Department of Energy Advanced Manufacturing Office

FCTO AMR
Washington, DC

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Advanced Manufacturing Office

www.manufacturing.energy.gov

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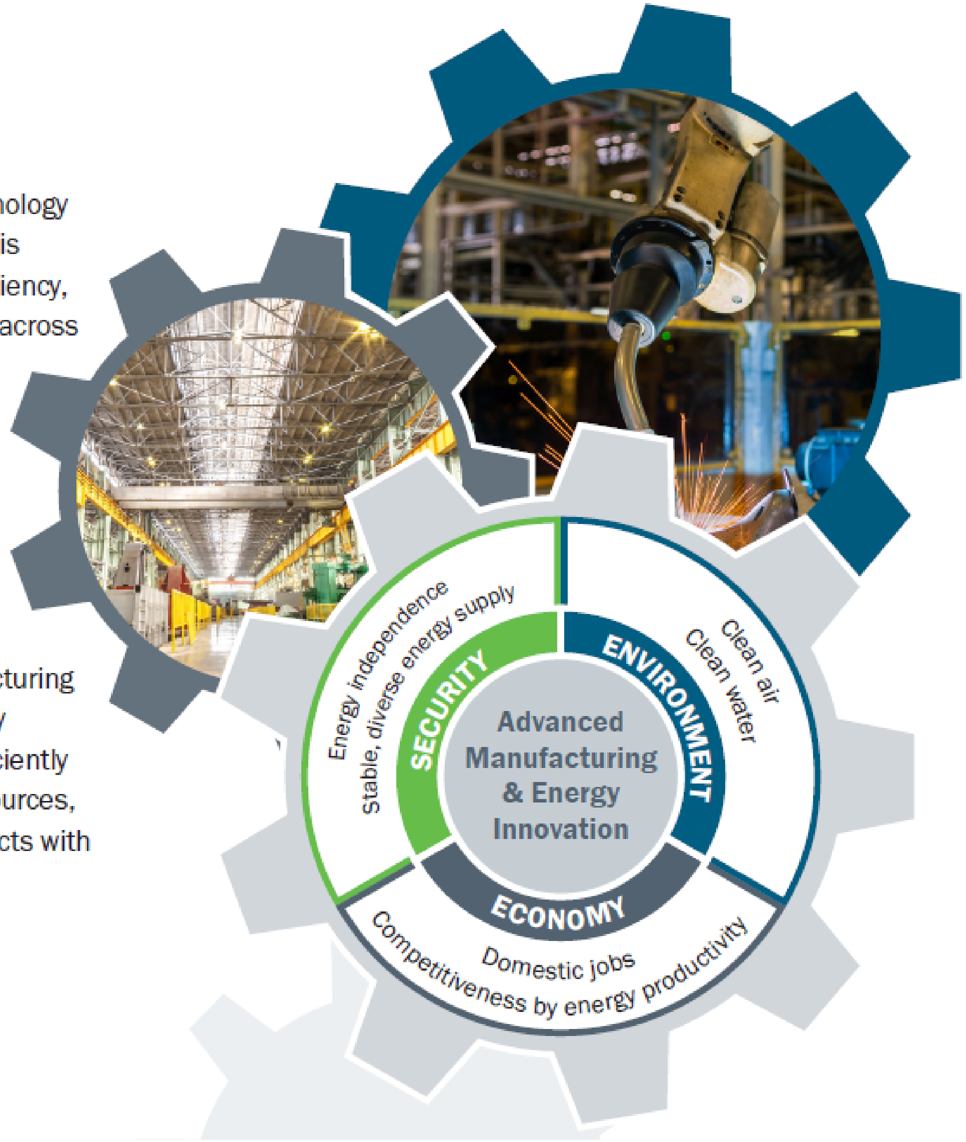
Department of Energy Advanced Manufacturing Office

Overview

The Advanced Manufacturing Office is the only technology development office within the U.S. Government that is dedicated to improving the energy and material efficiency, productivity, and competitiveness of manufacturers across the industrial sector.

AMO brings together manufacturers, not-for-profit entities, research organizations, and institutions of higher education to identify challenges; catalyze innovations; and develop cutting-edge material, process, and information technologies needed for an efficient and competitive domestic manufacturing sector. By targeting efficient manufacturing technologies, AMO seeks to drive energy productivity improvements in the U.S. manufacturing sector, efficiently utilize abundant and available domestic energy resources, and support the manufacture of clean energy products with benefits extending across the economy.



AMO: Vision, Mission, and Strategic Goals

VISION: U.S. global leadership in sustainable and efficient manufacturing for a growing and competitive economy.

MISSION: Catalyze research, development and adoption of energy-related advanced manufacturing technologies and practices to drive U.S. economic competitiveness and energy productivity.

AMO Strategic Goals

- Improve the productivity and energy efficiency of U.S. manufacturing
- Reduce lifecycle energy and resource impacts of manufactured goods
- Leverage diverse domestic energy resources in U.S. manufacturing, while strengthening environmental stewardship
- Transition DOE supported innovative technologies and practices into U.S. manufacturing capabilities
- Strengthen and advance the U.S. manufacturing workforce

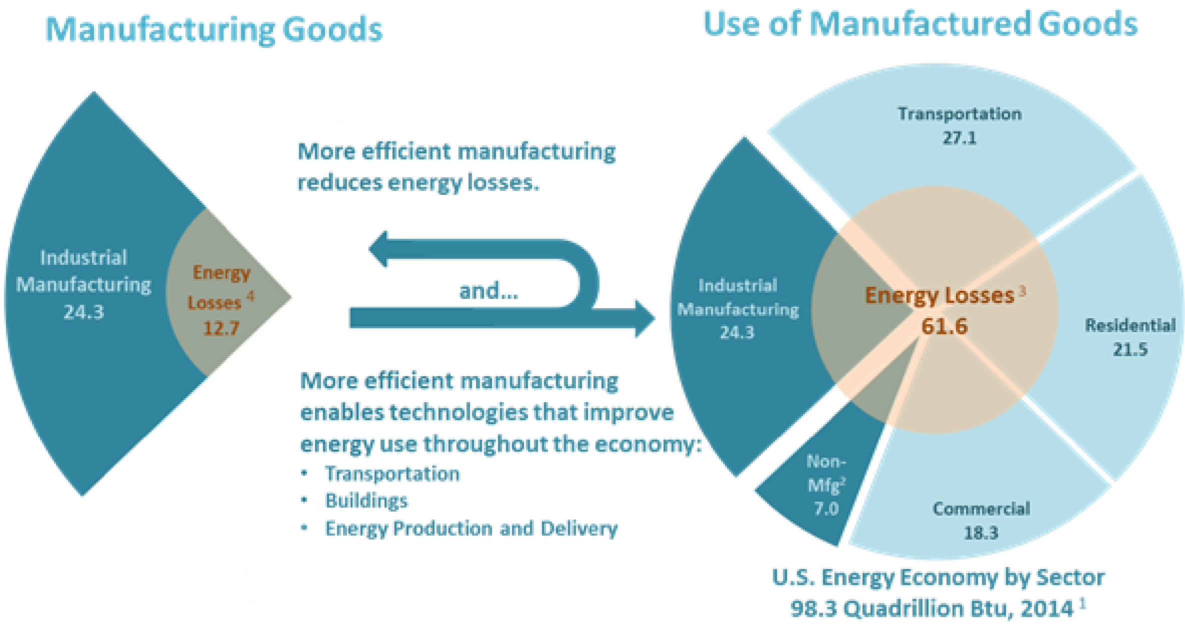
Big Economic & Energy Footprint

Manufacturing:

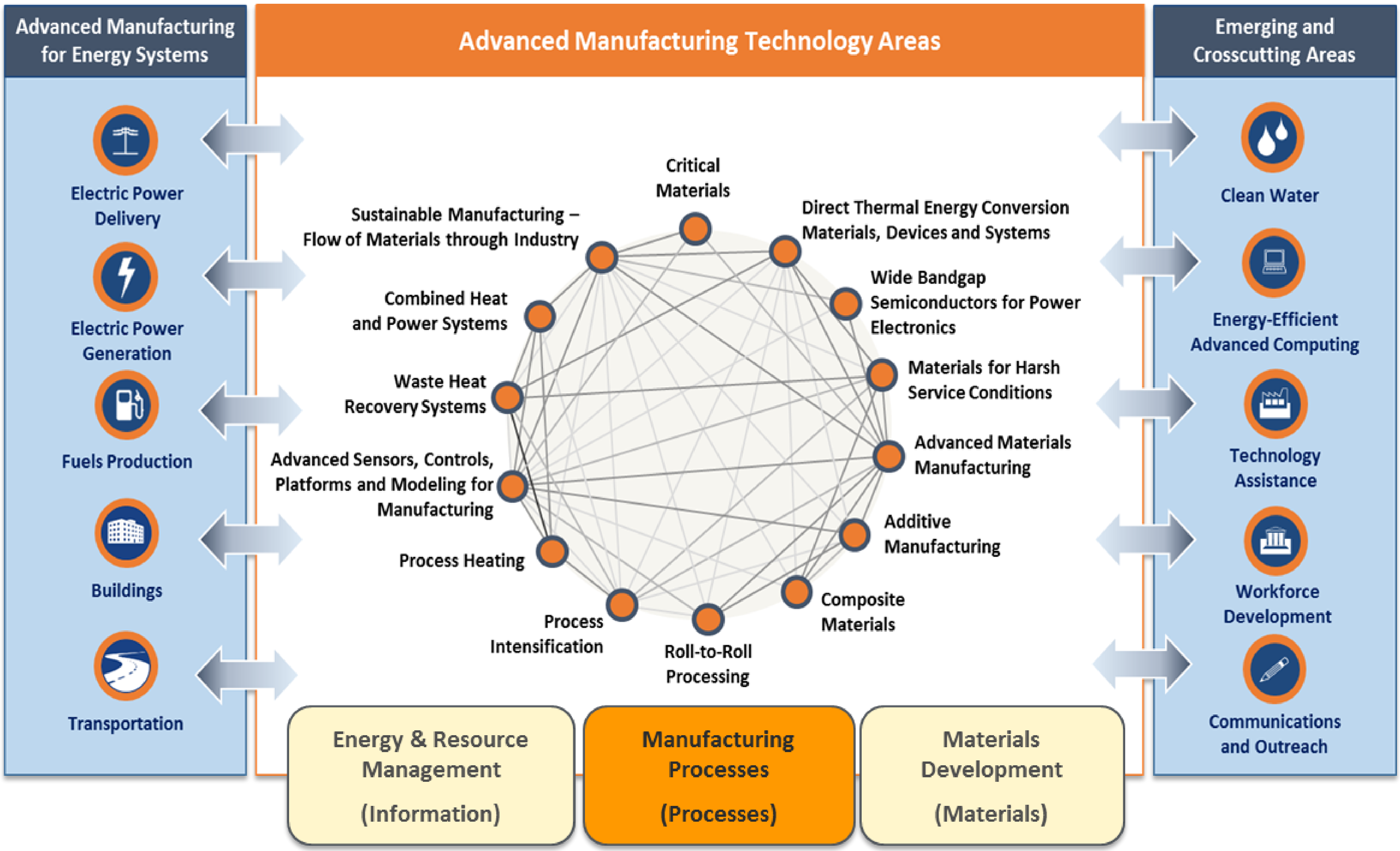
- Contributes ~$2 trillion to US GDP
- Accounts directly for ~12.5 million jobs
- Represents ~25% of nation's energy consumption
- Two-thirds of manufacturing sectors are energy intensive

Technology Innovation through Applied Research and Development in Advanced Manufacturing and Energy is a Foundation for Economic Growth and Jobs in the US

AMO Draft Multi-Year Program Plan available at https://www.energy.gov/sites/prod/files/2017/01/f34/Draft%20Advanced%20Manufacturing%20Office%20MYPP_1.pdf



QTR and Multiyear Program Plan (draft) Technologies



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Office Structure

Organizationally, AMO pursues its goals through the following three subprogram approaches:

R&D PROJECTS: Bridging the innovation gap

The Advanced Manufacturing R&D Projects subprogram supports innovative advanced manufacturing applied R&D projects that focus on specific high-impact manufacturing technology and process challenges. The subprogram invests in foundational energy-related advanced manufacturing technologies that impact areas relevant to manufacturing processes and broadly applicable platform technologies.

R&D CONSORTIA: Public-Private consortia model

The Advanced Manufacturing R&D Consortia subprogram helps the United States position itself as a world leader in strategic areas of manufacturing by bringing together manufacturers, suppliers, companies, institutions of higher education, national laboratories, and state and local governments in public-private R&D consortia. These partnerships create an innovation ecosystem that accelerates technology development and facilitates the transition of innovative advanced manufacturing technologies to industry.

TECHNICAL PARTNERSHIPS: Direct engagement with Industry

The Technical Partnerships subprogram provides critical support to the adoption of advanced energy efficiency technologies and practices. The subprogram supports the adoption of cost-effective combined heat and power (CHP) technologies; provides resources to assist manufacturers in reducing their energy use intensity; promotes the adoption of energy management programs, provides targeted energy efficiency, productivity, and waste/water use reduction practices to small- and medium-sized manufacturers.

Leadership

Dr. Rob Ivester, Director
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Technical Partnerships
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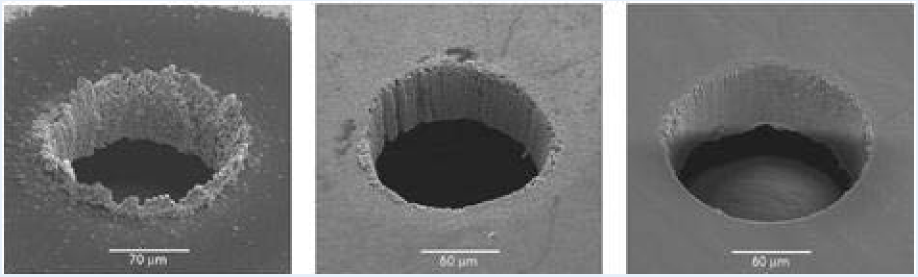
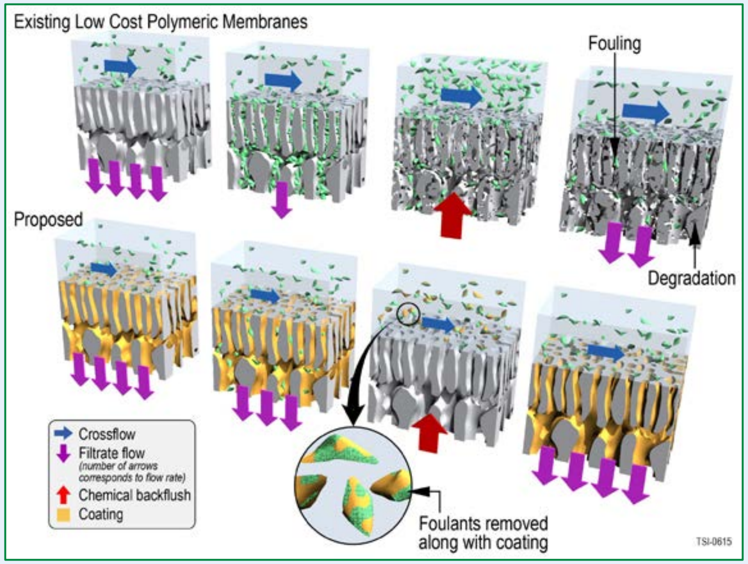
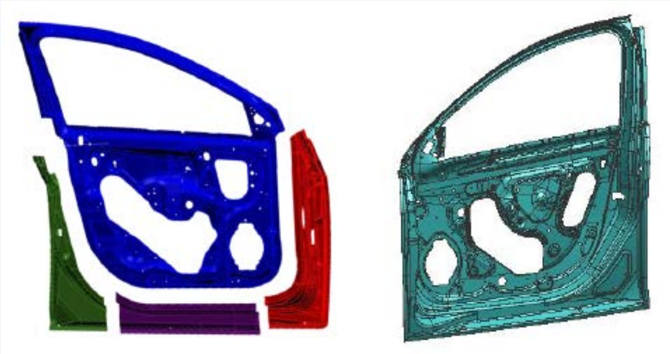
R&D Projects Examples (Manufacturing Processes)



Ultrafast, femtosecond pulse lasers (right) will eliminate machining defects in fuel injectors.
Image courtesy of Raydiance.



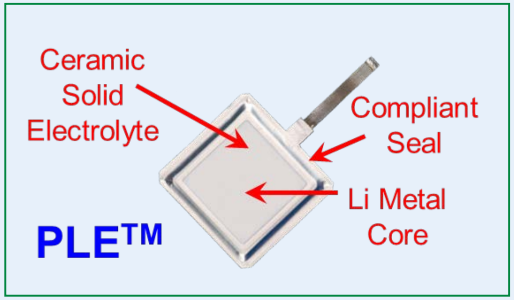
Protective coating materials for high-performance membranes, for pulp and paper industry. *Image courtesy of Teledyne*



Energy-efficient large thin-walled magnesium die casting, for 60% lighter car doors.

Graphic image provided by General Motors.

A water-stable protected lithium electrode.
Courtesy of PolyPlus



R&D Projects: Fuel Cell Related Activity

Ultra Efficient Combined Heat, Hydrogen, and Power System

Project Prime: FuelCell Energy, Inc.

Technology: Develop a combined heat, hydrogen and power tri-generation system (CHHP) to utilize reducing gas produced by a high-temperature fuel cell to directly replace hydrogen and nitrogen used in a metal annealing process, greatly improving the efficiency of the system and reducing annealing costs. The addition of hydrogen provides additional value for the
technology, and improves payback.

<u>Technology Update</u>

- The combined heat, hydrogen and power tri-generation system was successfully commissioned at the FuelCell Energy manufacturing plant in CT.
- System is fully operational at greater than 75% efficient at generating heat and power. The system also provides a stream of high purity hydrogen to the fuel cell anode manufacturing line.
- Additional application areas include metals (e.g. powdered copper) process industries that use a reducing atmosphere in manufacturing.

The high efficiency packaged CHHP system in operation at FuelCell Energy's manufacturing plant in CT .

R&D Projects: Hydrogen Related Activity

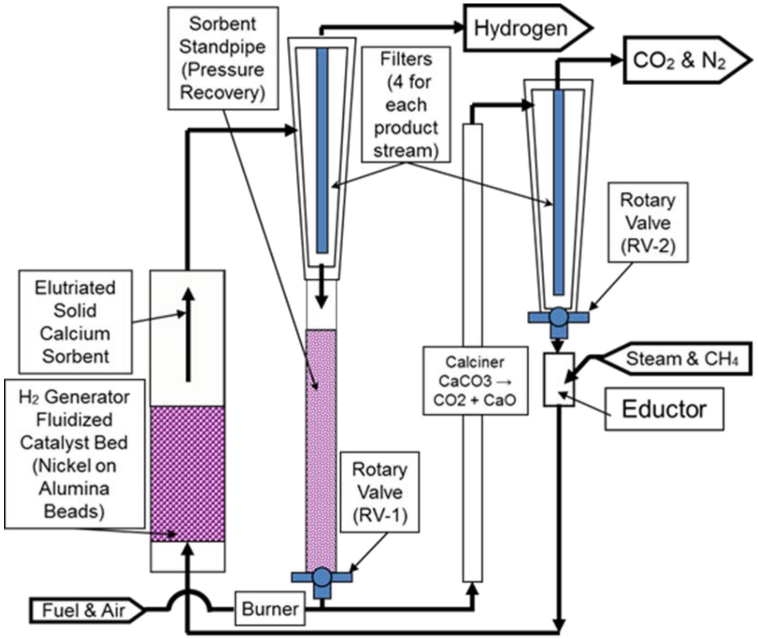
One Step Hydrogen Generation Through Sorption Enhanced Reforming

Project Prime: Gas Technology Institute
Project Partners: Energy & Environmental Research Center (EERC)

Technology: Develop low-cost hydrogen production technology using Sorption Enhanced Reforming (SER) that combines the reforming and water-gas shift processes into one-step. Calcium oxide sorbent is elutriated through a bubbling fluidized catalyst bed with methane and steam. Hydrogen end-users benefit from process intensification and reduced hydrogen cost (15% – 20%) through lower capital cost, improved efficiency, and smaller footprint. In addition, a separate CO2 stream arising from calcination reduces CO2 capture costs.

<u>Technology Update</u>

Successfully demonstrated a catalyst unsusceptible to de-activation by operating more than 28 hours in SER-mode.
Successfully demonstrated SER chemistry and process operation, with H2 purity and yield at or above expected levels for the sorbent feed rates used (sorbent feeding limited by mechanical systems)
Identified 75% reduction in the cost of carbon separation for the SER-based process.



R&D Projects: Hydrogen Related Activity

Low-temperature Electrochemical Activation of Ethane for Co-production of Chemicals/Fuels and Hydrogen

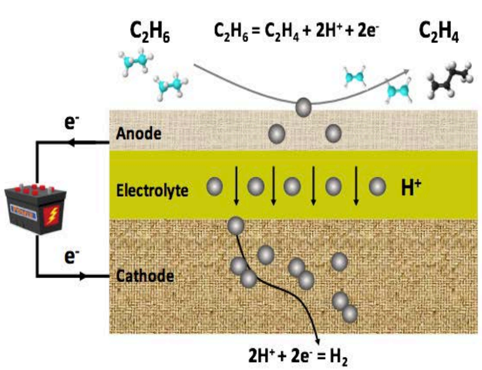
Project Prime: Idaho National Lab
Project Partners: University of Wyoming and Massachusetts Institute of Technology

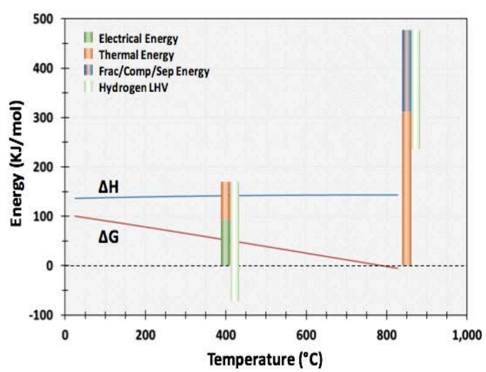
Technology Summary

- Transformational, low-thermal-budget, non-oxidative, electrochemical activation of ethane for co-production of chemicals/fuels and hydrogen
- Novel bifunctional deprotonation and coupling catalyst for targeted chemicals or liquid fuels production
- For the production of ethylene from ethane, the process energy was reduced by as much as 65% compared to the industrial steam cracking. If hydrogen heating value is taken into account, the electrochemical activation actually has a net energy gain of about 70 KJ/mol

Project Goals

- Demonstrate the co-production of chemicals or liquid fuels and hydrogen from ethane by a non-oxidative electrochemical deprotonation process at intermediate temperatures (300-500°C)
- Exceed the AMO goal of 50% process energy reduction, targeting two third process energy reduction in ethylene production compared to the industrial steam cracking
- Achieve high product selectivity by developing novel coupling catalysts





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Lab-Embedded Entrepreneurship Programs

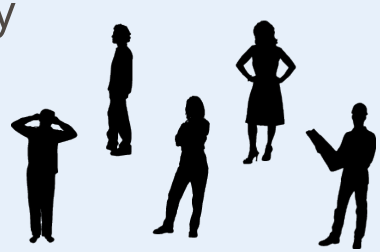
INNOVATION CROSSROADS @ Argonne NATIONAL LABORATORY

cyclotronroad @ BERKELEY LAB Lawrence Berkeley National Laboratory

CHAIN REACTION INNOVATIONS @ OAK RIDGE National Laboratory

② **Leverage** experts and facilities at a world-class R&D institute

① **Recruit** the world's best energy technology innovators



③ **Deploy** people, IP, and technology to the marketplace

VC

Corp.

M&A, Licensing

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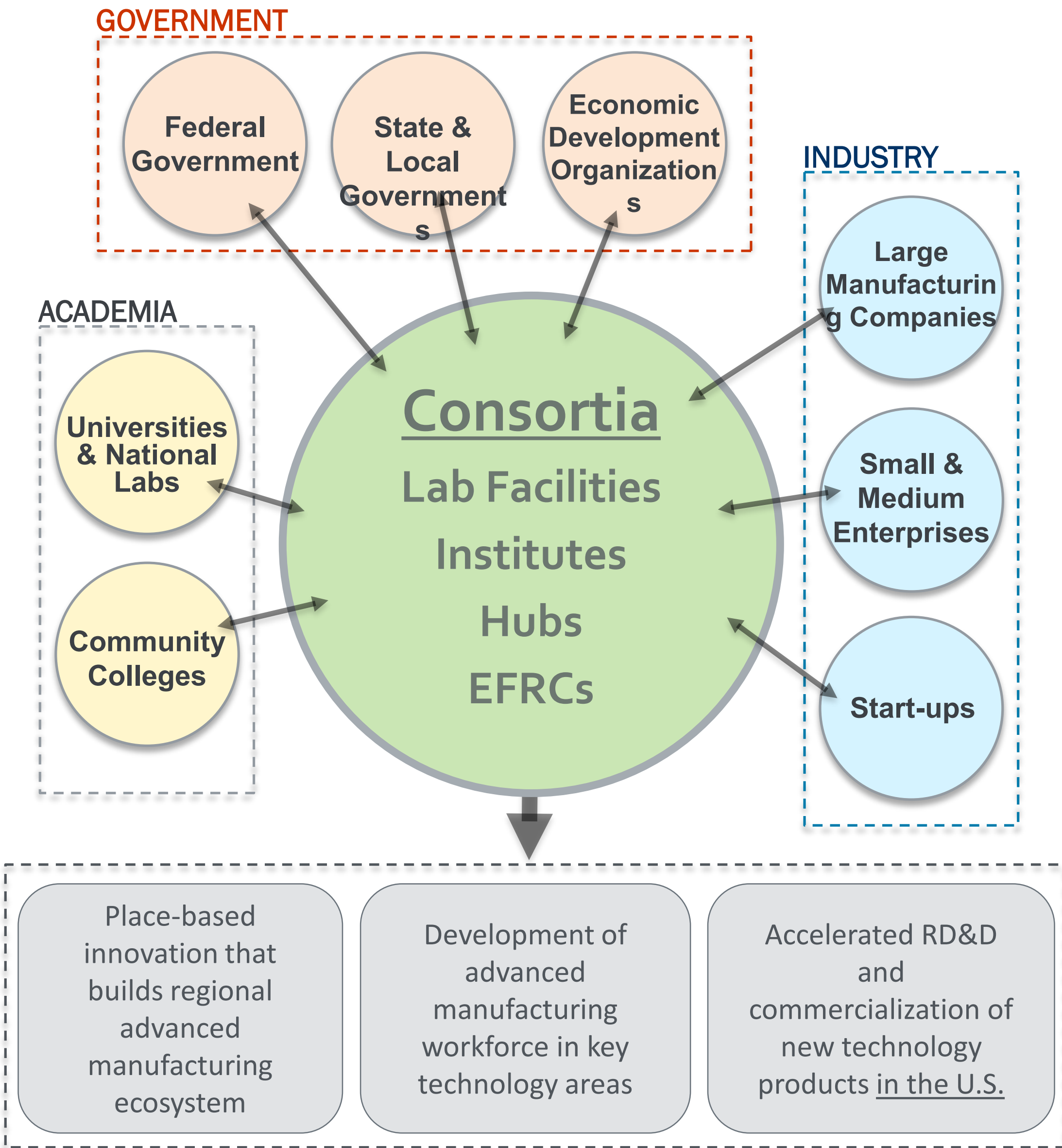
R&D Consortia



Each Consortia has:

- Clear technology focus
- TRL level suited to specific technology challenge
- Shared user facilities
- Ability to address critical challenges
- A balanced portfolio of projects

Manufacturing Demonstration Facility (ORNL)

Core R&D
R&D in materials, systems, and computational applications to develop broad of additive manufacturing

Industry Collaborations
Cooperative research to develop and demonstrate advanced manufacturing to industry in energy related fields

Education and Training
Internships, academic collaborations, workshops, training programs, and course curriculum for universities and community colleges.

Demonstrations
Executing on "moon shot" demonstrations to integrate partners, understand technical challenges, and accelerate technologies.

Core Research & Development Goals:

- Improved Performance Characteristics of AM Components Through Materials-Process Development
- Qualification and Certification Framework for AM Components
- AM Systems Optimized to Achieve Mainstream Manufacturing
- Comprehensive Understanding of AM Process Capabilities and Limits Through Physics-Based Simulation and Advanced Characterization

Wide Range of Additive Manufacturing Capabilities and Expertise

35 systems and **>$12M** of industry provided equipment

Electron beam melting

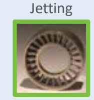

Developing in-situ characterization, feedback, and control
Heated powder bed
Expanding range of materials (Ti64, CoCr, 625, 718)
Precision melting of powder materials

Selective laser melting

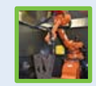

Unheated powder bed
Wide range of material choices (316L, 17-4PH, H13, Al, Ti, 718, 625)
Precision melting of metal powders
Up to 630 x 400 x 500mm build volume

Laser Metal deposition

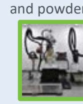

Site-specific material addition
Application of advanced coating materials for corrosion and wear-resistance
Repair of dies, turbines, etc.

Metal binder Jetting


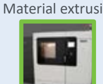
Metal matrix composites and sintered materials including:
Stainless steel + bronze
Tungsten + titanium
Ceramics + sand
Large build volumes (10 x 10 x 16in)
Fast build times (30 sec/layer)

Large-scale welding


Open-air environment
MIG welding arm with 6 DOF and 2 rotational degrees
Print size not restricted
Uses low-cost welding torches and wire
CAD-to-path functionality

Large-scale wire and powder feed


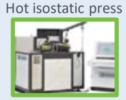
Laser wire and metal powder feedstock system for improved surface resolution and mechanical strength of large-scale metal components

Material extrusion


~0.005" – 0.007" resolution
Up to 914 x 610 x 914mm build volume
0.5 – 1.5 in3/hr.
Ultem and ABS

Large-scale laser metal


Reducing buy-to-fly ratio of aerospace components
Using 4kW laser and two 10 kW lasers to melt Ti64 wire
Inert system with argon-filled tent
Prints ~10cubic inches/hr.

Hot isostatic press


First rapid-quench HIP in US
180mm diameter
Can reach pressures of 25,000psi
Cooling rates of 3000C/min when cooled from 3000C
Can HIP and heat treatment in same cycle

Large-scale polymer deposition


Deposits up to 1000lbs. of pellet feedstock material per hour
Build volume up to 20' long x 6' wide x 8' tall
Printed >37 different polymers and composites
Dual material capabilities

Ingersoll Large-scale polymer deposition


Under development
Will have 46' x 23' x 10' build volume
Target deposition rate of 1000 lbs./hr.
Will be 10x larger and faster than previous commercial systems

Large-scale MVP thermoset system


4 axes + coordination with pumping system
16' x 8' x 42" build volume
Deposition rate: 50"/s
Resolution of ≤6mm

$7M of AM equipment awaiting arrival
- Vader system
- HAAS-hybrid system
- Multi-head large scale welding system
- 2nd GKN large-scale laser system

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Carbon Fiber Test Facility (ORNL)

The Carbon Fiber Technology Facility (CFTF) serves as a national resource to assist industry in overcoming the barriers of carbon fiber cost, technology scaling, and product and market development.

Oxidized fibers are converted into carbon fiber

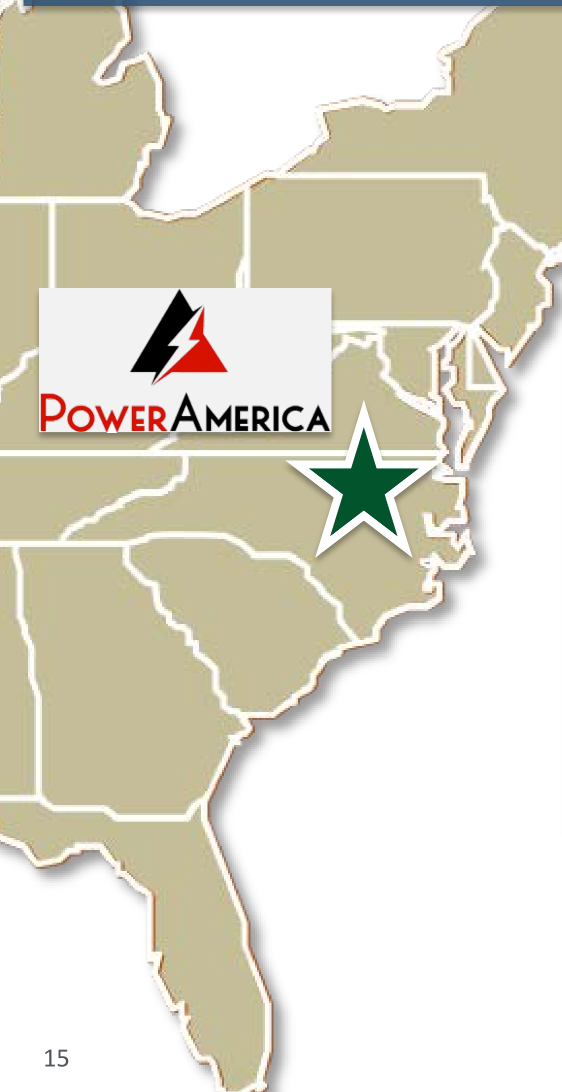
The Carbon Fiber Technology Facility (CFTF) serves as a national test-bed for government and commercial partners to scale-up emerging carbon fiber technology. As part of ORNL's DOE-funded Manufacturing Demonstration Facility, the CFTF serves as a hub for public–private partnerships in the emerging national network for innovations in manufacturing. One such partnership consisting of more than fifty companies, the Oak Ridge Carbon Fiber Composites Consortium has formed in Oak Ridge, Tennessee. The mission of the Consortium is to forge industry–government collaborations to accelerate the development and deployment of lower-cost carbon fiber materials and processes and create a new generation of strong, lightweight composite materials that will improve America's competitiveness.

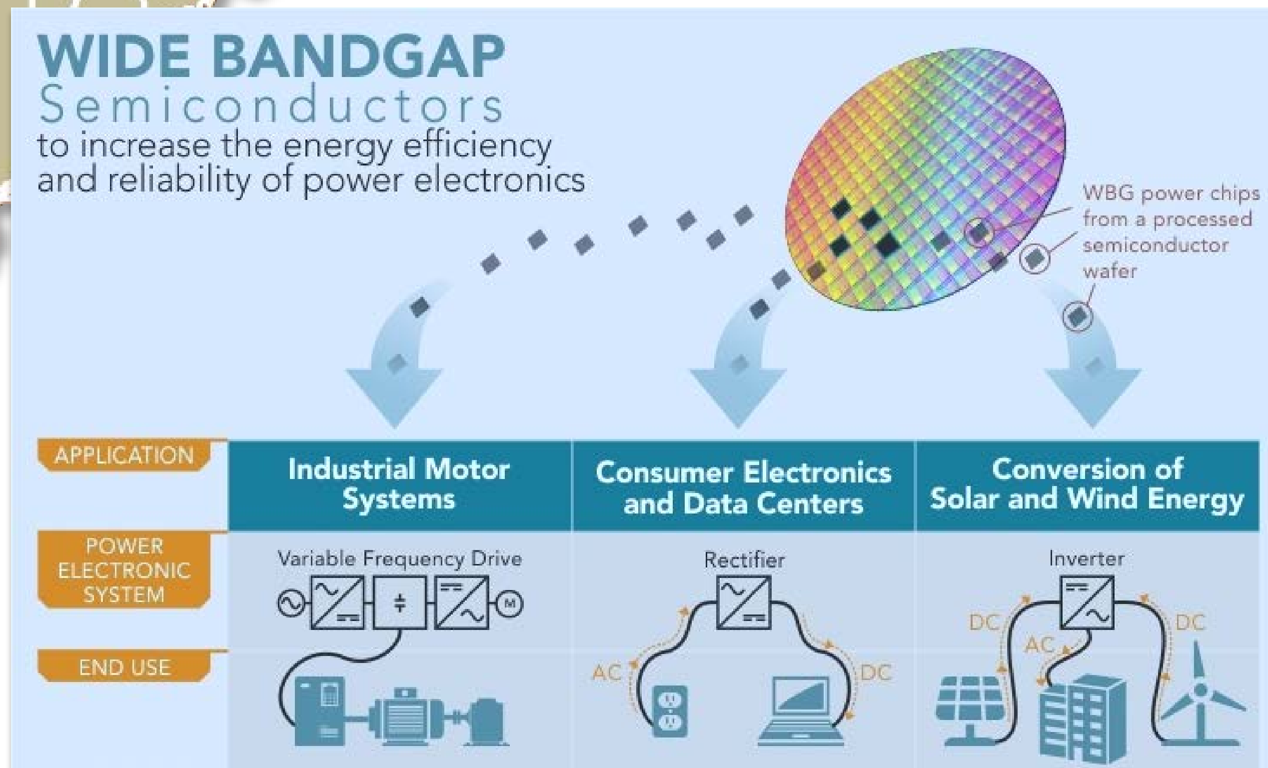
Role of the Carbon Fiber Technology Facility

- Demonstrate low-cost carbon fiber technology scalability with the last scaling step before full-scale commercial production
- Produce development quantities of low-cost carbon fiber needed for large-scale material and process evaluations and prototyping
- Deploy a training system, including educational internships and industrial training and recertification, for developing the future carbon fiber workforce

DOE Manufacturing USA Institute #1: PowerAmerica (Raleigh, NC)

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





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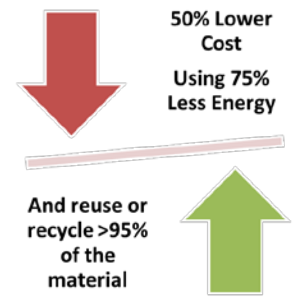
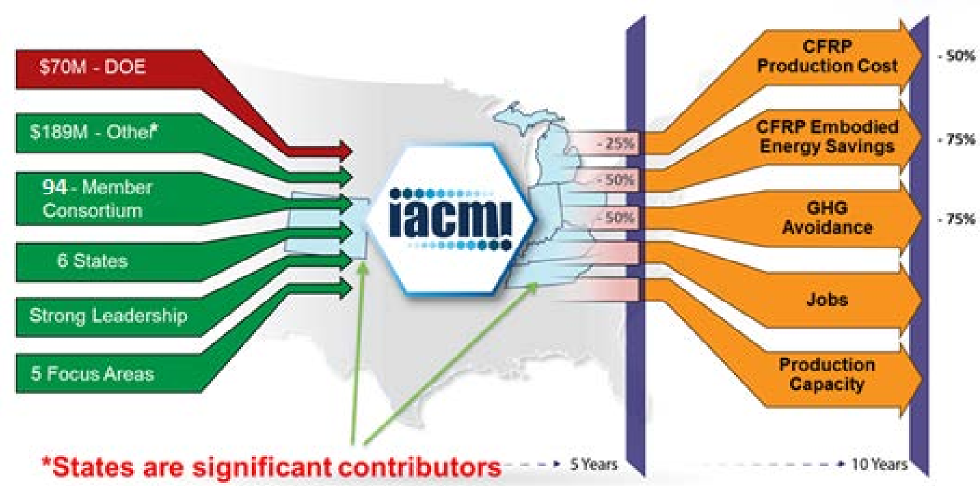
DOE Manufacturing USA Institute #2 – IACMI (Oak Ridge, TN)

Institute for Advanced Composite Material Manufacturing (IACMI): Develop and demonstrate technologies to produce carbon fiber composites at 50% the cost and 75% less energy.





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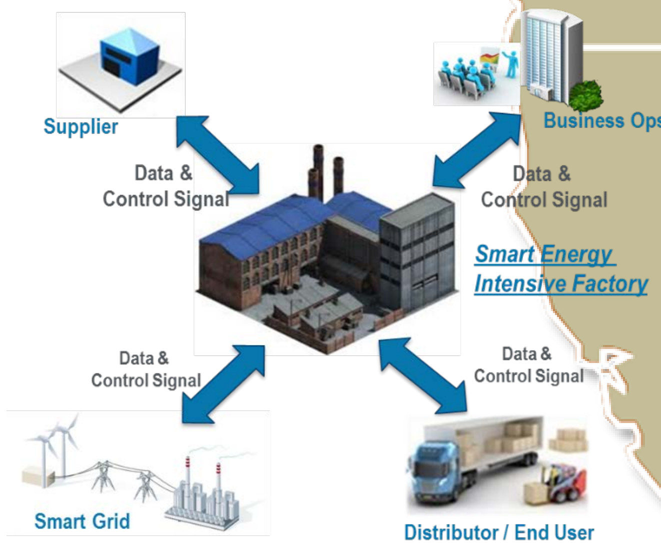
DOE Manufacturing USA Institute #3 – CESMII (Los Angeles, CA)

Clean Energy Smart Manufacturing Innovation Institute (CESMII):
Advanced sensors and controls for real-time process management

Institute Goals

- >50% improvement in energy productivity
- >50% reduction in installation cost of Smart Manufacturing hardware and software
- 15% Improvement in Energy Efficiency at systems level
- Increase productivity and competitiveness across all manufacturing sectors



CLEAN ENERGY SMART MANUFACTURING INNOVATION INSTITUTE

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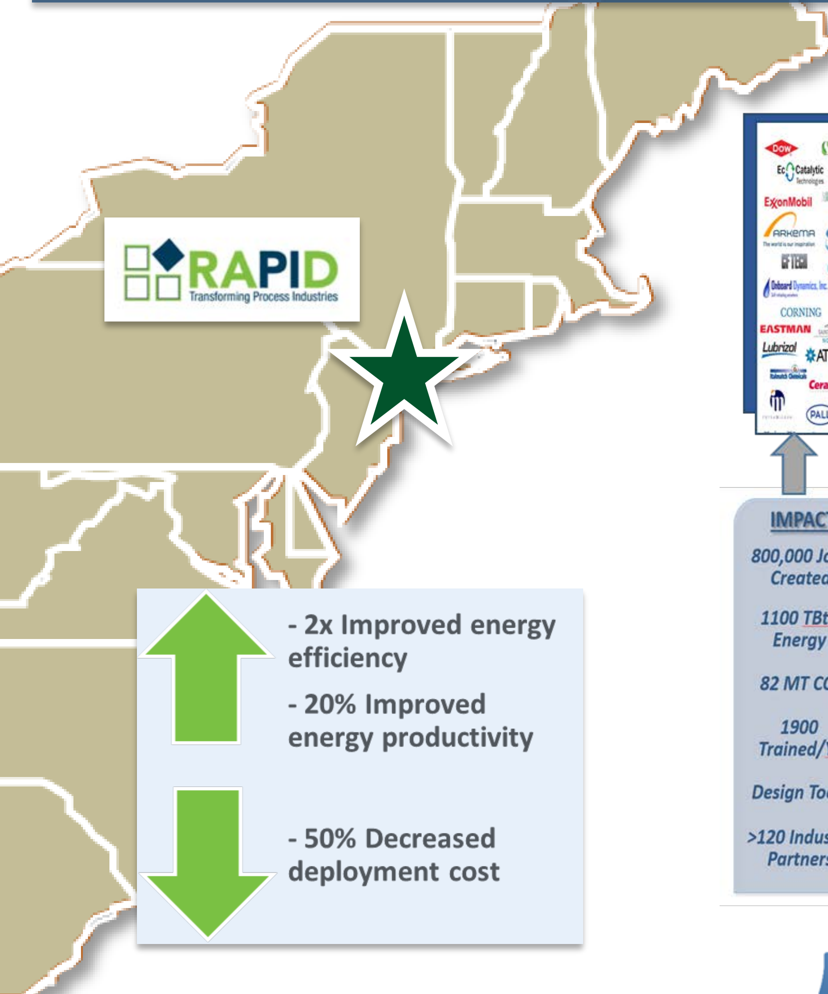
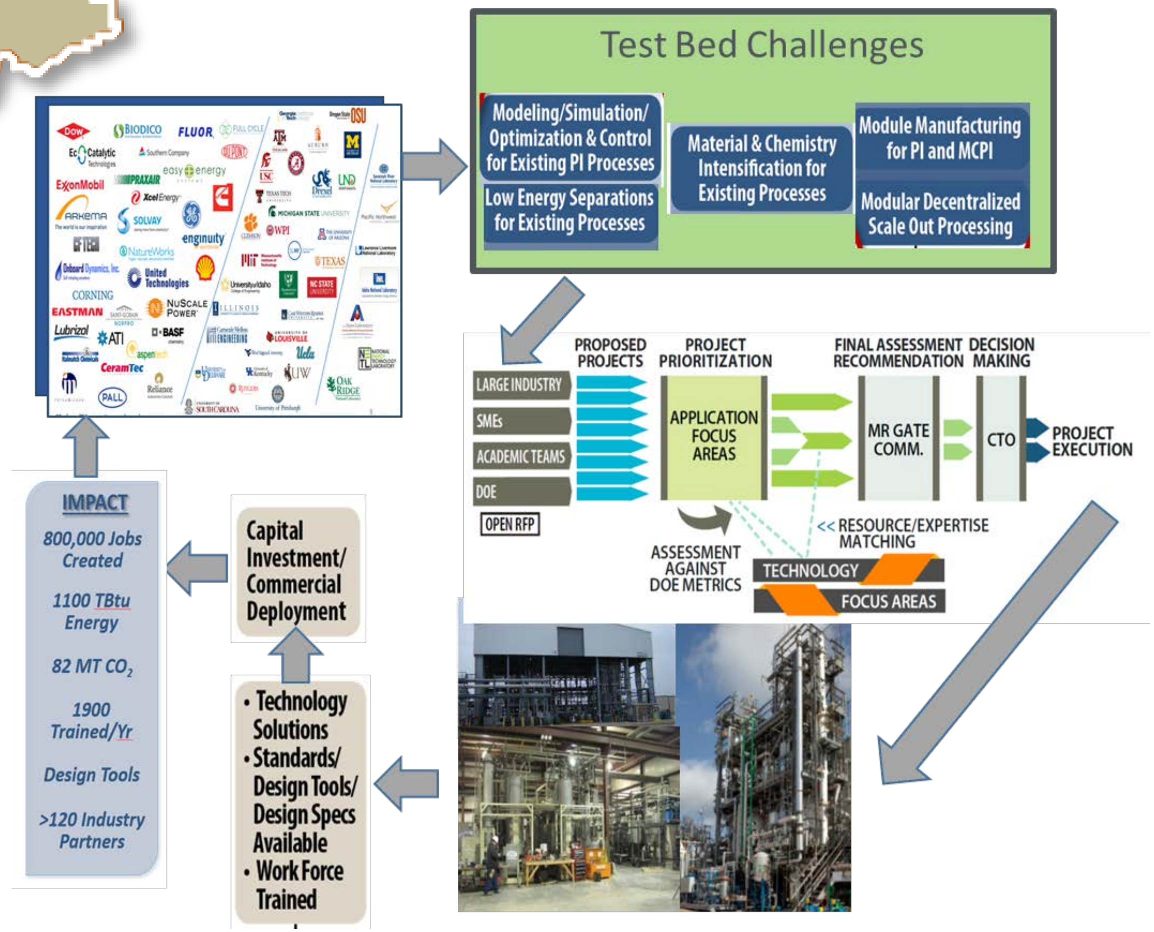
DOE Manufacturing USA Institute #4 – RAPID (New York, NY)

Rapid Advancement in Process Intensification Deployment (RAPID) Manufacturing Institute: Develop a set of technologies that bring significant reduction in equipment size, process complexity, cost or risk reduction that will result in…



- 2x Improved energy efficiency
- 20% Improved energy productivity
- 50% Decreased deployment cost



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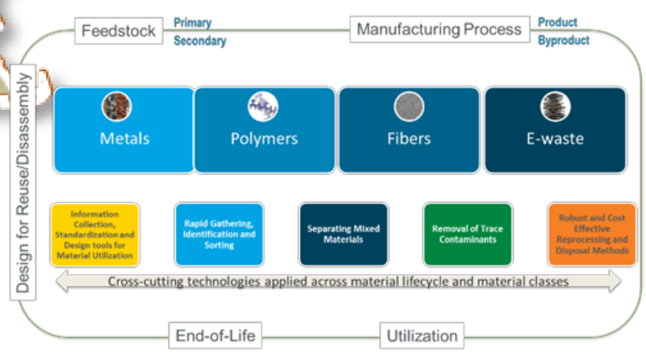
DOE Manufacturing USA Institute #5 – REMADE (Rochester, NY)

Clean Energy Manufacturing Innovation Institute for Reducing Embodied-energy and Decreasing Emissions (REMADE) in Materials Manufacturing: Reduce the embodied energy and carbon emissions associated with industrial-scale materials production and processing.



Key Technical Goals

- **Reduce energy and emissions** through reduction of primary material use
- **Achieve secondary (e.g. scrap, reused, recycled) feedstock** "better than cost and energy parity" for key materials, and
- **Widespread application of new platform technologies** across energy intensive industries and at key stages in the manufacturing process

Technology Focus Areas

SYSTEM ANALYSIS & INTEGRATION
Data collection, standardization, metrics, and tools for understanding material flow.

DESIGN FOR REUSE & DISASSEMBLY
Design tools for material utilization/reutilization, and design for reman or disassembly.

MANUFACTURING PROCESSES
Efficient use of materials, near net shaping, and use of secondary feedstock without loss of quality.

REMANUFACTURING / EOL REUSE
Efficient and cost effective technologies for cleaning, component restoration, condition assessment, and reverse logistics.

RECYCLING & RECOVERY
Rapid gathering, identification, sorting, separation, and contaminant removal reprocessing and disposal.

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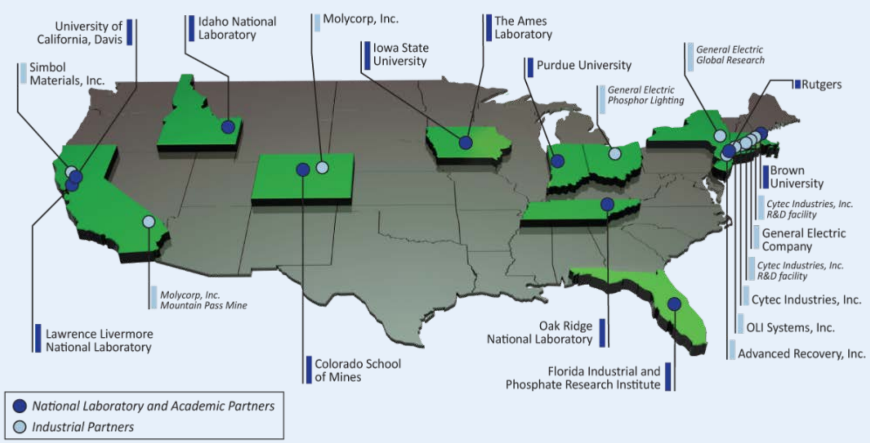
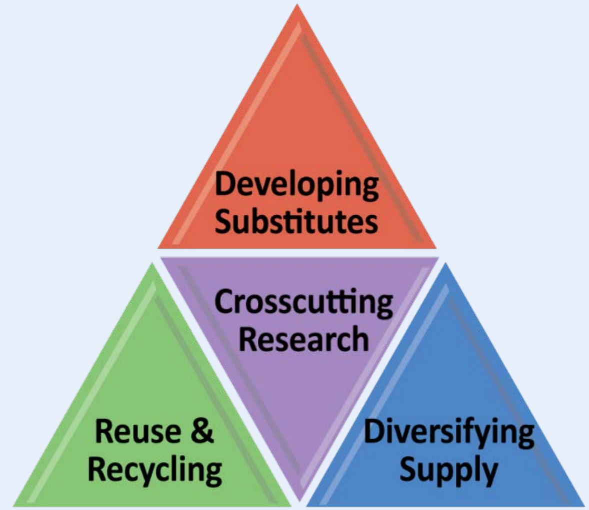
Energy Innovation Hub: Critical Materials Institute

CMI Accelerating Energy Innovations

Eliminate materials criticality as an impediment to the commercialization of clean energy technologies for today and tomorrow.





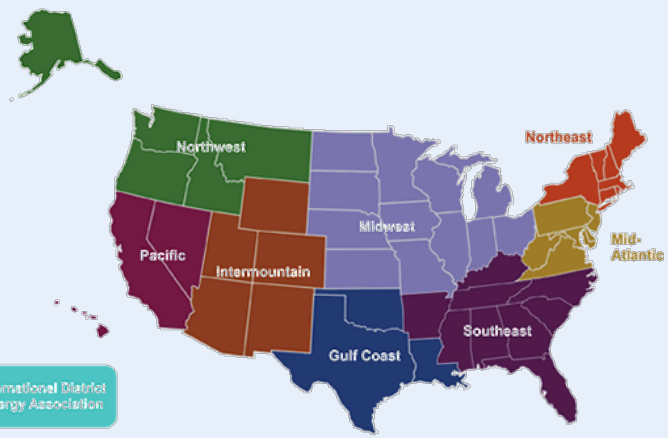
Selected Goals

- Materials supply chains assured for clean energy manufacturing in the US
- Commercialize at least one technology in each of its three technical focus areas
- Develop updated criticality assessments to ensure relevance of CMI research and identify potential critical materials for clean energy

Technical Partnerships Programs

Efficient On-Site Energy

Combined Heat and Power Technical Assistance Partnerships



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Energy-Saving Partnership

Better Buildings, Better Plants,

Industrial Strategic Energy Management

3M

Schneider Electric

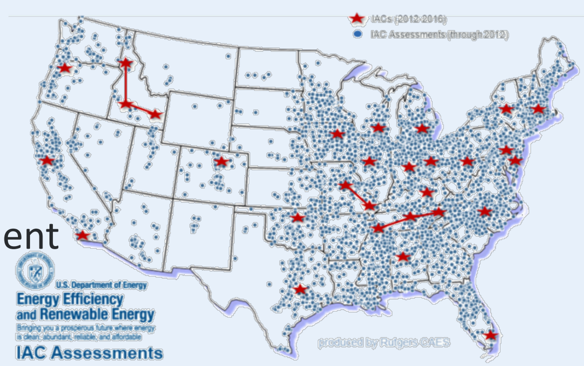
BRIGGS & STRATTON

Cummins

Johnson Controls

Student Training & Energy Assessments

University-based Industrial Assessment Centers



Better Plants
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