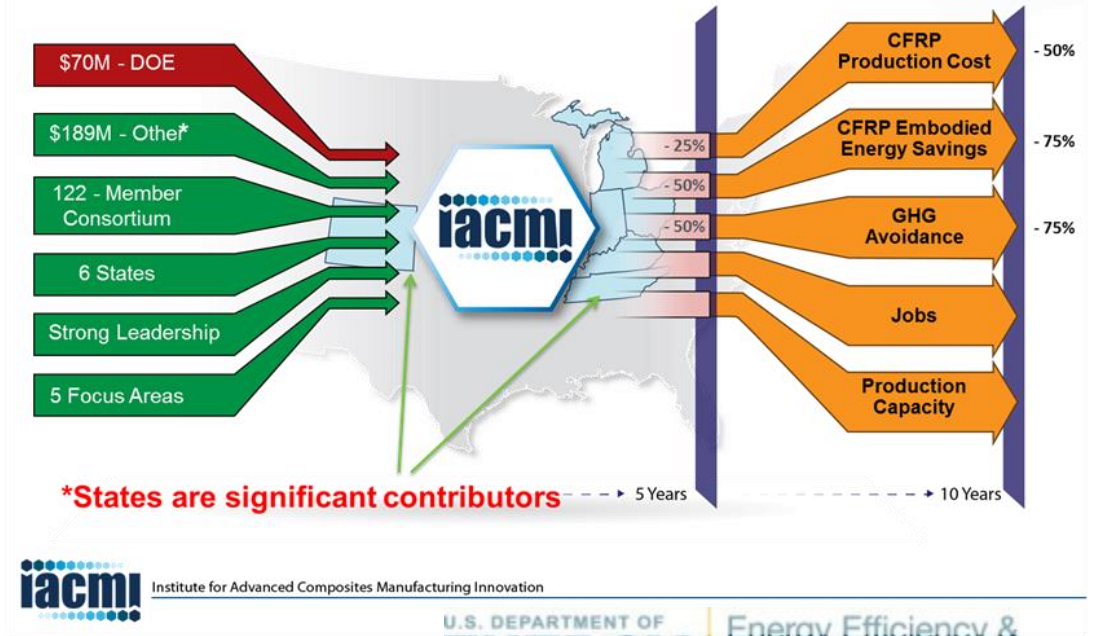
Objective

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



iacmi Institute for Advanced Composites Manufacturing Innovation

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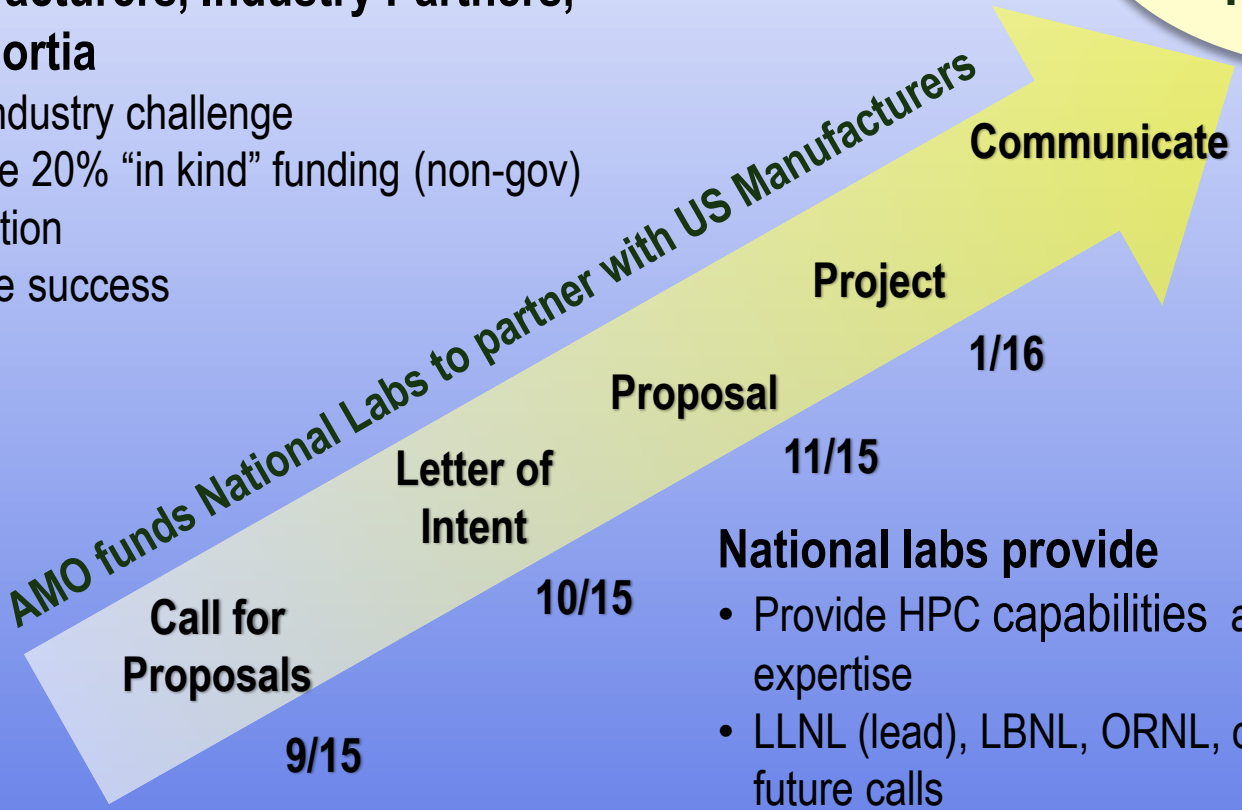
HPC4Mfg Program: Advancing Innovation

Increase Energy Efficiency - Advance Clean Energy Technologies

US Manufacturers, Industry Partners, and Consortia

- Identify industry challenge
- Contribute 20% "in kind" funding (non-gov)
- IP Protection
- Announce success



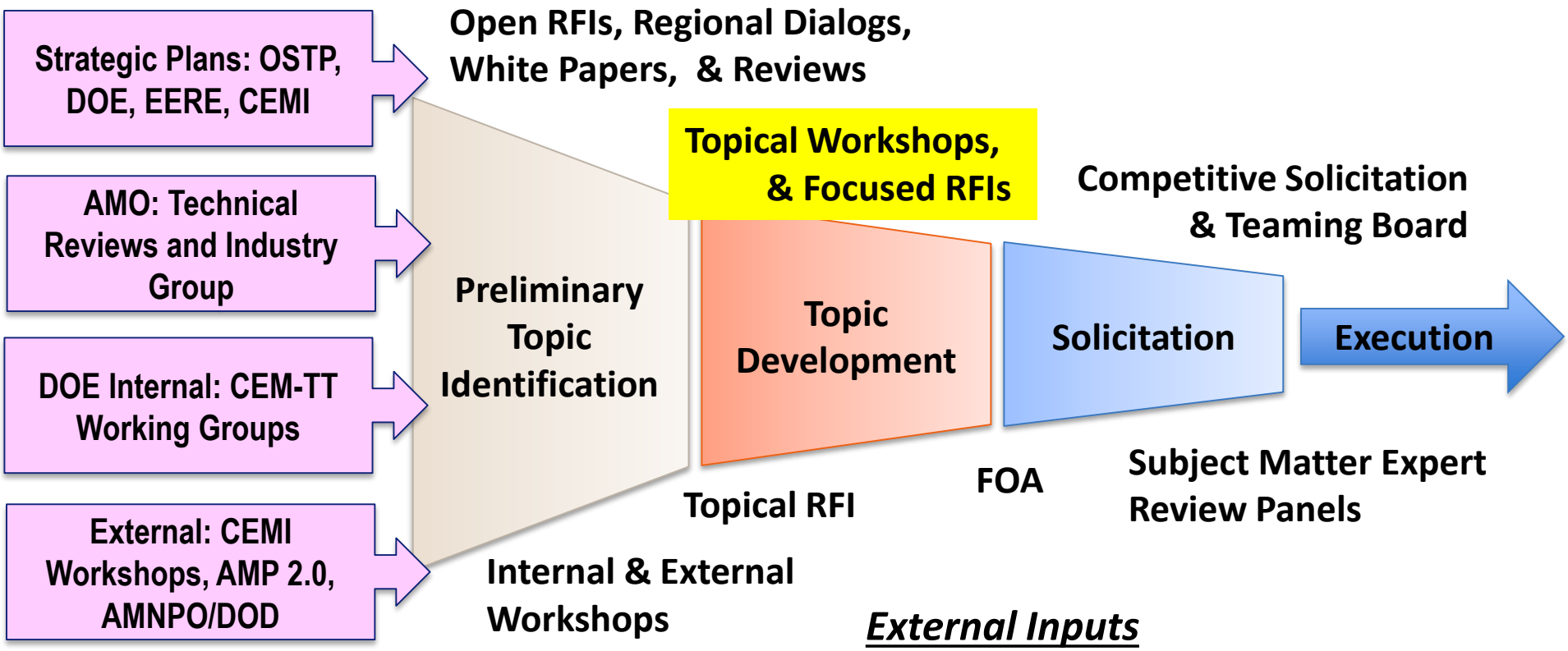
US Manufacturing losing market share and large energy consumer

National labs provide

- Provide HPC capabilities and mod / sim expertise
- LLNL (lead), LBNL, ORNL, other labs join in future calls
- Partner with industry to develop full proposal
- < $300k DOE funding
- Standard CRADA sympathetic to protection of industry IP

A limited number of Phase II projects may be considered

DOE Topic Development for Potential Institutes



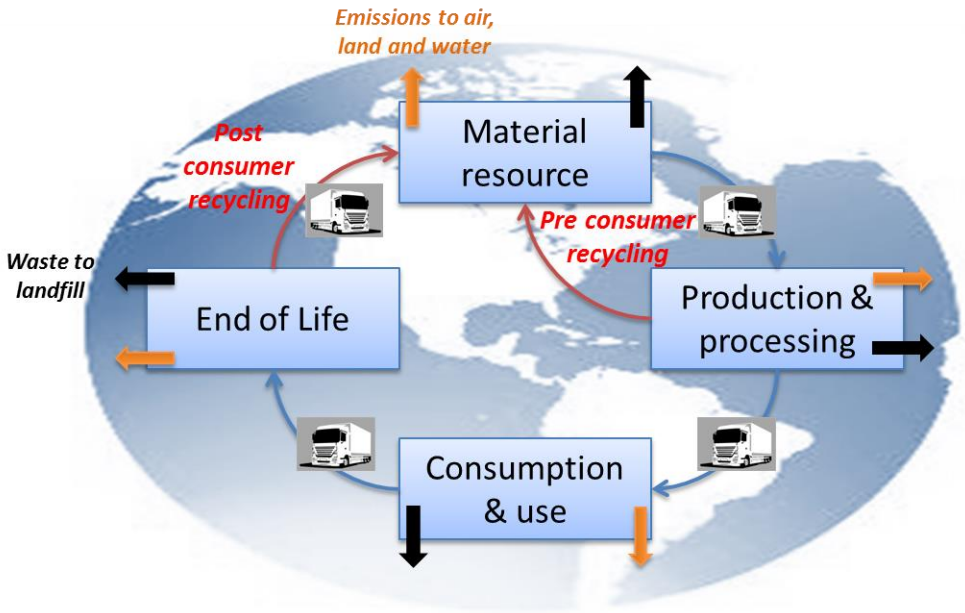
DOE Topic Identification Criteria

EERE Core Questions	Application to DOE Topic Selection
High Impact: *Why is this a high-impact problem?* *How would this technology development transform the marketplace?*	• **What is manufacturing challenge to be solved?** • **If solved, how does this impact clean energy goals?** • **If solved, who will care and why specifically?**
Additionality: *How will EERE Funding make a large difference relative to what the private sector (or other funding entities) is already doing?*	• **Who is supporting the fundamental low-TRL research & why wouldn't they support mid-TRL development?** • **Who else might fund this mid-TRL development & how might EERE/AMO support catalyze this co-investment?**
Openness: *How will EERE make sure to focus on broad problems and be open to new ideas, new approaches, and new performers?*	• **Has this mid-TRL Manufacturing Challenge been Stated Broadly?** • **Is there Fertile low-TRL Scientific Base to Address the Challenge?** • **Has a Broad Set of Stakeholders been Engaged in Dialogue?**
Enduring Economic Benefit: *How will EERE funding result in enduring economic benefit to the US, particularly the manufacturing sector?*	• **Would this Manufacturing Challenge Impact More than One Clean Energy Technology Application?** • **Is Industry Currently Trying to Identify Solutions?**
Proper Role of Government: *How does EERE funding represent a proper and high-impact role of government versus something best left to the private sector?*	• **What is the National Interest? What is the Market Failure? (Why Would Industry Not Solve this By Itself?)** • **Is there a Pathway for Federal Funding to End & What are the Metrics for This Transition?** • **Is there Large Potential for Follow-On Funding, & What are the Stage Gates to Follow-On Support?**
+ Appropriate Mechanism	• **Why is this specific mid-TRL Problem Best Addressed through a 5-Year, Multi-participant, Industry-oriented Institute (NNMI) now?**

Sustainable Manufacturing

- **Technology development to drive towards zero-waste manufacturing**
  - **Renewable and waste streams as feedstocks**
  - **Reducing waste in production and processing**
  - **Optimizing value in reuse of end-of-life materials**
  - **More efficient management of materials, energy, and water in the supply chain**
  - **Tools needed to enable sustainable decision making**

- **Potential Impacts:**
  - **Improved material efficiency through the supply chain will improve energy efficiency and increase competiveness**
  - **Reduction of green-house gas emissions and other waste products**



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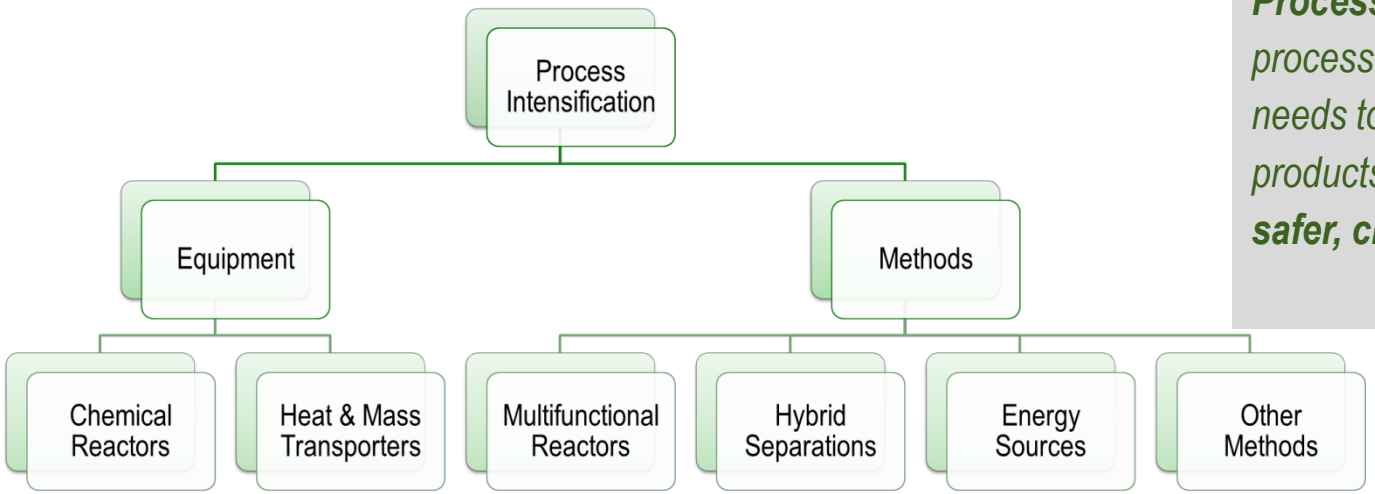
Modular Chemical Process Intensification



- Spinning disk & Static mixer Static mixing catalysts
- Microreactors
- Heat exchange reactors
- Supersonic gas/liquid
- Jet-impingement
- Rotating packed-bed

- Static mixers
- Compact heat exchanger
- Microchannel heat exchange
- Rotor/stator mixers
- Rotating packed beds
- Centrifugal adsorber

- Reverse-flow Reactive distillation
- Reactive extraction
- Reactive crystallization
- Periodic separating reactors
- Membrane reactors
- Reactive extrusion

- Membrane adsorption
- Membrane distillation
- Adsorptive distillation

- Centrifugal fields
- Ultrasound
- Solar energy
- Microwaves
- Electric fields
- Plasma technology

- Supercritical fluids
- Dynamic (periodic) reactor operation

Process intensification *is a chemical process with the precise environment it needs to flourish, results in better products, and processes which are* ***safer, cleaner, smaller, and cheaper****.*

- The BHR Group

Flatten Cost-Curve for Chemical Processes:

Higher Material Efficiency
Predictive Scaling
Scale-out vs. Scale-up

Potential Energy Applications:

Chemical Processes, PowerGeneration, Sustainable Fuels

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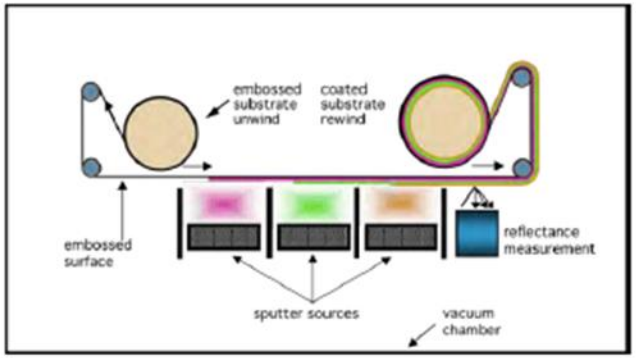
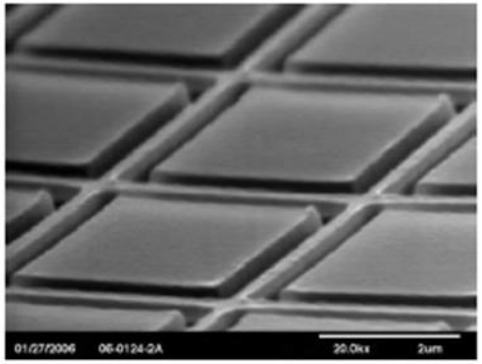
2D Fabrication / Advanced Roll-to-Roll Manufacturing

- **Technology development for the electronic manufacturing service (EMS) sectors to move from plate-to-plate standard lithography to continuous R2R processing.**
- **Miniaturization of critical feature sizes to the nanoscale**
- **Advancing tools and methods for process control, defect sensing, and real-time feedback**

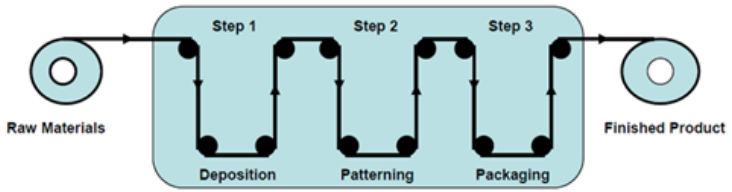
- **<u>Potential Energy Applications</u>:**

  Solar, Batteries, Fuel Cell MEAs, Separation Membranes, Building Envelopes, etc.





Prototype "Nano-Fab" using R2R at CAMM, Binghamton University (SUNY)



Idealized R2R Process Methodology

Advanced Materials Manufacturing

leveraging unique capabilities for fast-tracking materials to market, while expanding and enhancing the tools & methods in the core

Core Effort for Advanced Materials

unique set of in-house capabilities in accelerated energy-materials development

Advanced Modeling, Computing, and Simulation Capabilities

leveraging and expanding on the current MGI multi-physics, multi-scale computational base

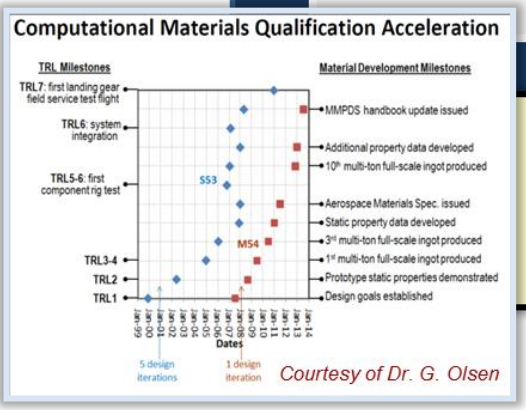
feedback pathways

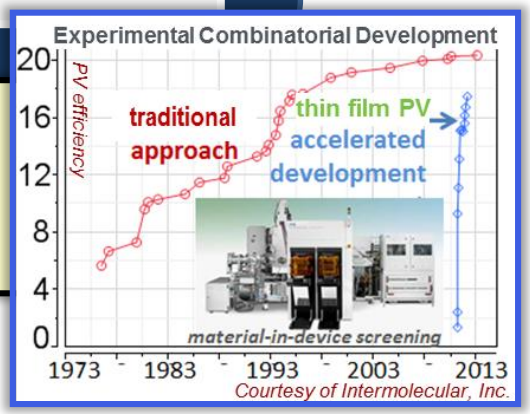
High Throughput Synthesis, Characterization & Analysis Capabilities

high productivity combinatorial discovery & development tailored to specific energy end uses

linkages in methods / data / intellectual property

Combines multi-physics, multi-scale computation with high-throughput synthesis and characterization for intelligent, focused RD&D in numerous energy technology thrusts, managed, e.g., in cross-cutting Materials Manufacturing Centers of Excellence (MMCOEs)





Leverages AMP 2.0

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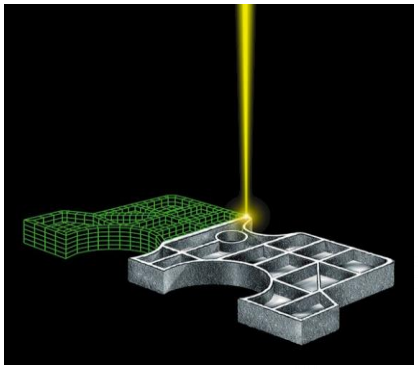
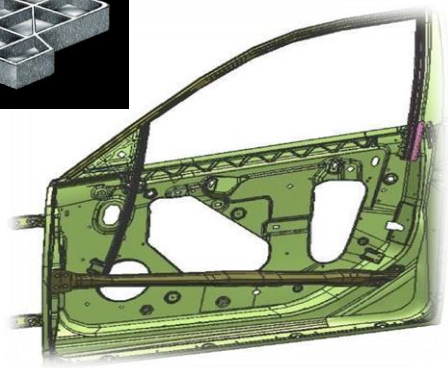
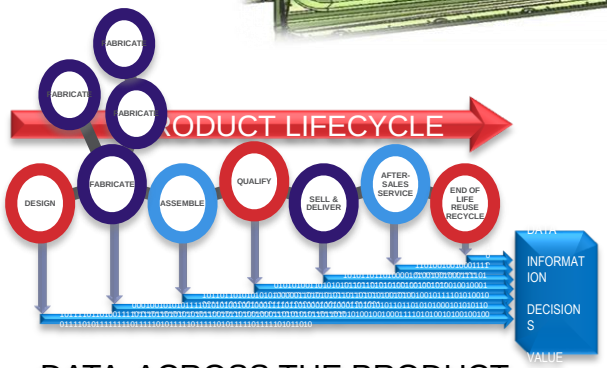
DOD Current and Planned Institutes

- America Makes
- Lightweight Innovations for Tomorrow (LIFT, formerly LM3I)
- Digital Manufacturing and Design Innovation
- Integrated Photonics Institute
- Flexible Hybrid Electronics

- Revolutionary Fibers and Textiles







DATA ACROSS THE PRODUCT LIFECYCLE

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Notice of Intents (NOI) for New Institutes

- **Department of Defense NOI for possible seventh and eighth Institutes (December 15, 2015)**

- **Department of Commerce/National Institute of Standards and Technology (December 21, 2015)**
  - **Collaborative Manufacturing Robotics**
  - **Biopharmaceuticals Manufacturing**
  - **Allows for consideration of all applications relevant to advanced manufacturing regardless of topic area**

- **See www.manufacturing.gov for details**

Concluding Remarks

- **The Advanced Manufacturing Office (AMO) uses a partnership approach with industry, academia, national labs, and government to develop cross-cutting technologies**
- **The Administration has awarded or announced nine Manufacturing Innovation Institutes (DOE – 3, DOD – 6); more Institutes planned for 2016**
- **DOE uses a rigorous process to select Institute topics that includes inputs from industry and universities; the DOD process is similar**