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

# AMO Overview

# HPC and Manufacturing

September 21, 2016

Washington DC


**Mark Johnson**

**Director**

**Advanced Manufacturing Office**

*www.manufacturing.energy.gov*

- **Overview of DOE Advanced Manufacturing Office**
- **Technology Assistance Programs**
- **Research and Development Consortia**
- **Research and Development Projects**

# Clean Energy and Manufacturing: Nexus of Opportunities


## Goals

- Develop a robust U.S. clean energy economy where products are developed here and manufactured here
- Make the entire U.S. manufacturing sector more competitive by making it more energy productive

# Advanced Manufacturing and Mission Innovation


Mission Innovation Clean Energy R&D Focus Areas

| | AUSTRALIA | BRAZIL | CANADA | CHILE | CHINA | DENMARK | EUROPEAN UNION | FRANCE | GERMANY | INDIA | INDONESIA | ITALY | JAPAN | KINGDOM OF SAUDI ARABIA | MEXICO | NORWAY | REPUBLIC OF KOREA | SWEDEN | UNITED ARAB EMIRATES | UNITED KINGDOM | UNITED STATES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INDUSTRY & BUILDINGS | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| VEHICLES & OTHER TRANSPORTATION | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | ● | | ● |
| BIO-BASED FUELS & ENERGY | ● | ● | ● | | ● | ● | ● | ● | ● | ● | ● | ● | | | ● | ● | ● | ● | ● | ● | ● |
| SOLAR, WIND & OTHER RENEWABLES | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| NUCLEAR ENERGY | ● | ● | ● | | ● | | | | | | | | | | | | ● | | ● | ● | ● |
| HYDROGEN & FUEL CELLS | ● | ● | ● | | | ● | ● | ● | ● | ● | | | ● | ● | | ● | ● | | | ● | ● |
| CLEANER FOSSIL ENERGY | | ● | ● | | ● | ● | | | ● | ● | ● | | | ● | | | ● | | | | ● |
| $CO_2$ CAPTURE, UTILIZATION & STORAGE | ● | ● | ● | | ● | ● | ● | ● | ● | | | | ● | ● | ● | ● | ● | | ● | ● | ● |
| ELECTRICTY GRID | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | ● |
| ENERGY STORAGE | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● |
| BASIC ENERGY RESEARCH | ● | | ● | | | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | | ● | ● | | ● |

Indicators are for key areas of R&D investment, but do not imply a comprehensive representation of a country's full R&D portfolio.

- **Doubling Clean Energy R&D**
- **Framework for Clean Energy Targets**
- **Includes Advanced Technologies for Manufacturing of Clean Energy Products and Efficiency in Manufacturing**

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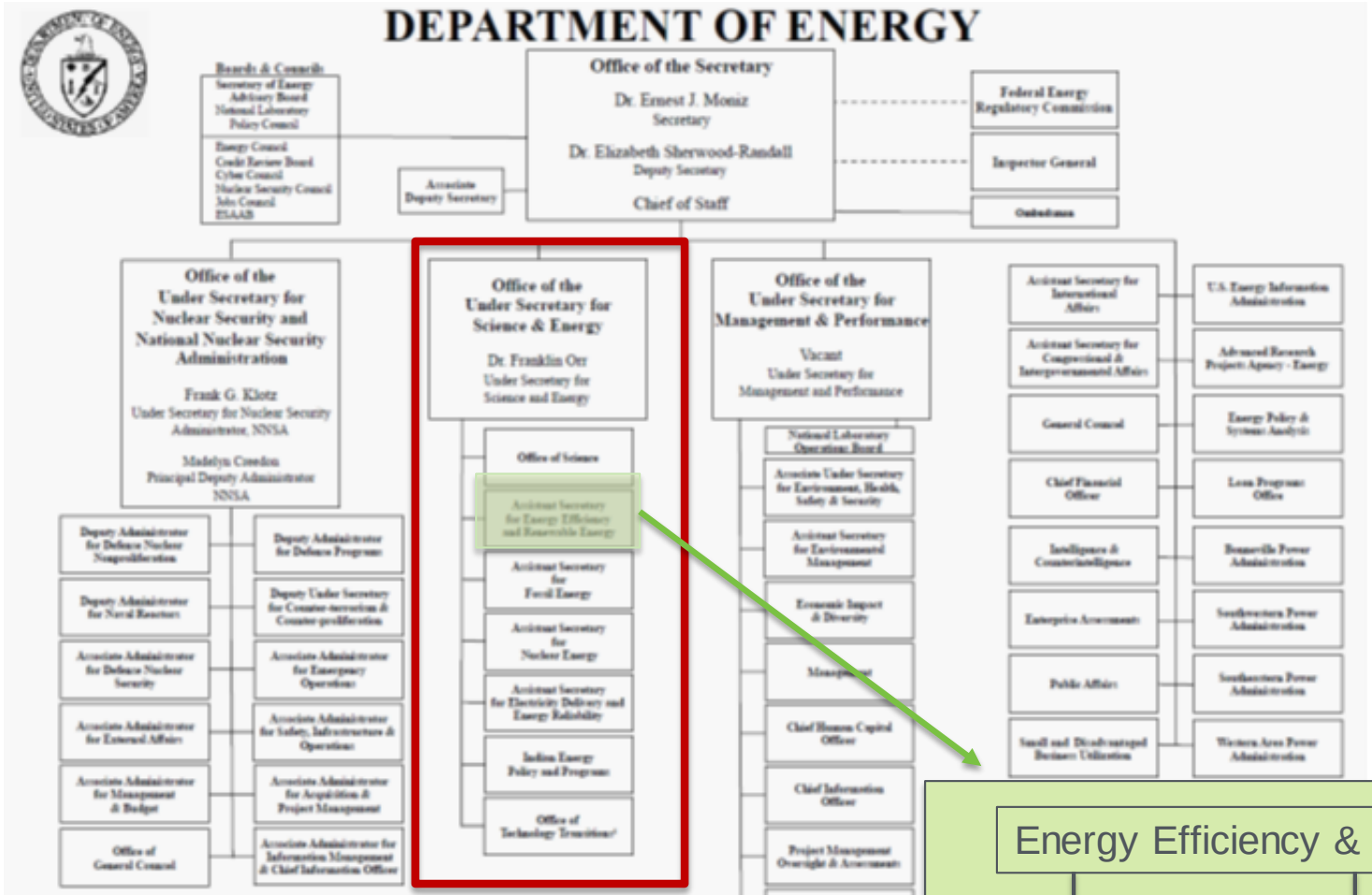
# Advanced Manufacturing in the Department of Energy



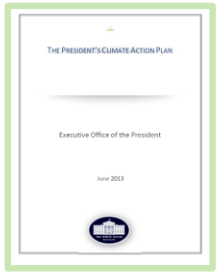

Basic and Applied Science Coordinated Materials & Manufacturing

Energy Efficiency & Renewable Energy

Sustainable Transportation | Energy Efficiency | Renewable Power

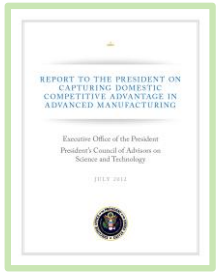
Advanced Manufacturing Office

# Advanced Manufacturing – Strategic Framing




## Climate Action Plan

(EOP / CEQ / OSTP 2014)



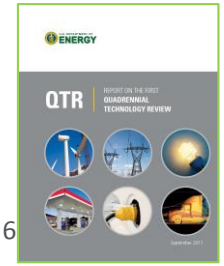

## Advanced Manufacturing Partnership (AMP2.0)

(NEC / PCAST / OSTP 2014)



## Strategic Plans

(DOE 2014 & EERE 2016)




## Quadrennial Technology Review

(DOE / Science and Technology 2015)

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

**2) Platform Materials, Process and Information Technologies for Clean Energy Manufacturing with Sustainable Life-Cycle Impact**

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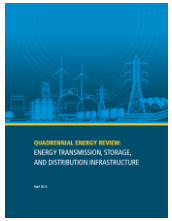
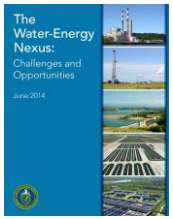
# Some Additional Manufacturing Related Issues



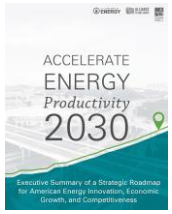

**Quadrennial Energy Review (QER): 2015**

- Manufacturing for Infrastructure and the Grid




**Water-Energy Nexus: 2014**

- Water for Energy & Energy for Water

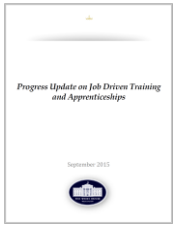



**Energy Productivity 2030: 2015**

- Double GDP/kJ Economy from Energy

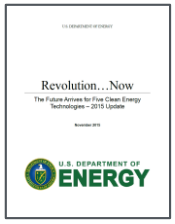

**Innovation Strategy: 2015**

- Technology, Workforce & Capabilities




**Job Training and Apprenticeship: 2015**

- Advanced Manufacturing Skills and Opportunities




**Revolution Now: 2015**

- Cost Effective New Technologies

**3) Promotion of Innovation Partnerships**

**4) Tools and Training**

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# Energy Intensive Industries

**Primary Metals**
**1608 TBTU**

**Petroleum Refining**
**6137 TBTU**

**Chemicals**
**4995 TBTU**

**Wood Pulp & Paper**
**2109 TBTU**

**Glass & Cement**
**716 TBTU**

**Food Processing**
**1162 TBTU**

# Processes for Clean Energy Materials & Technologies

## Energy Dependence: Energy Cost Considered in Competitive Manufacturing

Solar PV Cell

Carbon Fibers

Light Emitting Diodes

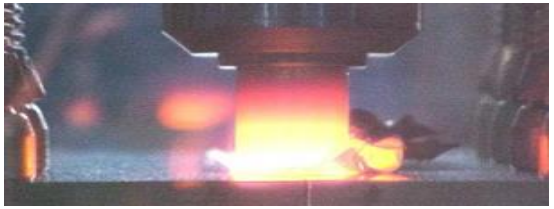
Electro-Chromic Coatings

Membranes

EV Batteries

Multi-Material Joining

Water Desalination



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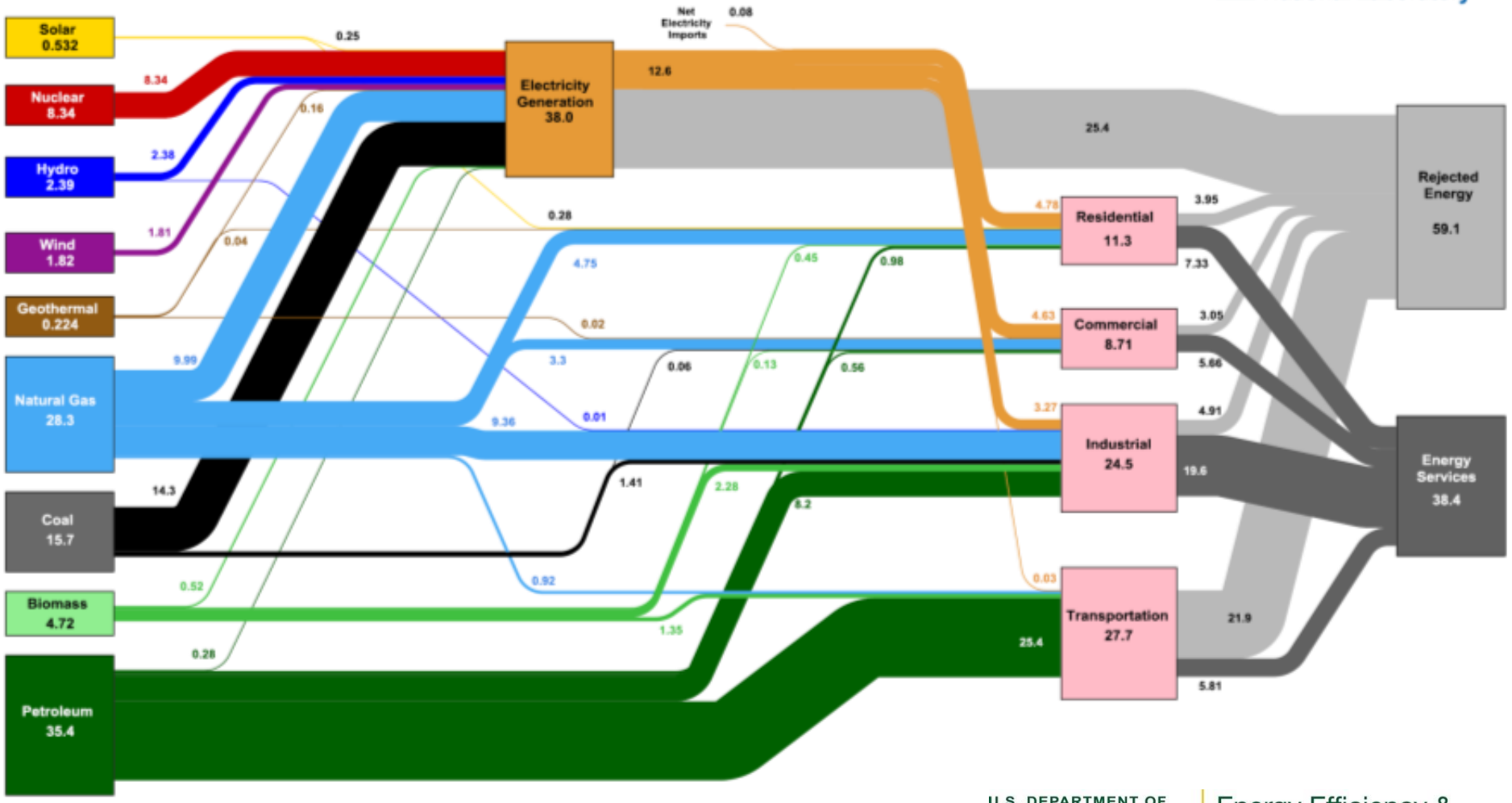
# Estimated U.S. Energy Consumption in 2015: 97.5 Quads




Lawrence Livermore National Laboratory

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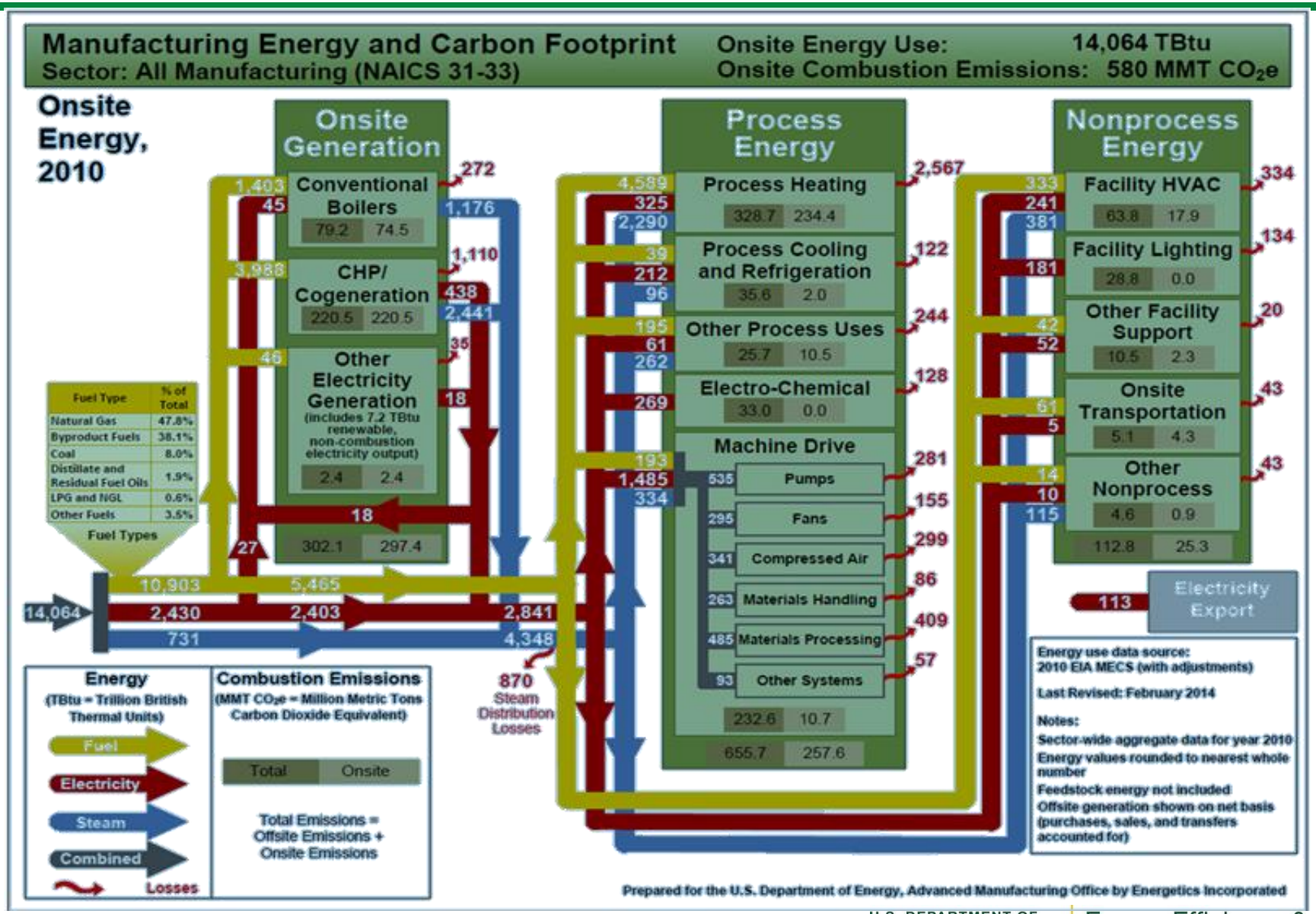
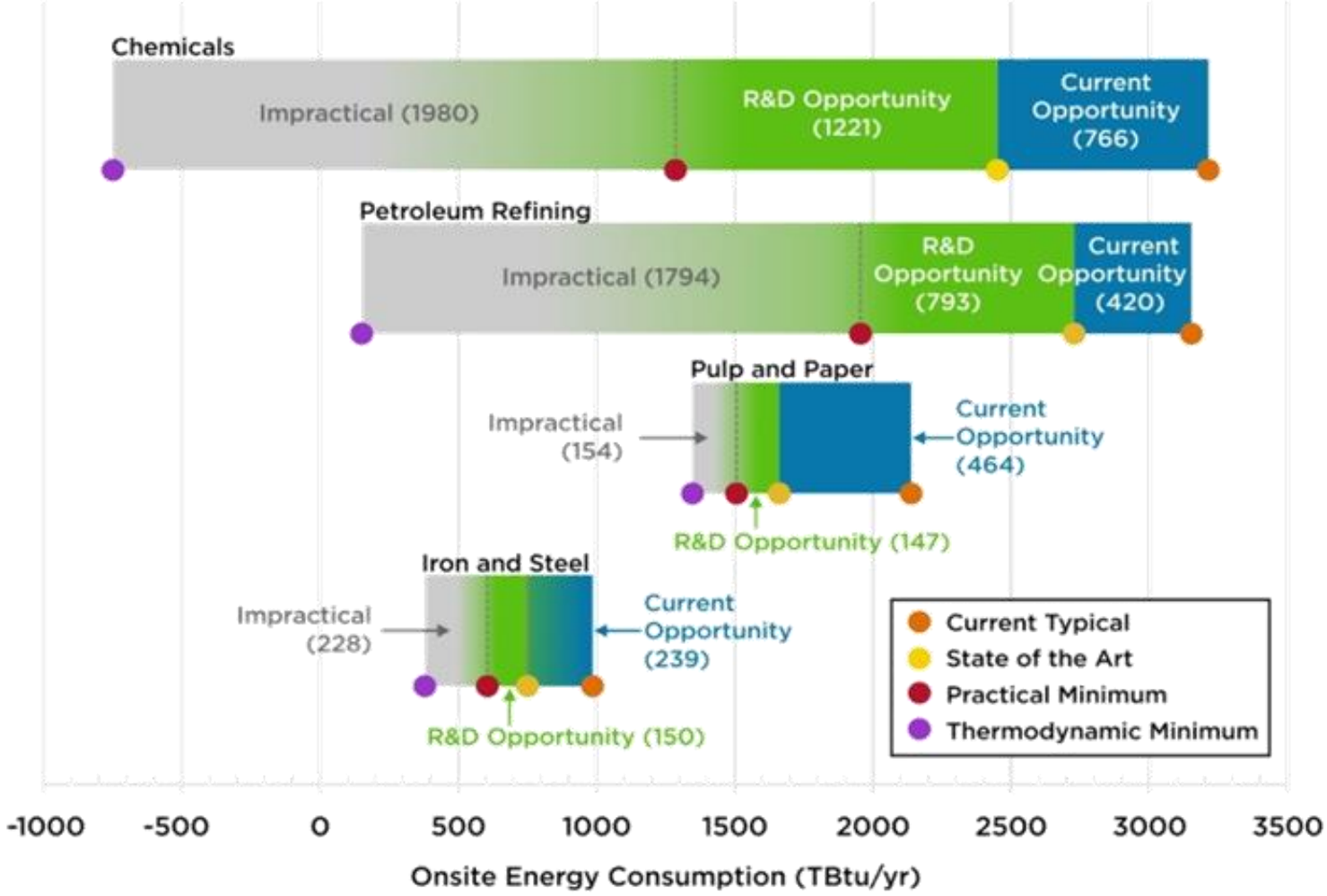
# Deeper Look at Energy in Manufacturing



# Manufacturing Bandwidth Studies: Energy Savings Potential




*Current opportunities represent energy savings that could be achieved by deploying the most energy-efficient commercial technologies available worldwide. R&D opportunities represent potential savings that could be attained through successful deployment of applied R&D technologies under development worldwide*



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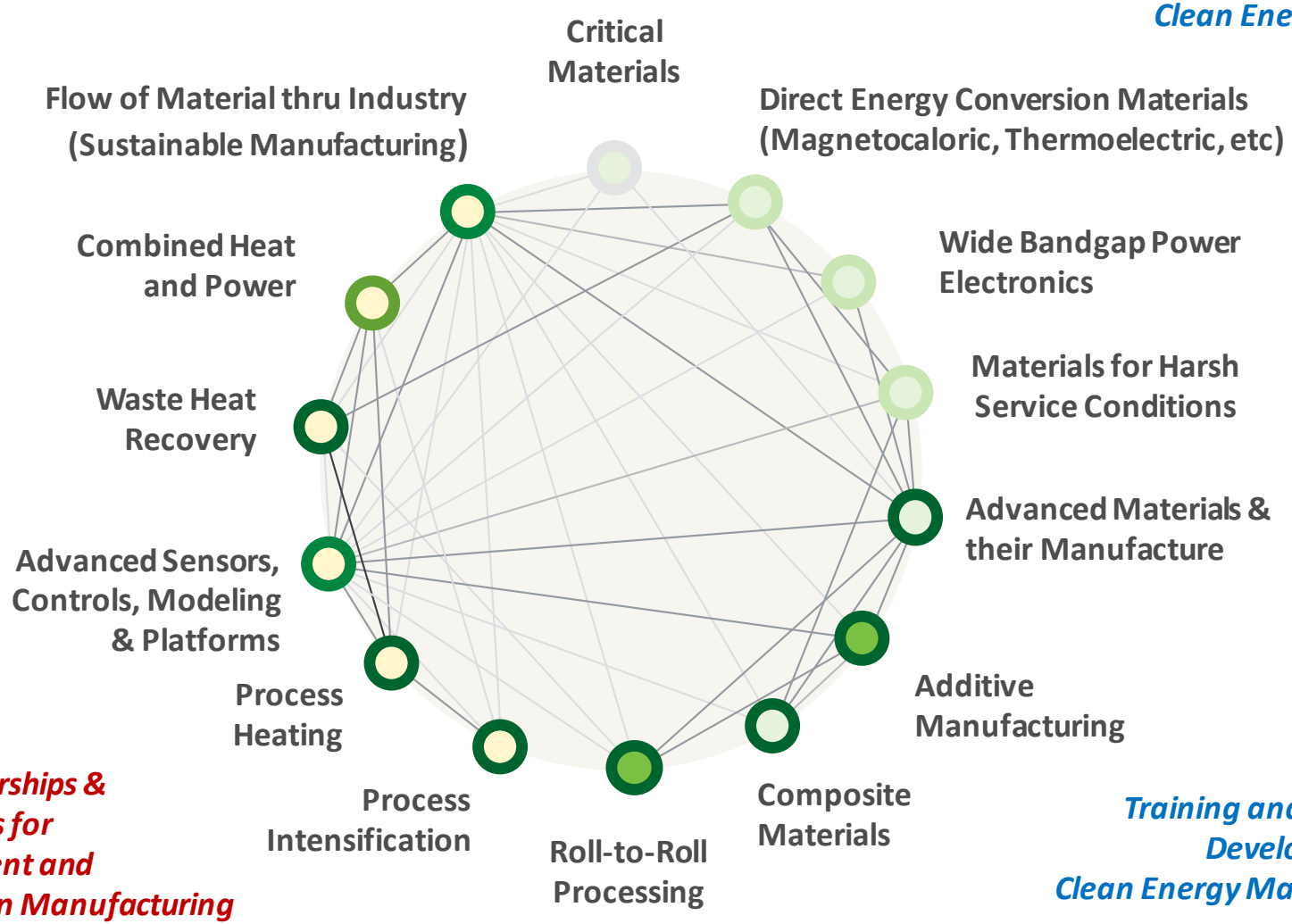
# Quadrennial Technology Review: Manufacturing

***Technologies for Energy Efficiency & Productivity in Manufacturing***

***Enabling Platform Technologies for Clean Energy Products***




***Tools, Partnerships & Best Practices for Energy Efficient and Productivity in Manufacturing***

***Training and Workforce Development for Clean Energy Manufacturing***

# Advanced Manufacturing Topical Areas

## Efficiency Technologies for Manufacturing Processes (Energy, $CO_2$)

(1) Advanced Sensors, Controls, Modeling and Platforms (HPC, Smart Manufacturing)

(2) Advanced Process Intensification

(3) Grid Integration of Manufacturing (CHP, DG and DR)

(4) Sustainable Manufacturing (Water-Energy, New Fuels & Reused 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)

**Next Step:**
Revise AMO Multi-Year Program Plan (MYPP) With Office Specific Approach in Each Technical Area

QTR Manufacturing (Ch.6) Focus Areas are mapped to Advanced Manufacturing technology topical areas

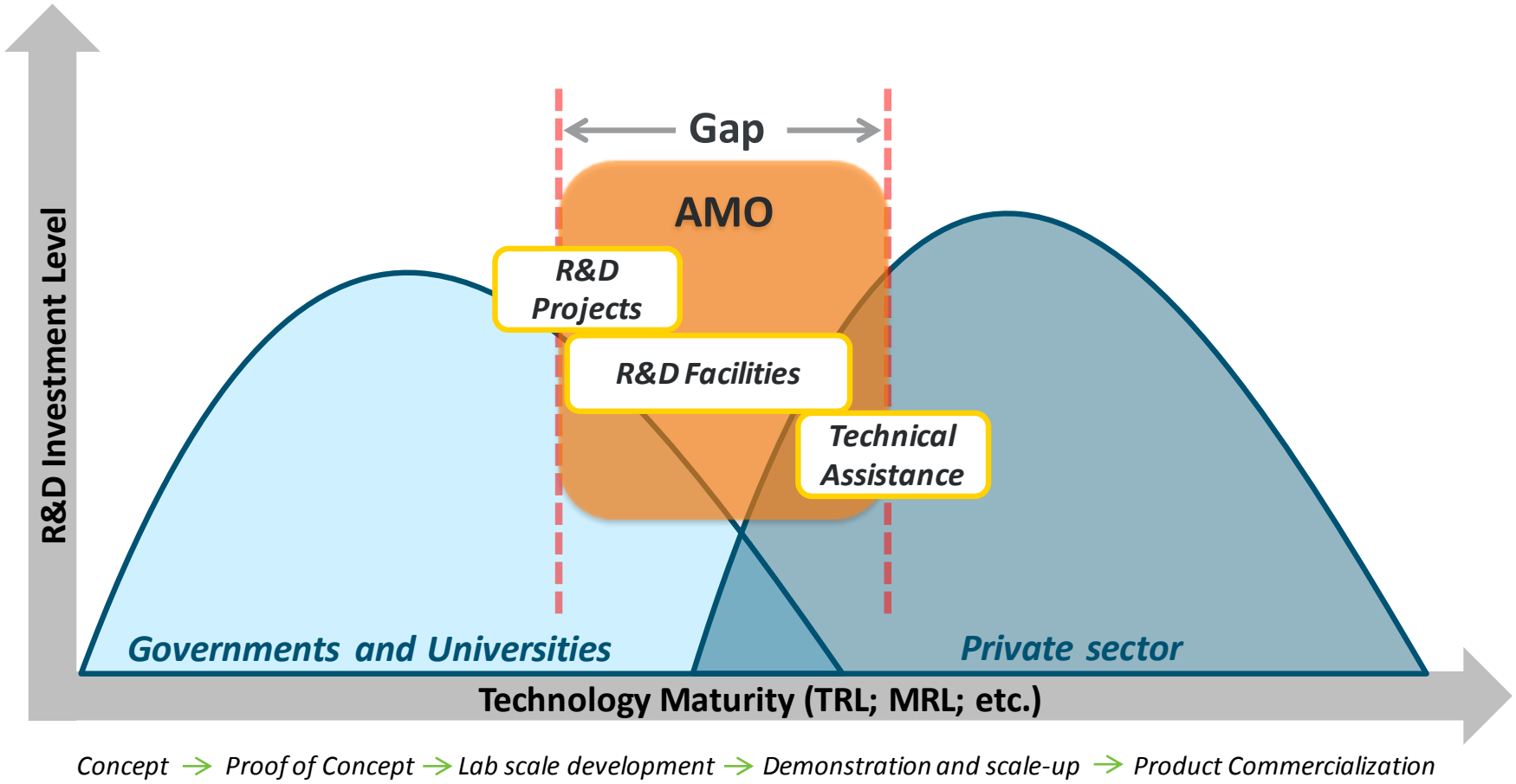
# Possible Impact Areas of Cross-Cutting Technology for Energy Intensive Industry Sectors

| | | Chemicals & Bio-chemicals | Petroleum Refining | Primary Metals | Forest & Food Products | Clean Water |
|---|---|---|---|---|---|---|
| SMART Manufacturing | | ● | ● | ● | ● | ● |
| Process Intensification | | ● | ● | ● | ● | ● |
| CHP & Grid Integration | | ● | ● | ● | ● | ● |
| Sustainable Manufacturing | | ● | | ● | ● | ● |

**Many Sector Specific Roadmaps Being Revised through Complementary Program Supported by NIST / AmTech**

# Bridging the Gap from Discovery to Manufacturing

## AMO: Advanced Manufacturing Office



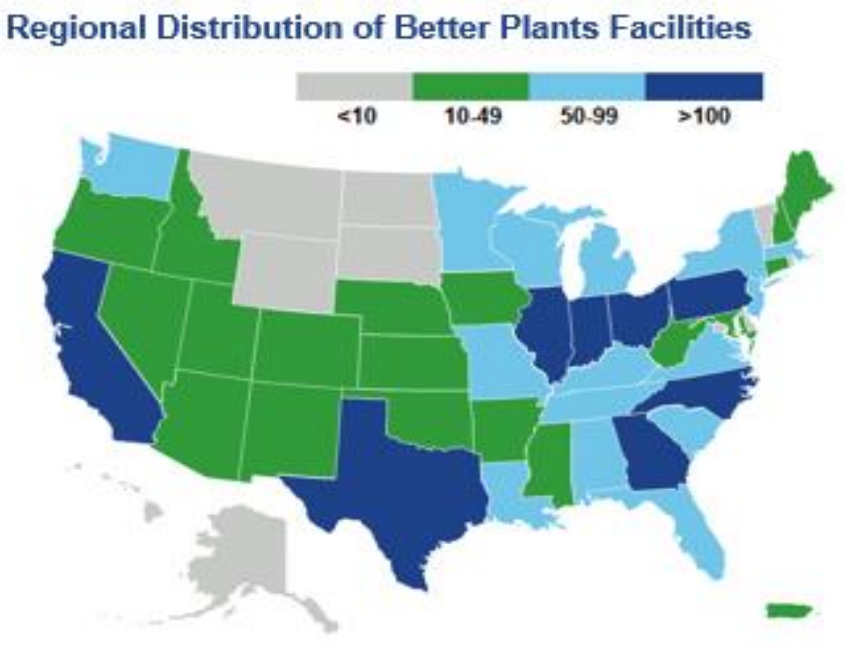
- Overview of DOE Advanced Manufacturing Office
- **Technology Assistance Programs**
- Research and Development Consortia
- Research and Development Projects

# Technical Assistance: Better Plants

- Key component of President's Better Buildings Initiative to improve energy efficiency of commercial and industrial buildings by 20% by 2020.
- Voluntary pledge by leading manufacturers and industrial-scale energy users to reduce energy intensity
- DOE provides technical assistance to meet goals

## Better Plants Snapshot

| Partnership Size | Total |
|---|---|
| Number of Partner Companies | 157 |
| Approximate Number of Facilities | 2,400 |
| Percent of U.S. Manufacturing Energy Footprint | 11.4% |
| **Reported Savings through 2014** | |
| Cumulative Energy Savings (TBtu) | 457 |
| Cumulative Cost Savings (Billions) | $2.4 |
| Cumulative Avoided $CO_2$ Emissions (Million Metric Tons) | 26.6 |
| Average Annual Energy-Intensity Improvement Rate | 2.1% |




- To date, Better Plants Partners have saved $2.4 billion in cumulative energy costs (more than 0.45 Quads of energy)

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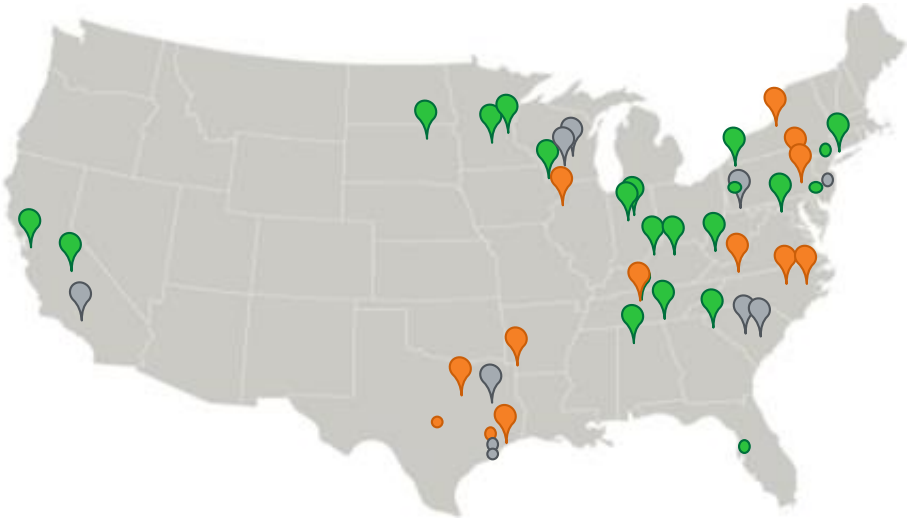
# Superior Energy Performance™

Superior Energy Performance
U.S. DEPARTMENT OF ENERGY

- SEP is a certification program that helps facilities meet the ISO 50001 energy management standard and verify the savings they achieve
- 28 plants have been certified so far. Nine improved energy performance by an average of 10% and saved over $500,000 per year



**ISO 50001 is a foundational tool that any organization can use to manage energy**

**ISO 50001**

Components in place:
- Top Management
- Energy Team
- Policy
- Planning
- Baseline
- Performance Metrics

**Superior Energy Performance**

**ISO 50001**

Single facility ISO 50001 conformance with verified energy performance improvement

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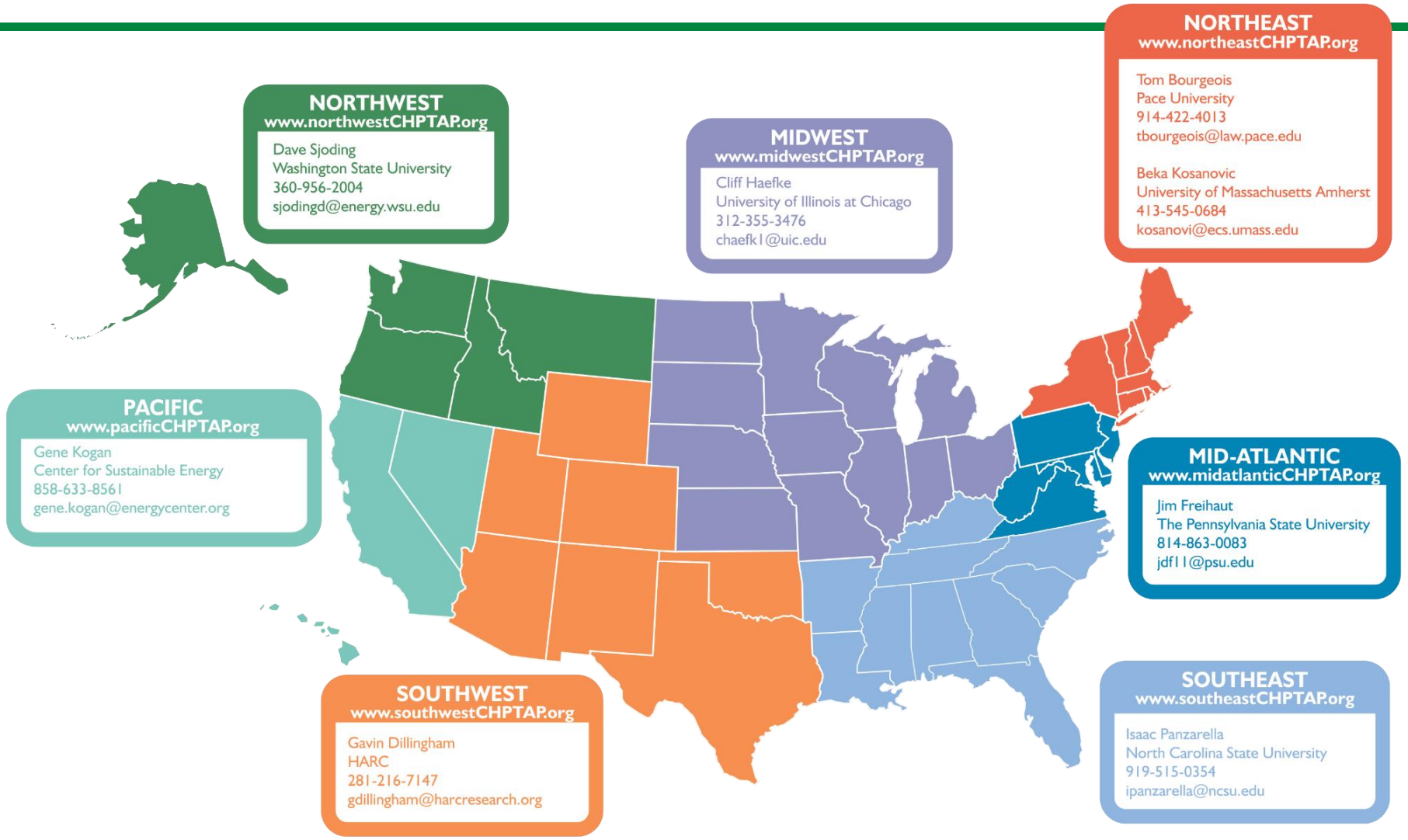
# Technical Assistance: Combined Heat and Power




**DOE CHP Technical Assistance Partnerships (CHP TAPs): Program Contacts**

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# Technical Assistance: Industrial Assessment Centers

## Energy Assessments & Student Training

University-based Industrial Assessment Centers

Support for small/medium sized manufacturing

Energy.gov/IAC

- Overview of DOE Advanced Manufacturing Office
- Technology Assistance Programs
- **Research and Development Consortia**
- Research and Development Projects

# Shared R&D Facilities & Consortia

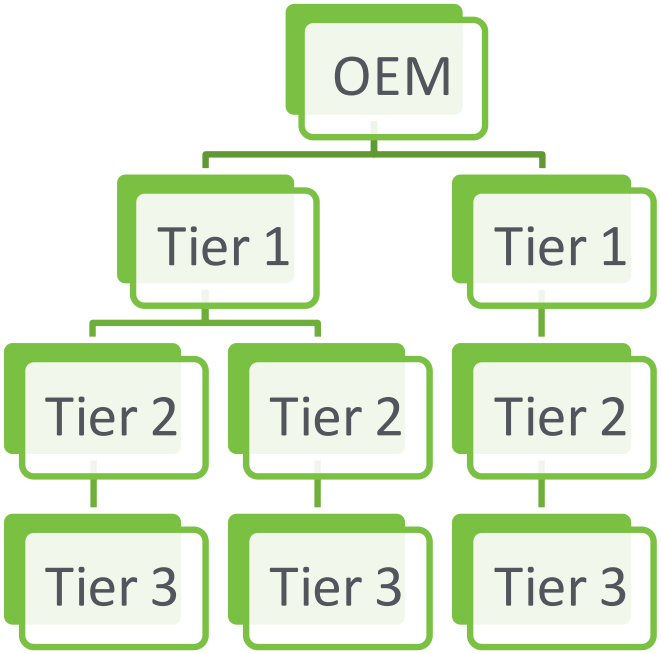
Address market disaggregation to rebuild the industrial commons

## 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**

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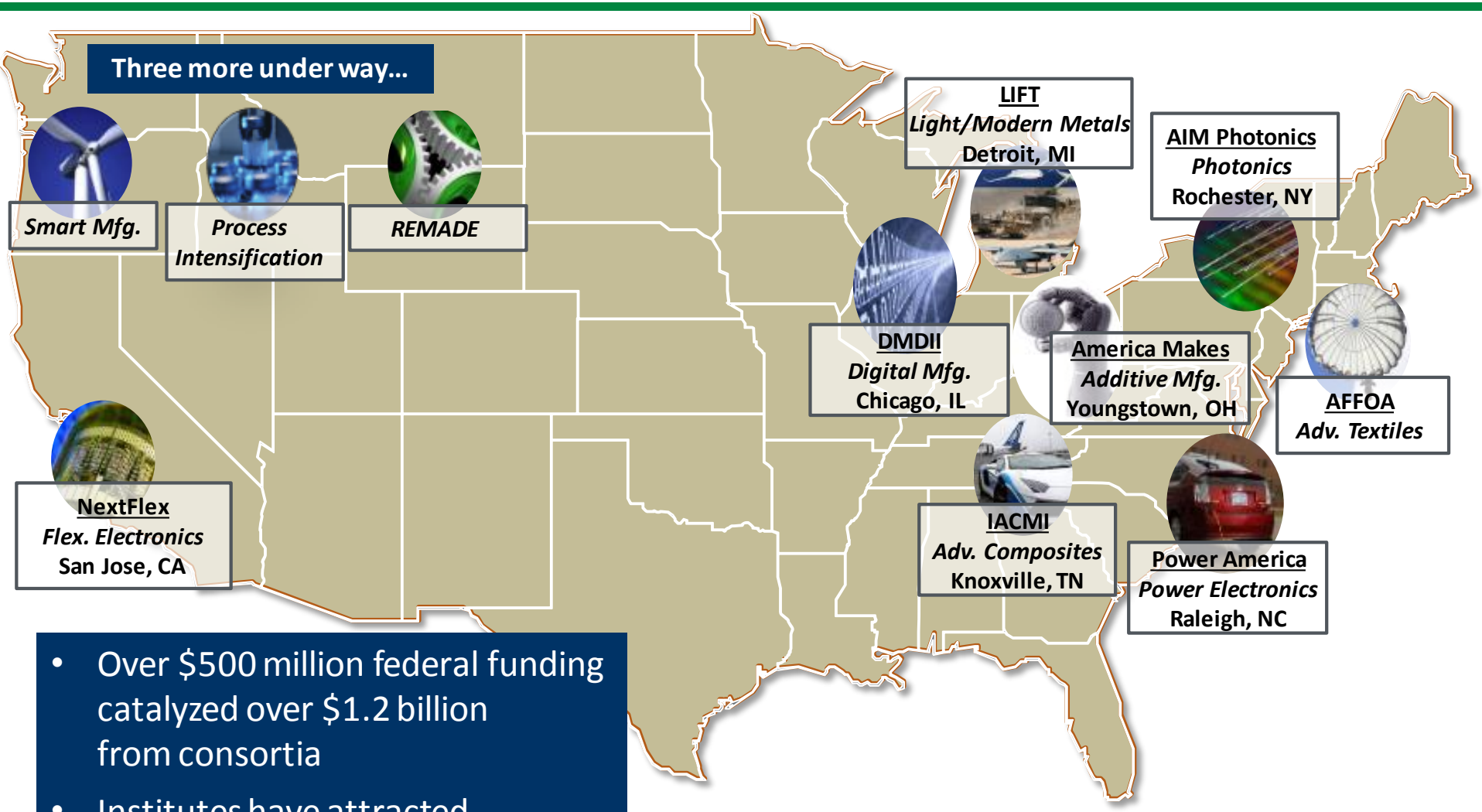
# 11 Manufacturing Innovation Institutes launched to date




- Over $500 million federal funding catalyzed over $1.2 billion from consortia
- Institutes have attracted hundreds of companies and universities as active partners from across the country



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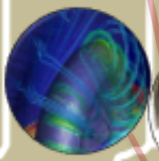
# DOE NNMI Institute #2 – Carbon Fiber Composites (Oak Ridge, TN)

- Established regional centers of excellence across a number of fiber composite applications

**Colorado**
Wind Turbines
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

**Michigan**
Vehicles
MICHIGAN STATE UNIVERSITY

**Indiana**
Innovative Design, Predictive Modeling & Simulation
PURDUE UNIVERSITY



**Ohio**
Compressed Gas Storage
UDRI
UNIVERSITY of DAYTON RESEARCH INSTITUTE

**Tennessee**
Composite Materials & Process Technology
OAK RIDGE National Laboratory
THE UNIVERSITY of TENNESSEE
UNIVERSITY OF KENTUCKY

**50% Lower Cost**

**Using 75% Less Energy**

**And reuse or recycle >95% of the material**

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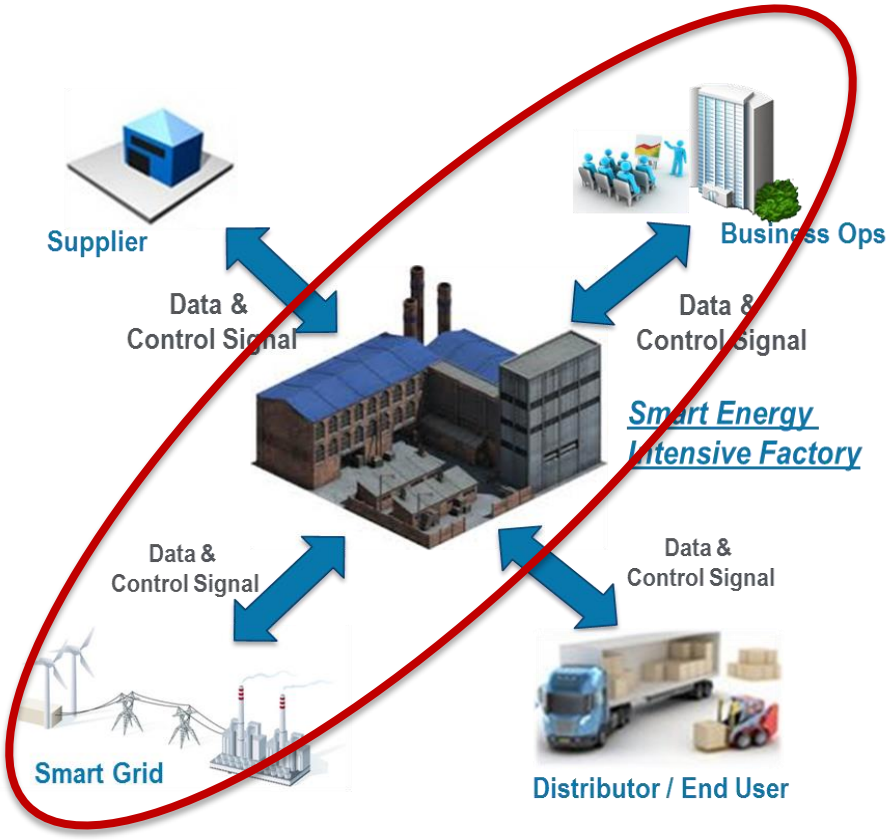
# DOE NNMI Institute #3 – Smart Manufacturing (UCLA/SMLC Lead)

- Advanced sensors and controls for real-time process management




**Focus on Real-Time For Energy Management**

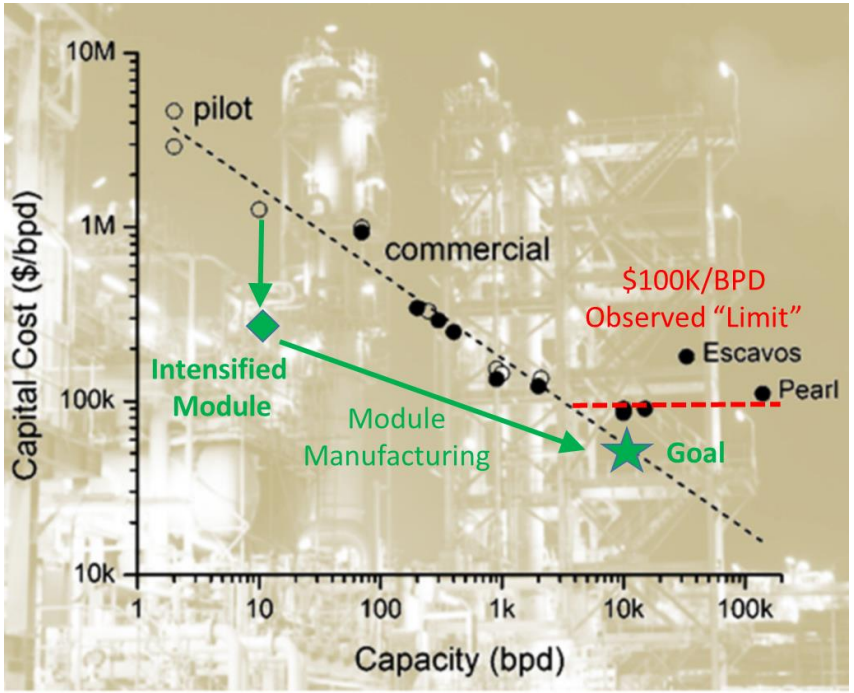
## Institute Goals

- >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

# Modular Chemical Process Intensification

Process Intensification has significant potential to improves costs, increase scalability, improve safety and enhance technology for variety of energy intensive, energy related and clean energy manufacturing applications

- Applied research and development into the Equipment, Methods and Technologies: Catalysis, Reactions, Separation, Mixing, Hybrid or Integrated Processes, Heating/Cooling, Thermal Recovery, etc.
- Test-bed demonstration of PI in first-of kind applications
- Develop technologies for manufacturing of process intensified modules.
- Dissemination of knowledge, pre-competitive testing of standards and practices, and education of workforce
- Potential Impact on several key sectors:
  Chemicals, Refining, Fiber (Pulp/Paper), Fuel Cells, Natural Gas, Environmental Management, Bio-Mass Processing, etc.




Example Possible Application: Gas to Liquids

**Proposals in Review**

# Two upcoming AMO / DOE-led NNMI Institutes

## Up to $70 million in Federal cost share for each:

**Modular Chemical Process Intensification:** Focus on breakthrough technologies to dramatically improve energy efficiency of novel chemical manufacturing processes.

→ Funding Opportunity and Teaming Lists can be found at https://eere-exchange.energy.gov/

**REMADE:** Dramatically reduce life-cycle energy consumption through the development of technologies for reuse, recycling, and remanufacturing of materials.

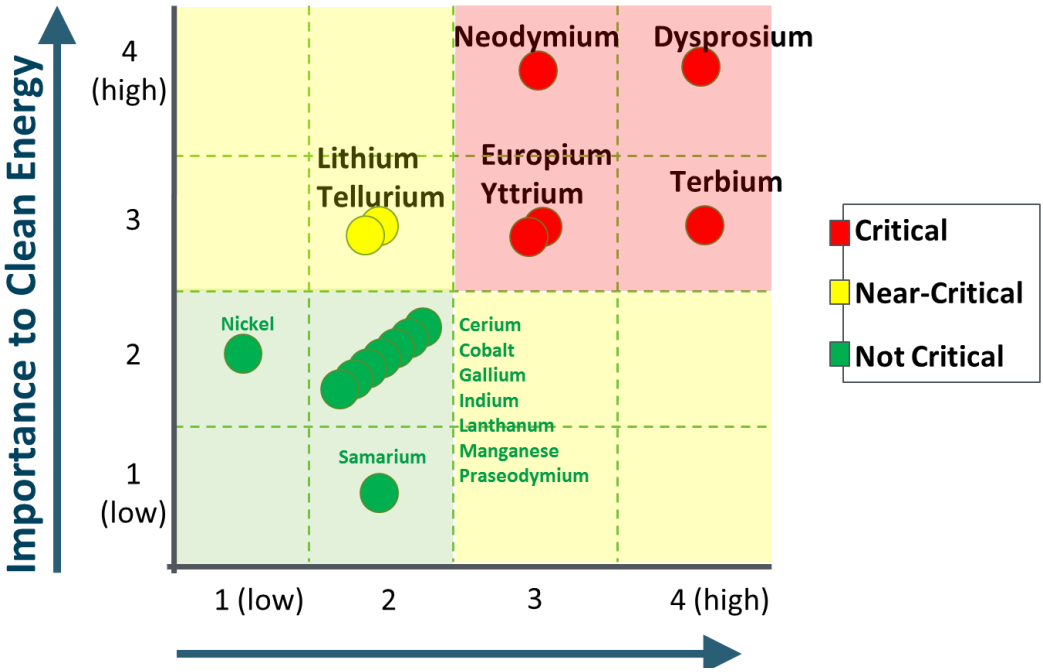
→ Funding Opportunity released in June

CMI Accelerating Energy Innovations

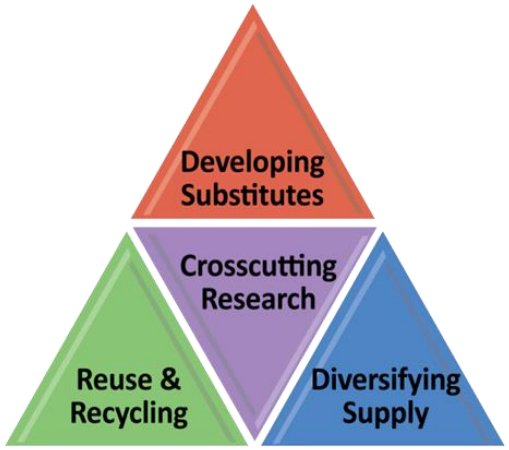
# Critical Materials Institute

*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.

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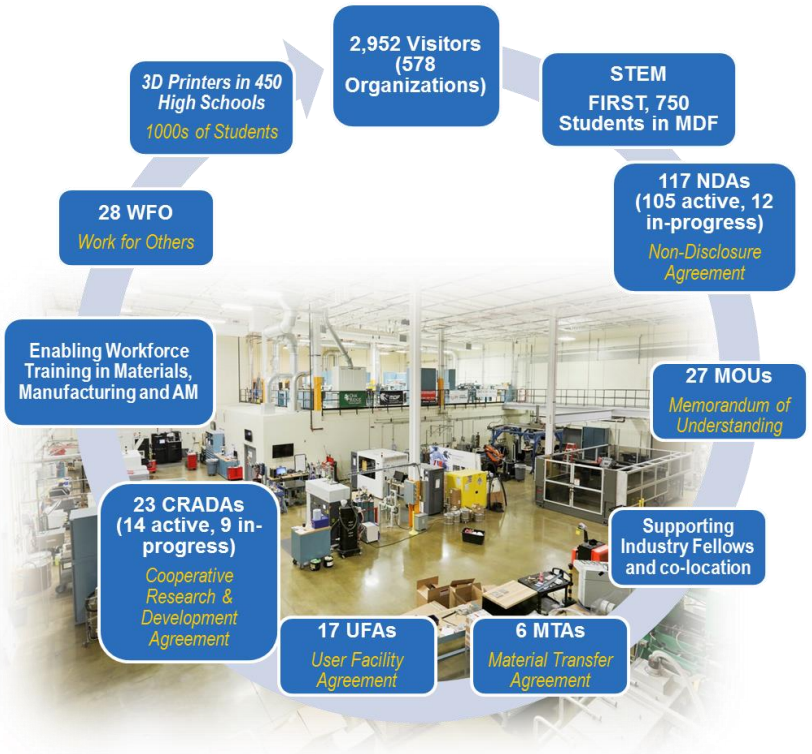
# Manufacturing Demonstration Facilities

- Shared Innovation Space
- Supercomputing Capabilities
- Scientific Infrastructure


America Makes





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# Additive Manufacturing – Transformational Technology
## Big-Area Additive Manufacturing (BAAM)

**Printed Cobra Project:**
**Design to Prototype**
**Six (6) people in six (6) weeks. January 2015**

- Designed & Printed Car (with Shelby)
- Printer Optimization Design Software (with Dassault)
- Developed Surface Process (with Tru-Design)
- Developed blended polymer / fiber (with Techmer)
- Developed Unique 3D Printing Tool (with Cincinnati)

# Rapid Innovation Applied to Building Technologies

## June 2014

First printed go-cart structure

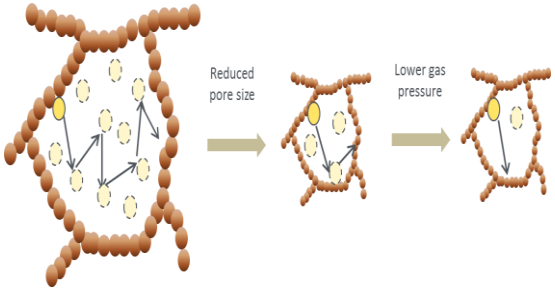
## September 2014

First printed car, created in collaboration with industry

## January 2015

3D-printed Shelby Cobra

## Apply the Science




New MAI technology uses an alternative manufacturing process that could **halve the cost** of traditional vacuum insulation panel (VIP) and simplify their application into building envelopes.

## Develop the Technology

Twice the energy savings of IECC 2012 at half the thickness

## Demonstrate Energy Savings

ORNL Demonstrated MAI in Integrated Building, in partnership with Clayton Homes & SOM Partners

**Partnership across Offices**

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# Partnerships with Vehicles and Buildings R&D

3D Printing of Large Area Structures

Partnership with Designers, Manufacturers, Universities, Laboratories and Suppliers

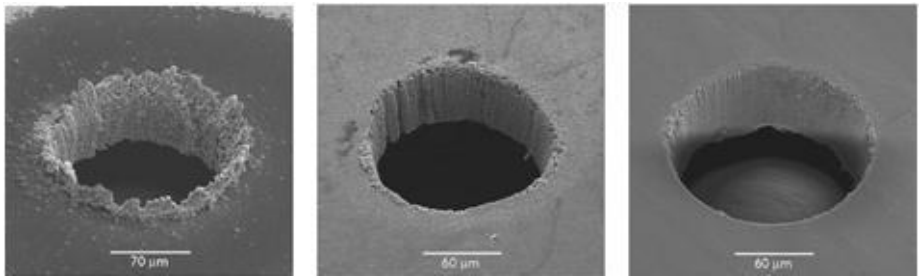
# MDF: 3D Printing Wind Blade Molds


## Bringing Manufacturing Innovation to the Renewable Energy Space

- Enable innovative blade designs
- Achieve lower overall costs and higher efficiencies
- Collaboration with Oak Ridge, Sandia, and TPI Composites

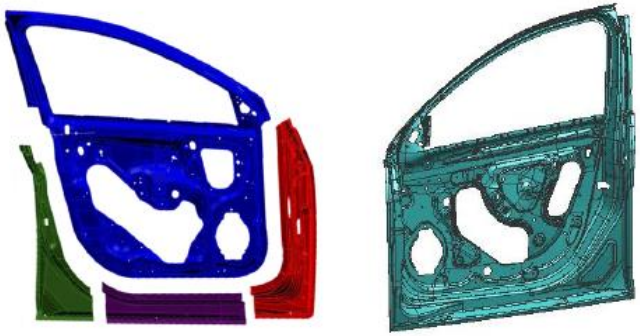
- Overview of DOE Advanced Manufacturing Office
- Technology Assistance Programs
- Research and Development Consortia
- **Research and Development Projects**

# R&D Projects: Manufacturing Processes



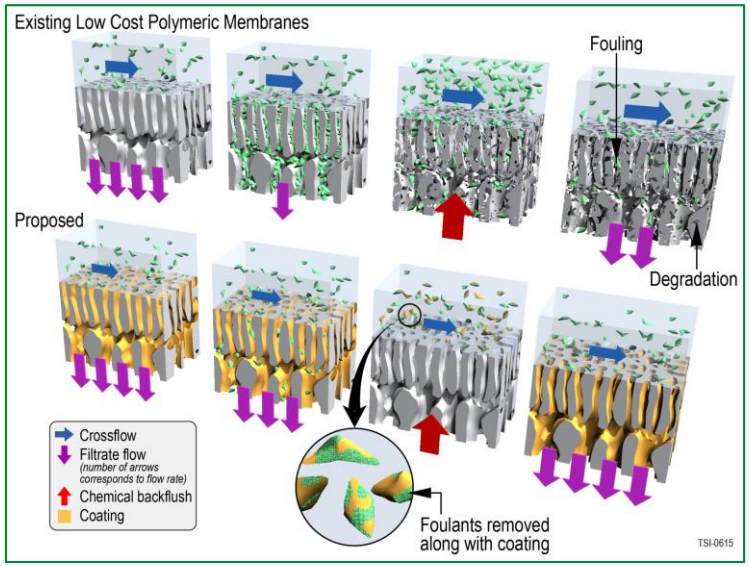

**Ultrafast, femtosecond pulse lasers (right) will eliminate machining defects in fuel injectors.**

*Image courtesy of Raydiance*.



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

*Graphic image provided by General Motors.*

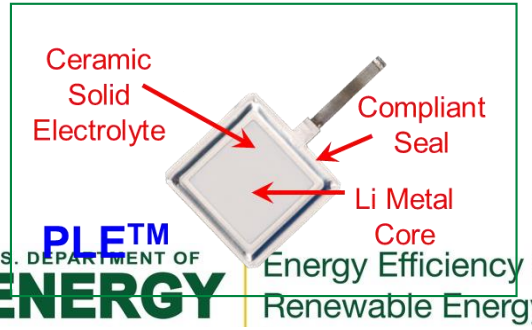



**Protective coating materials for high-performance membranes, for pulp and paper industry.**

*Image courtesy of Teledyne*

**A water-stable protected lithium electrode.**

*Courtesy of PolyPlus*

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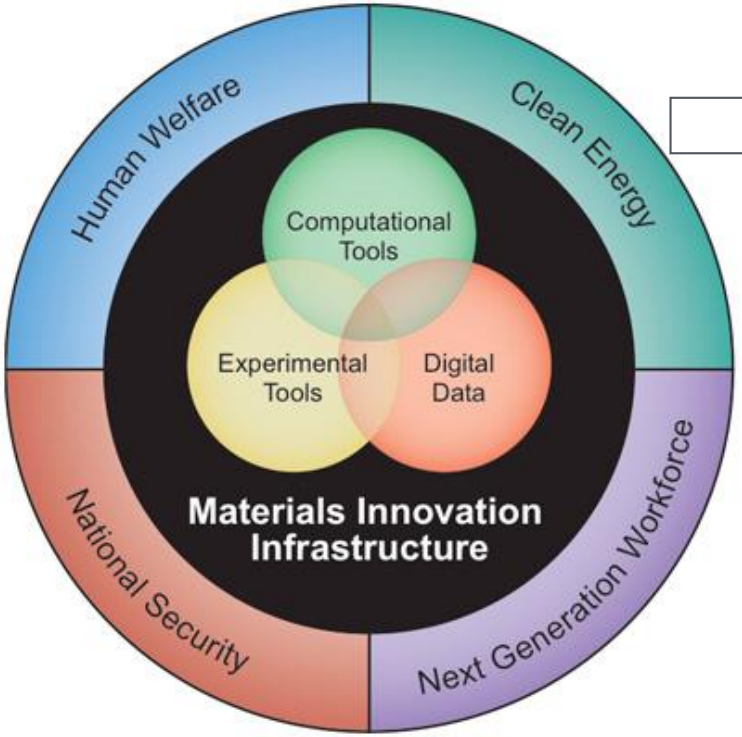
# In Support of the Materials Genome Initiative (MGI)




**MGI - Framework**

**Energy Materials Network**
U.S. Department of Energy

*Coordinated resource network with a suite of capabilities for advanced materials R&D*

| | | | |
|---|---|---|---|
| Predictive Simulation Across Scales | Synthesis & Characterization | Rapid Screening | End Use Performance |
| Process Scalability | Process Control | Real-time Characterization | Reliability Validation |

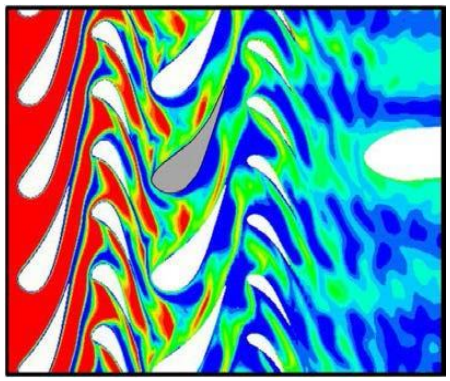
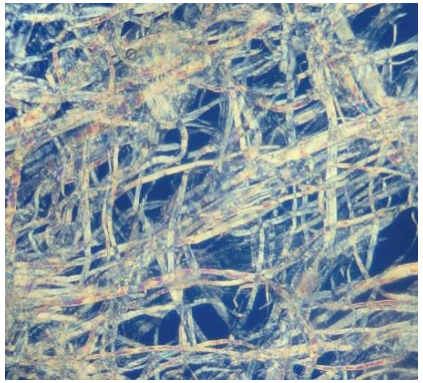
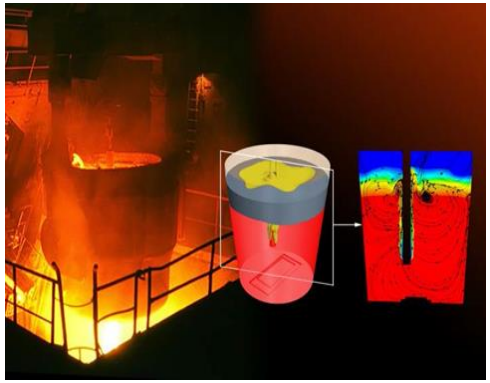
Data Management & Informatics

**Materials Design & Synthesis** → **Functional Design** → **Process Scale-Up & Qualification**

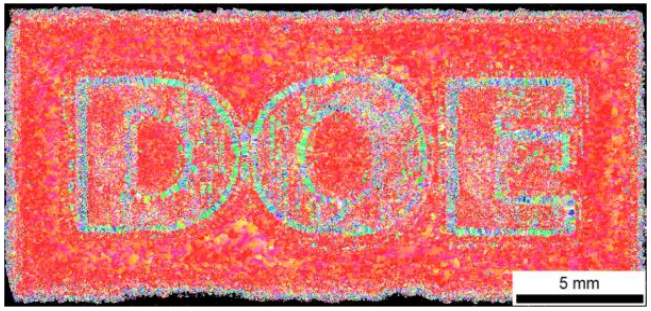
*New Material Innovations for Clean Energy 2X Faster and 2X Cheaper*

# High Performance Computing for Manufacturing (HPC4Mfg)

- Program teams manufacturers with DOE's network of National Labs
- Applying High Performance Computing to face critical manufacturing challenges


- **Identify New Manufacturing Relevant Technical Challenges to Apply HPC**
- **High Impact Multiscale Modelling Opportunities**
- **Connect to Computation Thought Leaders in Labs**
- **Demonstrate Value in Projects and Share Results**
- **Opportunity for Lab Talent (esp. Early Career) to Partner with Clean Energy Implementation Community**

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# High Performance Computing for Manufacturing (HPC4Mfg)

- Sponsored by the DOE's Advanced Manufacturing Office (AMO)
- Teams manufacturers with DOE's National Labs to apply High Performance Computing to face critical manufacturing challenges
- $3M in funding available in each round
- Applications due every 6 months
- More information at www.hpc4mfg.org

Lawrence Livermore National Laboratory

BERKELEY LAB
Bringing Science Solutions to the World

OAK RIDGE National Laboratory


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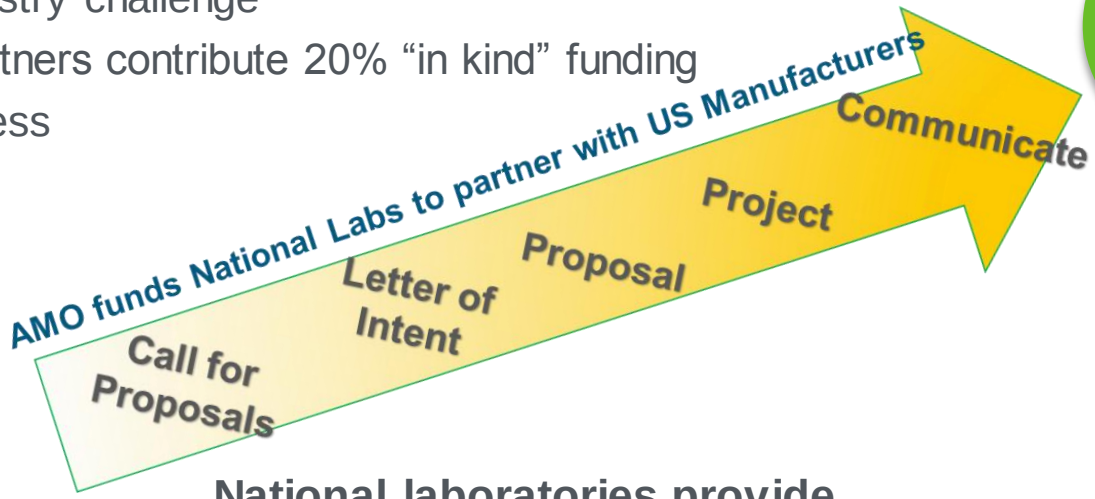
# HPC4Mfg Program: Advancing Innovation

**Framework:**

- Business-friendly terms and streamlined partnering process
- Leverage decades of investment in platforms, codes, and expertise
- Emphasis on open sharing of successes benefits entire sector

**U.S. Manufacturers, Industry Partners, and Consortia**

- Identify industry challenge
- Industry partners contribute 20% “in kind” funding
- Share success




**Increase Energy Efficiency - Advance Clean Energy Technologies**

**National laboratories provide**

- HPC capabilities and modeling/simulation expertise
- Assistance to industry to develop full proposal
- Develop standard CRADA sympathetic to protection of industry IP
- DOE funding < $300K

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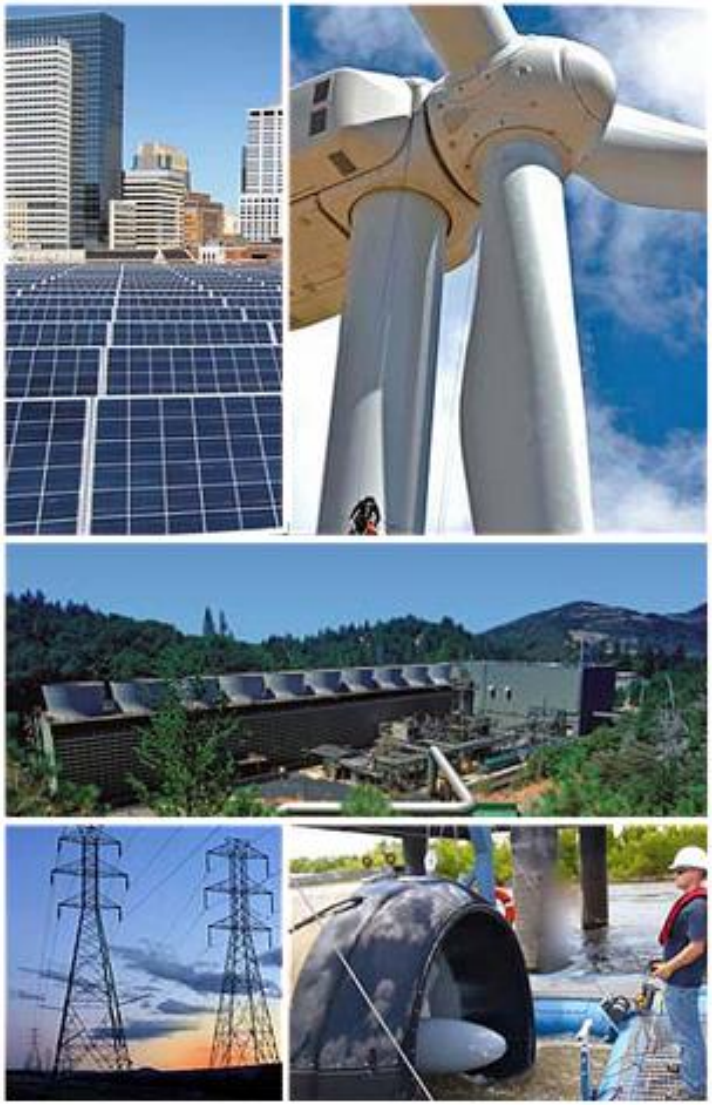
# R&D: Next Generation Electric Machines (NGEM)

- Focus on developing energy efficient, high power density, integrated medium voltage drive systems.

Current efforts:

- Manufacturing of high performance thermal and electrical conductors
- Manufacturing of low-loss silicon steel
- High temperature superconducting wire manufacturing
- Manufacturing of other enabling technologies to increase performance.

**Potential to save 1.6% of total U.S. electricity consumption each year**



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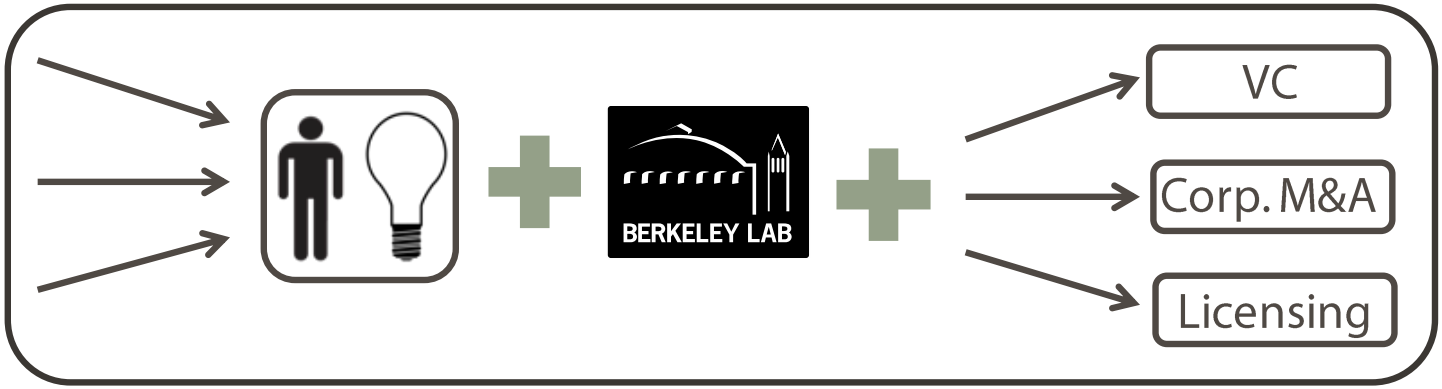
# Mission Innovation: Cyclotron Rd and Innovation Accelerators

## Embedded Accelerator Model:

Let the nation's best energy innovators "spin in" to our national labs




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

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

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

…First pilot phase spurred **$10 million in follow-on funding** and launched 5 **privately-funded startups**

http://www.cyclotronroad.org/



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# What does Success Look Like?

**Energy Products Invented Here…**

**…And Competitively made here for 21st Century**

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# Thank You

Questions?