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

U.S. Advanced Manufacturing and Clean Energy Technology Challenges

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www.manufacturing.energy.gov

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AMO Peer Review

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Outline

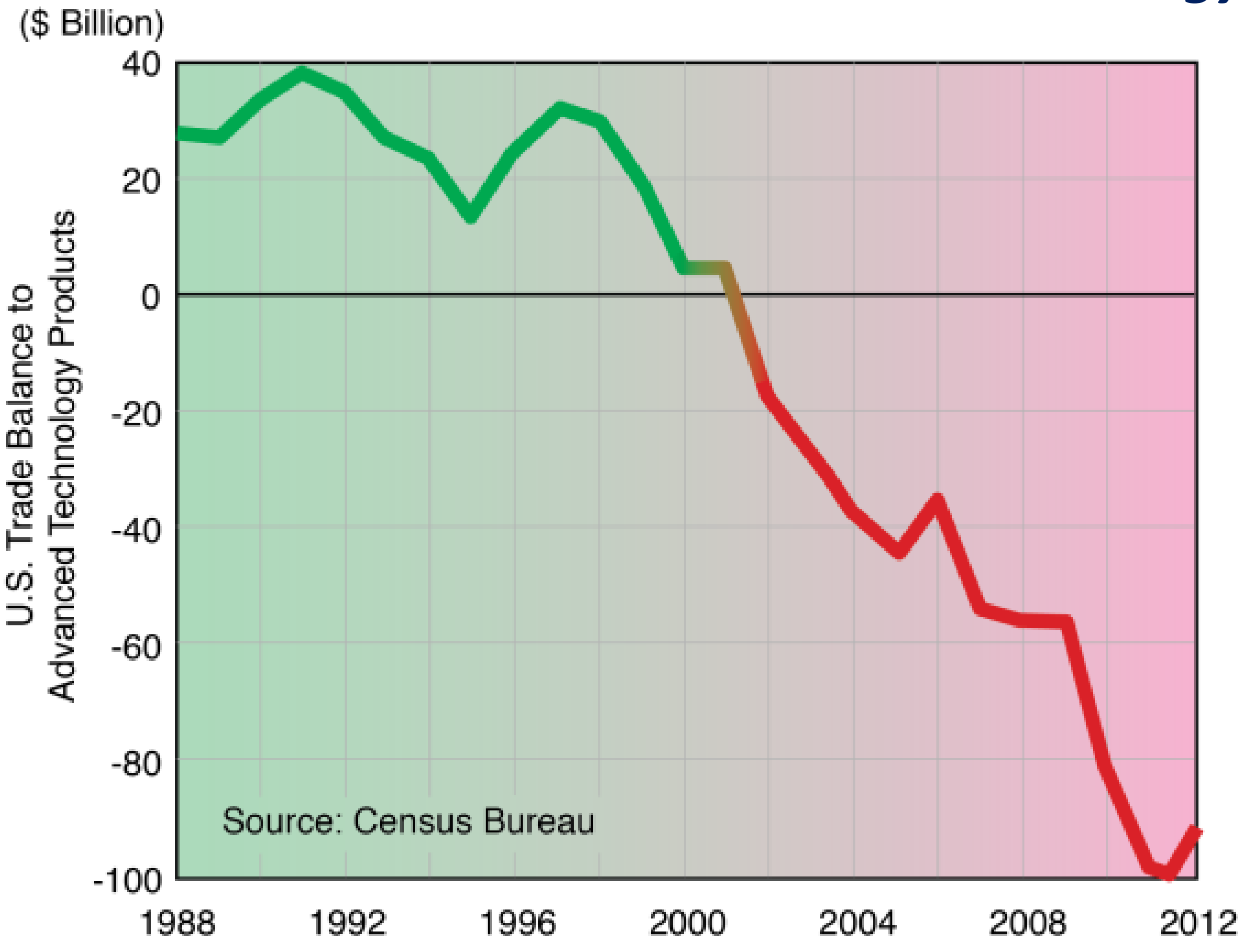
- Big Picture on Manufacturing in US
- Focus on Advanced Manufacturing
- AMO Organization
    - Technical Assistance
    - R&D Facilities
    - R&D Projects
- Goals for Meeting

Products invented here, now made elsewhere

Significance of U.S. Manufacturing

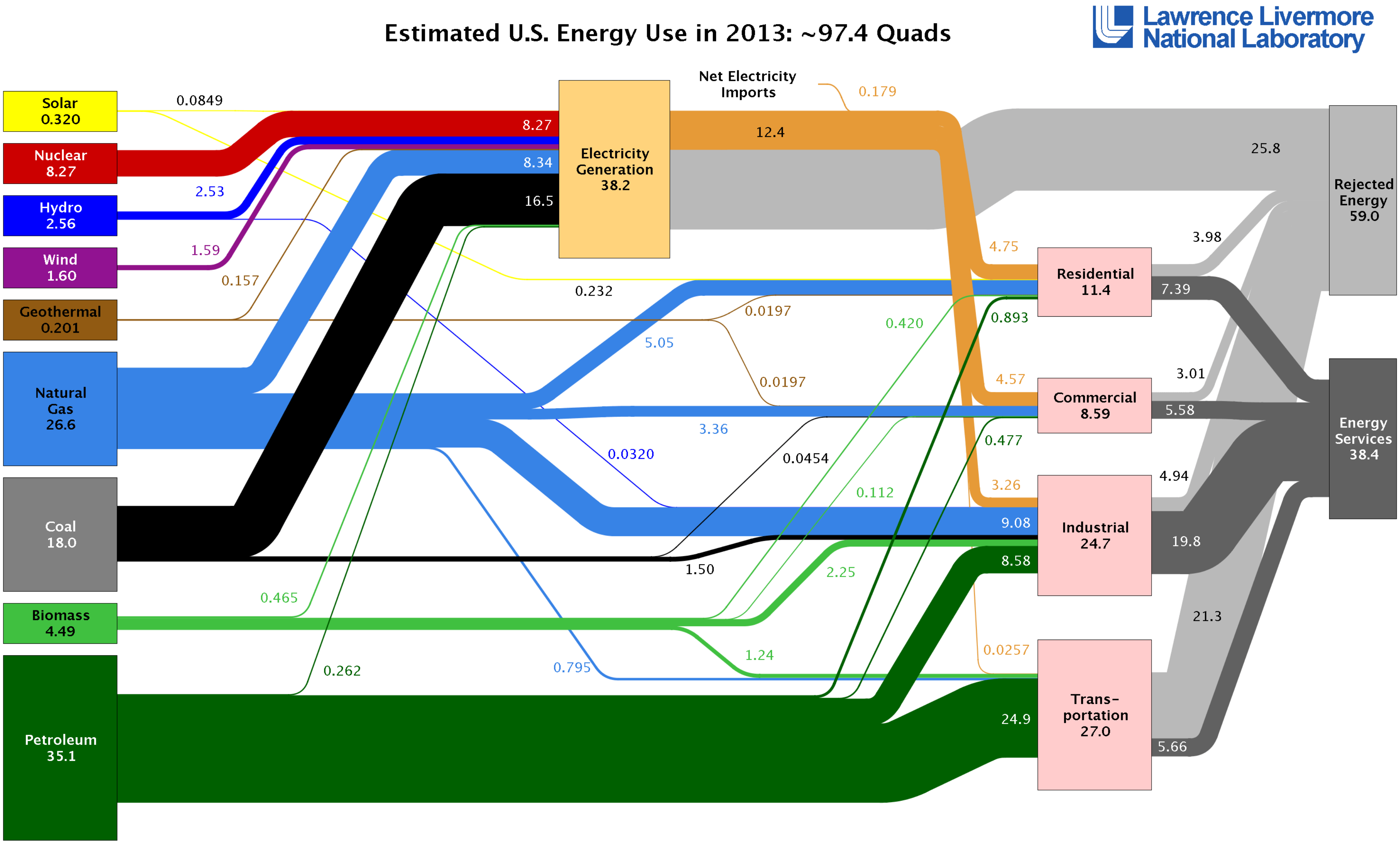
11% of U.S. GDP, **12** million U.S. jobs, **60%** of U.S. Exports

U.S. Trade Balance of *Advanced Technology*



Swung to historic deficit, lost 1/3rd of workforce

Energy Efficiency & Manufacturing Technology



Source: LLNL 2014. Data is based on DOE/EIA-0035(2014-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Clean Energy: Nexus of Opportunities

- Energy self-reliance
- Stable, diverse energy supply

- Competitiveness in clean energy
- Domestic jobs

- Clean air
- Climate change
- Health

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A Transformational Moment in History

- Changing Fuel and Feedstock Mixtures

- Nearing Cost-Competitiveness in Clean Energy Technologies – Cross-over Point within next Decade (Wind, Solar, Battery EV, Distributed Generation, Lightweight, Grid)

- Re-shoring: Productivity Adjusted Labor Rates are Globally Competitive and Export Transport is Advantaged

The Time is NOW to Convert a Short Term Window of Opportunity to a MULTI-GENERATION Economic Advantage

and

Achieve Cost Effective Clean Energy

What is Advanced Manufacturing?

A family of activities that:

- Depend on the use and coordination of information, automation, computation, software, sensing, and networking; and/or
- Make use of cutting edge materials and emerging capabilities.

Advanced Manufacturing involves both:

- *New ways to manufacture existing products*; and
- The manufacture of *new products emerging from new advanced technologies*.

Definition from: President's Council of Advisors on Science and Technology, "Report to the President on Ensuring America's Leadership in Advanced Manufacturing," June 2011, p. ii

www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf.

Or more Simply

Manufacturing

Making Stuff and/or Doing Value Added Work Using the Stuff that is Made

Advanced Manufacturing

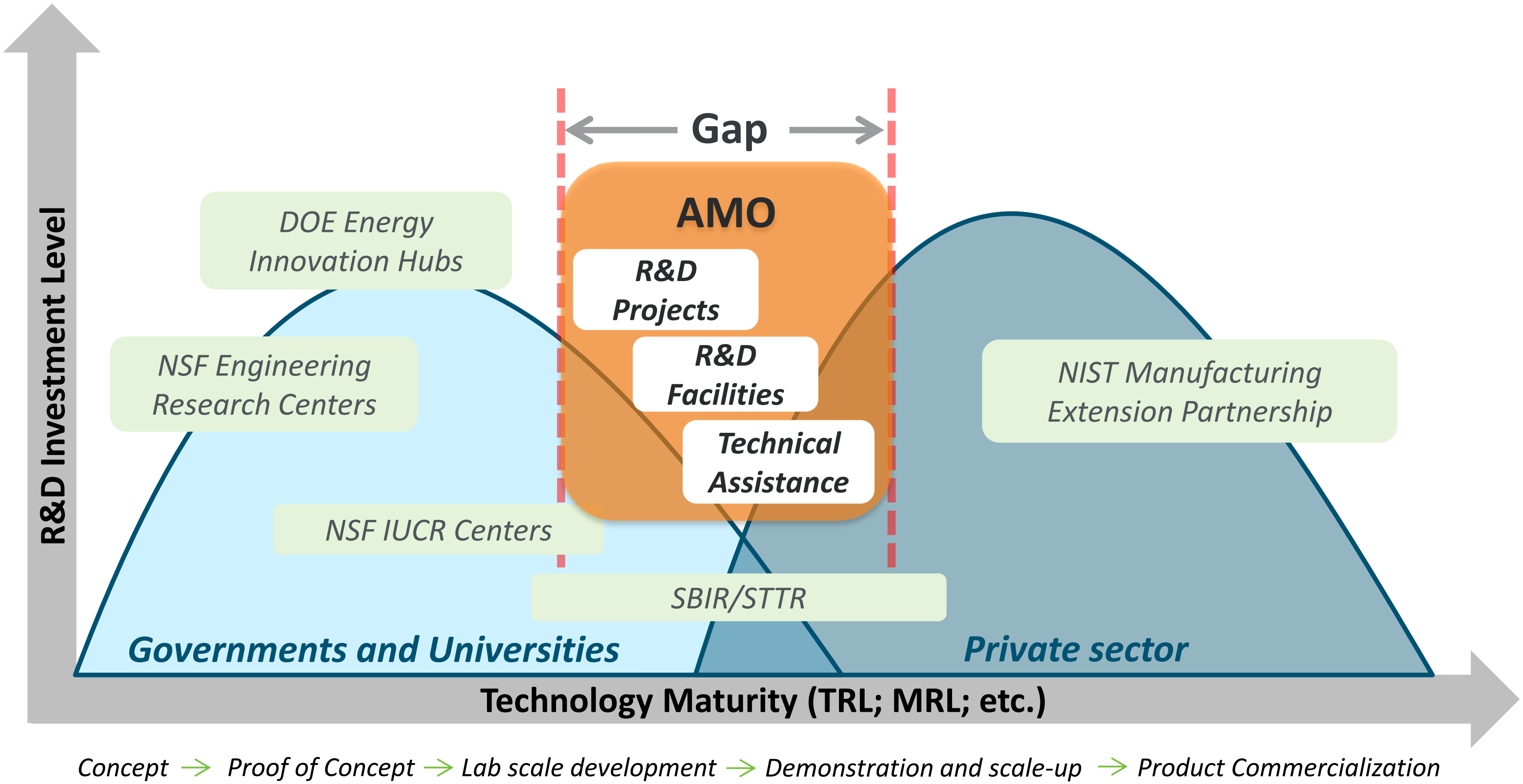
Making Stuff Using Technology as a Key Enabler or as a Relative Competitive Advantage

Clean Energy Manufacturing

Making Stuff that Reduces Energy or Environmental Impacts in its Making, Use, or Disposal.

AMO: Bridging the Gap

AMO Investments leverage strong Federal support of basic research by partnering with the private sector to accelerate commercialization



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Advanced Manufacturing Office (AMO): Purpose

Carbon Fiber from Microwave Assisted Plasma Process

Laser Processing for Additive Manufacturing

AMO's Purpose is to Increase U.S. Manufacturing Competitiveness through:

- ✓ **Manufacturing Efficiency - Broadly Applicable Technologies and Practices**
  - examples: Industrial motors, Combined heat and power (CHP), Industrial efficiency best practices.
- ✓ **Efficiency - Energy Intense Processes**
  - examples: Aluminum, Chemicals, Steel
- ✓ **Cross-cutting Innovations - Clean Energy Manufacturing Technologies**
  - examples: Wide-Bandgap semiconductors, Power electronics, Additive manufacturing, Advanced composites, Roll-to-roll processes, Digital manufacturing

Advanced Manufacturing Office (AMO): Structure

R&D Projects

- Manufacturing Efficiency – Broadly Applicable
- Efficiency –Energy Intense Processes
- Cross-cutting – Clean Energy Manufacturing Technologies

R&D Facilities

- Manufacturing Efficiency – Broadly Applicable
- Cross-cutting – Clean Energy Manufacturing Technologies

Technical Assistance

- Manufacturing Efficiency – Broadly Applicable & Adoptable

AMO: Vital Element in Advanced Manufacturing Strategy

Executive Branch Leadership:

National Economic Council (Jason Miller)

Office of Science and Technology Policy (Alex Slocum)

- Advanced Manufacturing Partnership (AMP 2.0)
- Presidents Council of Science and Technology Advisors (PCAST)

Inter-Department Coordination:

Advanced Manufacturing National Program Office (Mike Molnar/NIST)

- National Network of Manufacturing Institutes (pilot network)

OASD (MIPB) Defense Mantech Office (Adele Ratcliff)

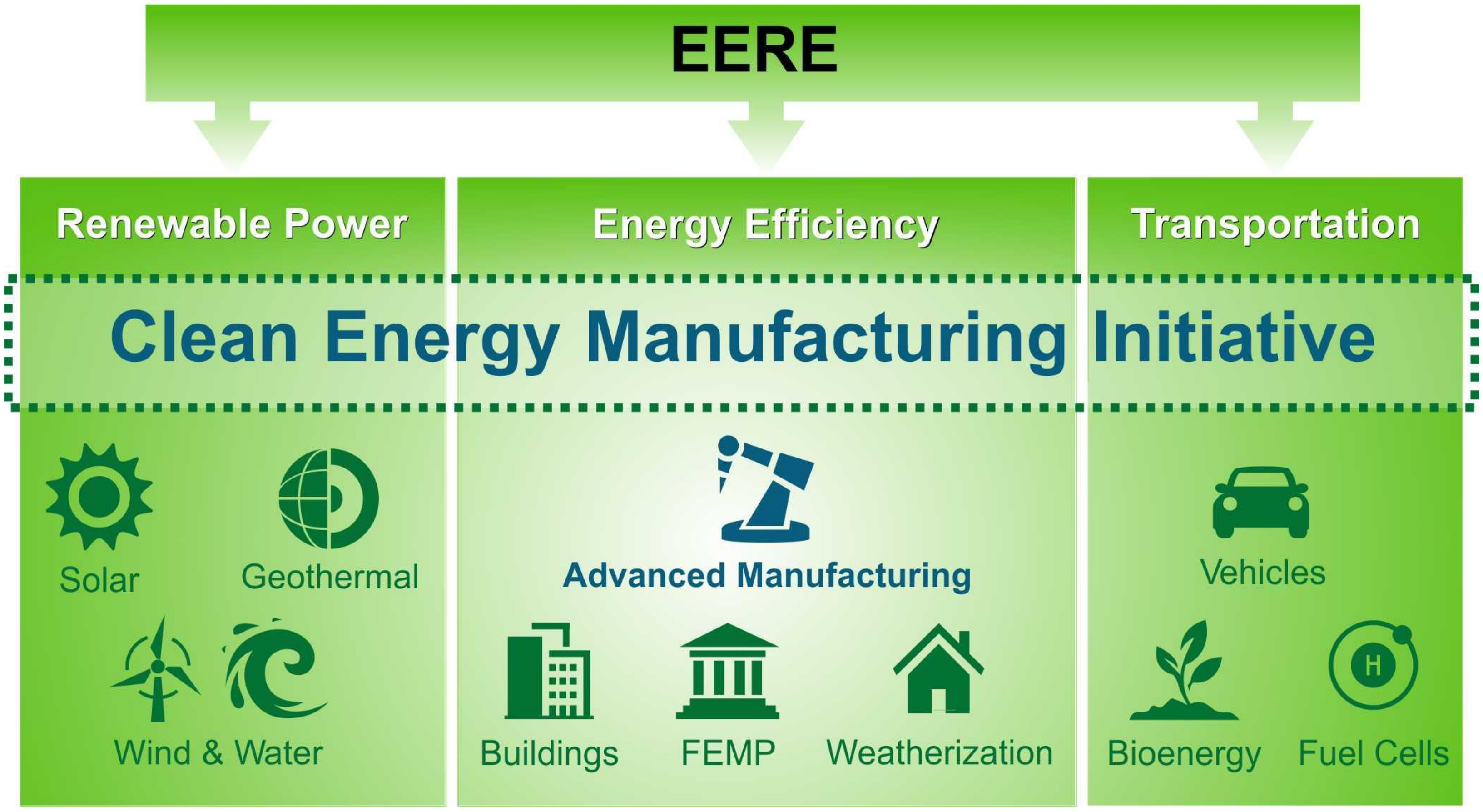
Department of Energy Coordination:

Clean Energy Manufacturing Initiative [CEMI] TechTeam (Libby Wayman)

Advanced Manufacturing Partnership (AMP 2.0)

- Technology Development
  - Advanced Materials Development and Manufacturing
  - Sensors-based Control and Big-Data in Manufacturing
  - Visualization and Decision Analytics in Manufacturing
- Education
  - Workforce and End-to-End Human Capacity Building
- Scale-Up
  - Capital Challenge for Scaling
- NNMI
  - Network Value Proposition, Leveraging and Best Practices
- Image of Manufacturing
  - Getting beyond the 4D's (capture the maker movement)

Clean Energy Manufacturing Initiative – EERE



Collaboration toward:

- Common goal to collectively ***increase U.S. manufacturing competitiveness***

Coordination for:

- Comprehensive Strategy
- Collaborative Ideas

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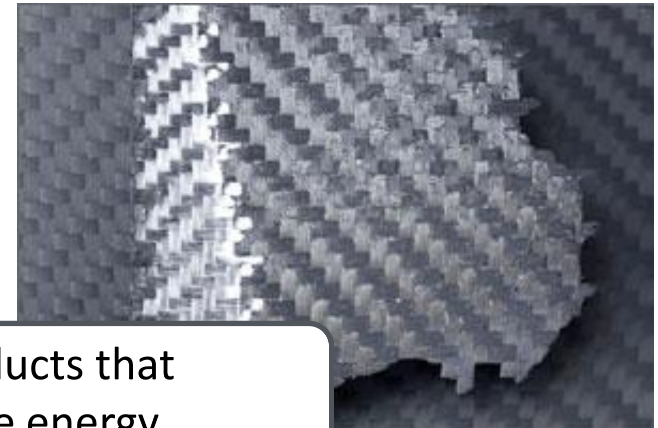
Clean Energy Manufacturing Initiative – DOE Tech Team

- **EERE:** Mark Johnson, Mark Shuart, Tony Tubiolo, Carol Schutte, Lynn Daniels, Austin Pugh, Andreas Marcotty, Katharine Burnham, Libby Wayman
- **Office of Fossil Energy:** Regis Conrad, Samuel Tam
- **Indian Energy Policy & Programs:** Pilar Thomas
- **Office of Nuclear Energy:** Martha Shields, Alison Hahn, Erica Bickford, Michael Worley
- **Office of Electricity:** Henry Kenchington, Rachna Handa
- **Office of Science:** Tim Fitzsimmons
- **Economic Impact & Diversity:** Chris Ford, Andre Sayles
- ARPA-E: Peder Maarbjerg
- **Energy Information Administration:** Peter Gross, Paul Otis
- **EPSA:** Henry Kelly
- **Loan Programs Office:** David Yeh, Brendan Bell, Dong Kim, Brian Mahar, Colin Bishopp
- **Intelligence & Counter Intelligence:** Anita Street
- **National Nuclear Security Administration:** Kevin Greenaugh

Clean Energy Manufacturing Initiative: 2 Objectives

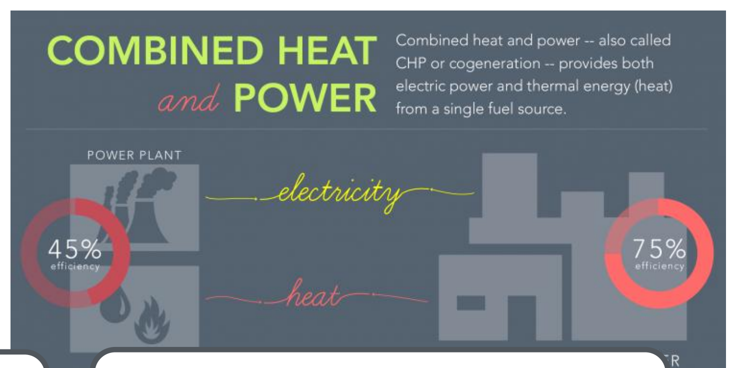
1. **Increase U.S. competitiveness in the production of clean energy products**



Products that generate clean energy

Products that save energy

2. **Increase U.S. manufacturing competitiveness across the board by leveraging energy productivity and low-cost domestic fuels and feedstocks**



Advanced Manufacturing Technologies

Combined Heat & Power

Industrial Energy Efficiency

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Clean Energy Manufacturing Initiative – CEMI

Cross-Cutting Collaboration (DOE-wide) to Enhance and Amplify Individual Efforts Related to Manufacturing

- Win the game in Clean Energy Manufacturing in US
- Leverage Unique Resources, Opportunities, Technologies, Capabilities and Efficiencies

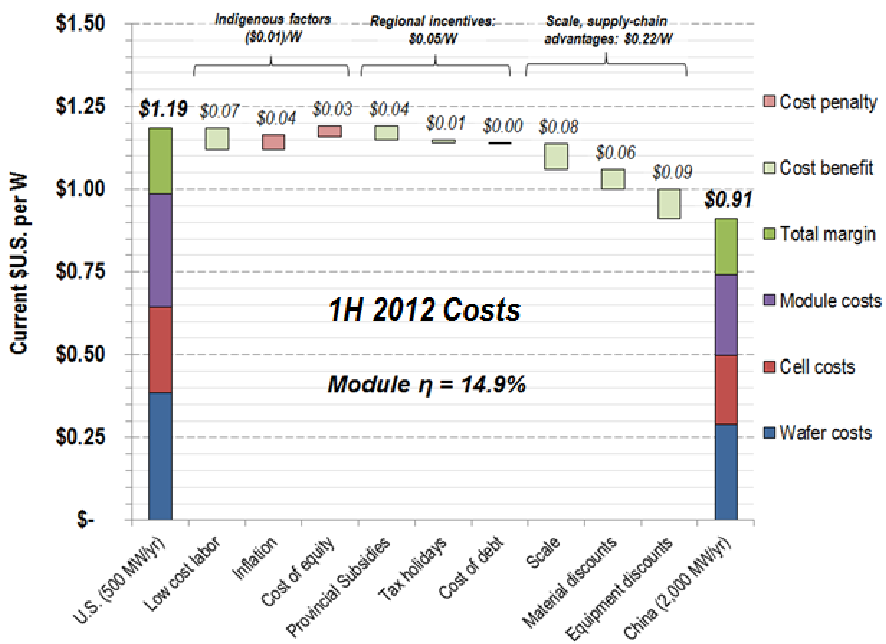
Activities:

Cross Department Leverage

Competitiveness Analysis

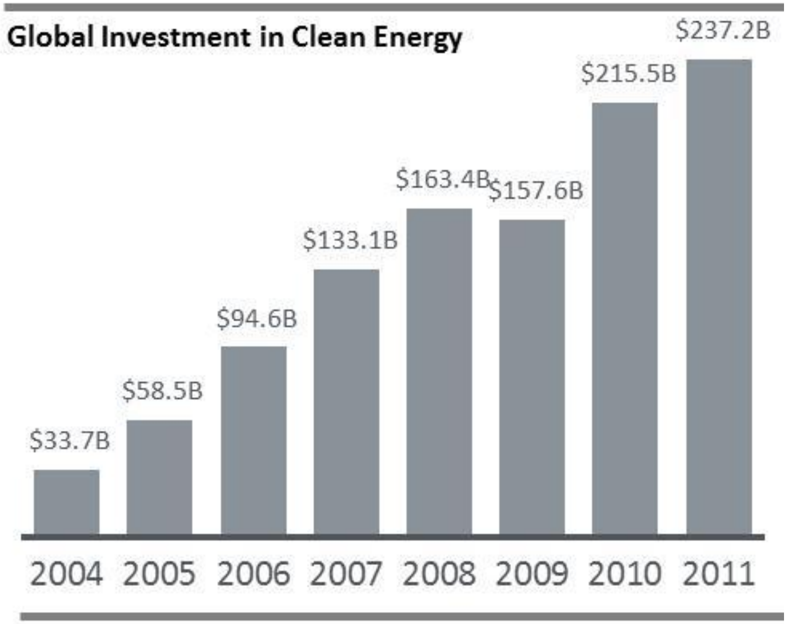
Planning and Opportunities

Outreach and Events



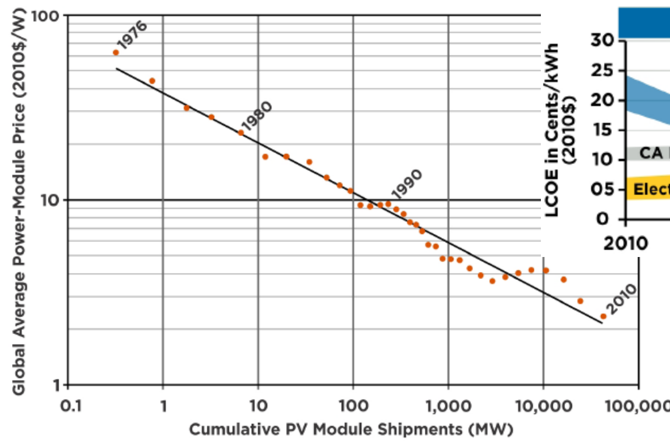
The Opportunity & Challenge of Clean Energy Manufacturing

A Large and Growing Market

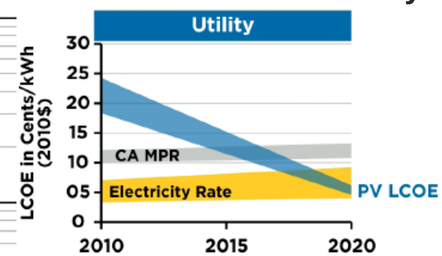


Cost Competitive Technologies

Solar Module Price Vs. Shipments



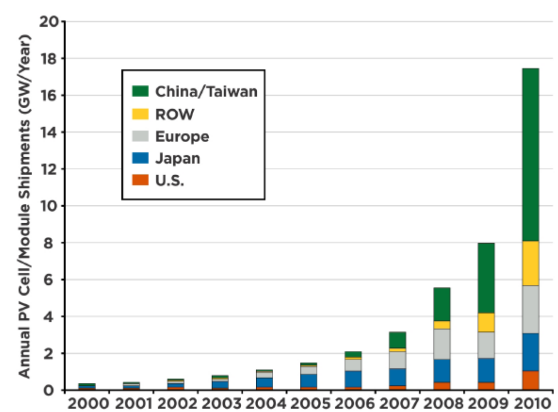
Cost of Solar Electricity



Source: SunShot Vision

Sources: Mints (2011), Mints (2006), Strategies Unlimited (2003)

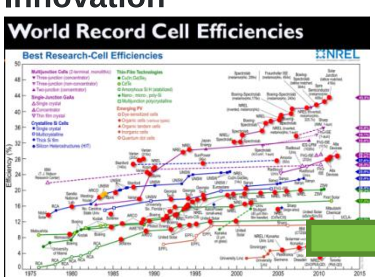
Race to Capture the Market



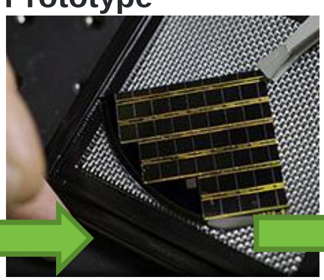
Source: Mints (2011a)

Investments in Innovation through Scale-up

Innovation



Prototype



Process R&D

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AMO Elements

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

1. **Research and Development Projects**
2. **Shared R&D Facilities**
3. **Technical Assistance** – driving a corporate culture of continuous improvement and wide scale adoption of proven technologies, such as CHP, to reduce energy use in the industrial sector

Better Plants and Superior Energy Performance

DOE Advanced Manufacturing Office has two complementary programs:

- **Better Plants**
  - **Corporations** set a goal, establish baseline, track energy use, and report data
  - Corporations report to DOE on an annual basis on a portfolio of facilities.

- **Superior Energy Performance (SEP)**
  - **Facility-level** certification and recognition program to demonstrate energy management excellence and sustained energy savings.
  - Energy performance improvement is verified by a third party SEP verification body retrospectively in past 3 to 10 years.

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Better Plants Program

- Voluntary pledge to reduce energy intensity by 25% over ten years over <u>all</u> facilities
- Over 120 Program Partners, over 1,750 plants, ~8% of the total U.S. manufacturing energy footprint
- Partners implement cost-effective energy efficiency improvements that:
  - ➢ Save money
  - ➢ Create jobs
  - ➢ Promote energy security
  - ➢ Strengthen U.S. manufacturing competitiveness
- **Through the Better Plants Program, companies receive national recognition and technical support from DOE**

Superior Energy Performance

A market-based, ANSI-ANAB accredited certification program that uses ISO 50001 as a foundational standard and verifies continual energy performance improvement.

DOE lead: Paul Scheihing
Email: paul.scheihing@ee.doe.gov
1-202-586-7234
http://superiorenergyperformance.energy.gov

International Organization for Standardization

ISO 50001

Components in place:

- Top Management
- Energy Team
- Policy
- Planning
- Baseline
- Performance Metrics

Superior Energy Performance

Single facility ISO 50001 conformance with verified energy performance improvement

ISO 50001

Superior Energy Performance (SEP)

- Builds off of ISO 50001, an energy management standard
- ANSI/ANAB-accredited certification program
- Verifies energy performance improvement for overall facility (systems based)
- Findings: 17 SEP certified plants have improved their energy performance between 6 and 25% over a three year period.

Better Plants Partners	SEP Certified Plant	Implementing SEP Certification	SEP Trained
Non-Better Plants Partners	SEP Certified Plant	Implementing SEP Certification	SEP Trained

* Map data points are intended for illustrative purposes only.

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Superior Energy Performance Certified Plants

Facility Name	% Energy Performance Improvement*
Mack Trucks | *Macungie, PA ***	**41.9**
Volvo Trucks, NA | *Dublin, VA*	**25.8**
Dow Chemical Company | *Texas City, TX: Manufacturing facility*	**17.1**
Bridgestone Americas Tire | *Wilson, NC ***	**16.8**
Harbec Plastics | *Ontario, NY*	**16.4**
3M Canada Company | *Brockville, Ontario, Canada*	**15.2**
Cook Composites and Polymers | *Houston, TX*	**14.9**
Cummins | *Whitaker, NC*	**12.6**
General Dynamics | *Scranton, PA*	**11.9**
Allsteel | *Muscatine, IA*	**10.2**
Cooper Tire | *Texarkana, AR*	**10.1**
Olam Spices | *Gilroy, CA*	**9.8**
Owens Corning | *Waxahachie, TX*	**9.6**
Dow Chemical Company | *Texas City, TX: Energy systems facility*	**8.1**
Nissan, NA | *Smyrna, TN*	**7.2**
Freescale Semiconductor, Inc. | *West Austin, TX*	**6.5**
3M Company| *Cordova, IL*	**6.2**

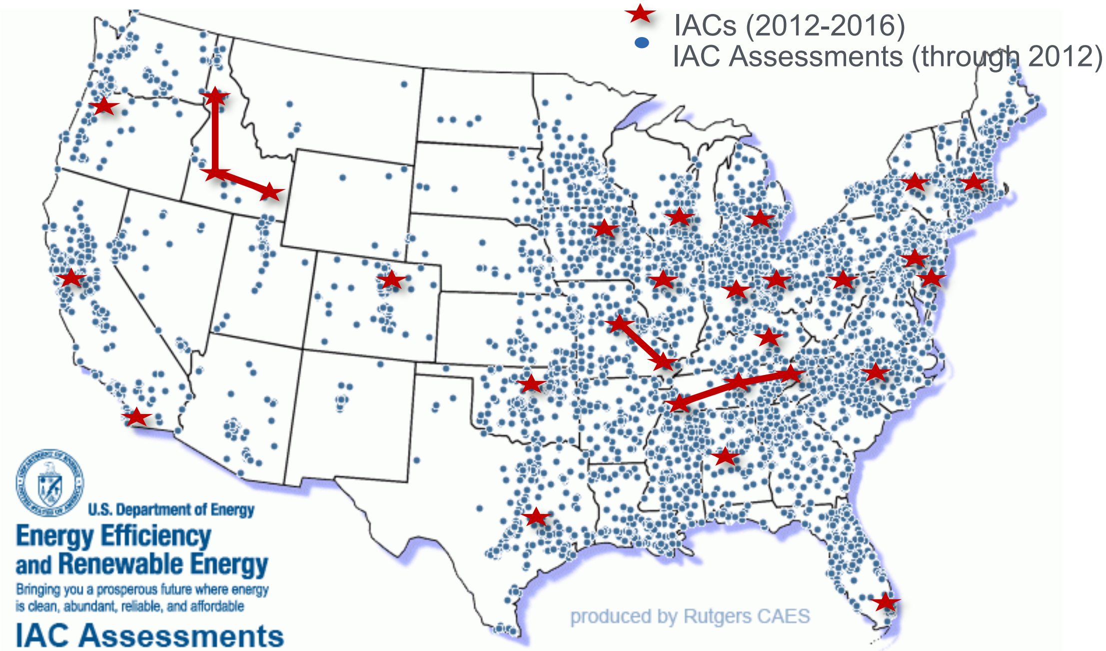
17 plants certified through January 2014

* Energy performance improvement is over a 3-year period, including capital and operational improvement

** Mature energy pathway and improvement over 10 years

Industrial Assessment Centers (IACs)

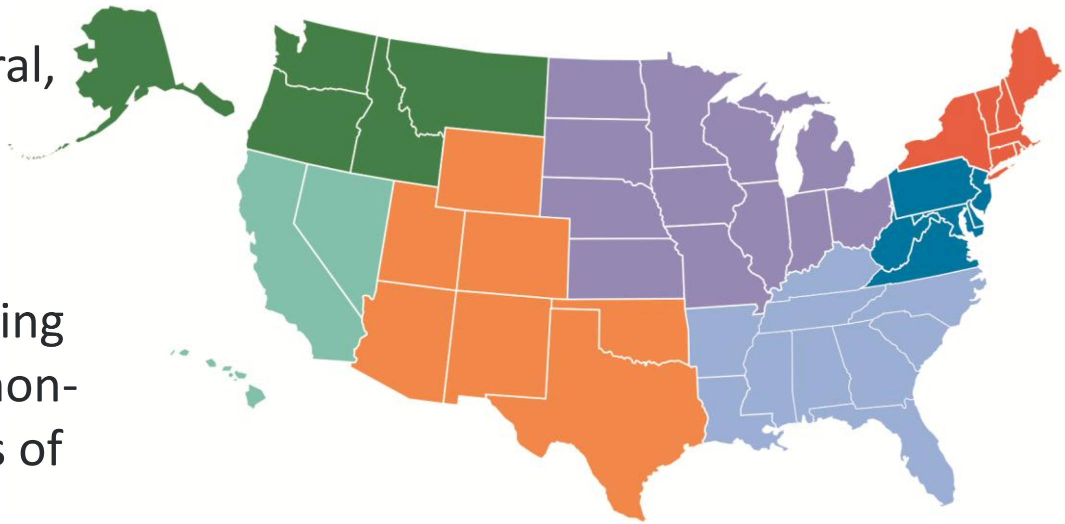
- IAC Program: Targets Energy Savings in Small-Medium Size Firms
- An Average IAC client will save more than $46,000 in energy and process improvements (nearly 4X return in 18 months)
- Secondary benefit: Training next generation of Energy Leaders



CHP Technical Assistance Partnerships

For Efficient On-Site Energy with Combined Heat and Power

- **Market Opportunity Analysis:** Analyses of CHP market opportunities in industrial, federal, institutional, and commercial sectors
- **Education and Outreach:** Providing information on the energy and non-energy benefits and applications of CHP
- **Technical Assistance:** Providing technical assistance to end-users through the project development process from initial CHP screening to installation



www1.eere.energy.gov/manufacturing/distributedenergy/chptaps.html//

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AMO Elements

Three primary partnership-based vehicles to engage with industry, academia, national laboratories, and local and federal governments:

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

Shared R&D Facilities

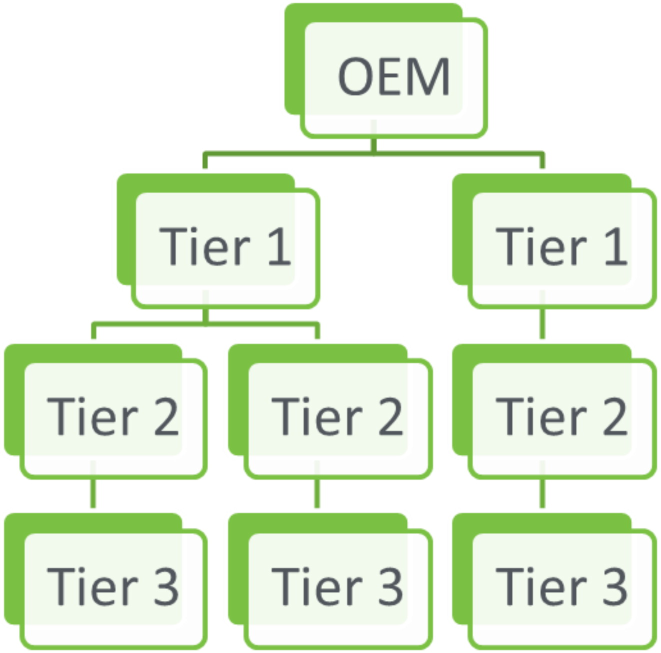
- Address market disaggregation to rebuild the industrial commons

Then

Ford River Rouge Complex, 1920s

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

Now



- **How do we get innovation into manufacturing today?**

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AMO-supported R&D Facilities

1. **Manufacturing Demonstration Facility** at Oak Ridge National Lab
2. **America Makes**, The National Additive Manufacturing Innovation Institute
3. **Critical Materials Institute**: *A DOE Energy Innovation Hub* at Ames National Lab
4. **Next Generation Power Electronics Manufacturing Innovation Institute**
5. **Composites Materials and Structures Manufacturing Innovation Institute** (future – active solicitation)

DOE Assistant Secretary David Danielson during ribbon cutting ceremony of the Carbon Fiber Technology Facility at Oak Ridge National Laboratory. Carbon fiber has the potential to improve the fuel efficiency of vehicles.

Photo courtesy of Jason Richards, Oak Ridge National Laboratory.

Shared R&D Facility: Oak Ridge National Lab
Manufacturing Demonstration Facility

Supercomputing Capabilities

Spallation Neutron Source

Carbon Fiber

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

Program goal is to reduce the cost of carbon fiber composites by improved manufacturing techniques such as MAP, which if scaled successfully could reduce carbonization cost by about half compared to conventional methodology.

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.

Why Additive Manufacturing?

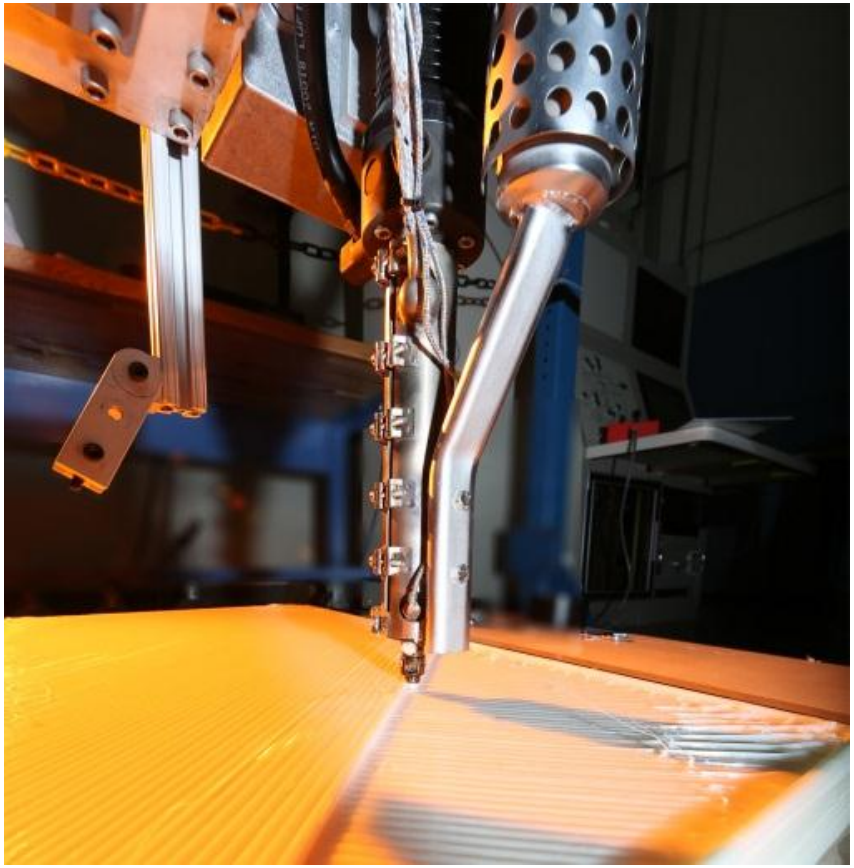


Image courtesy Oak Ridge National Laboratory

Advantages

- Energy savings
- Design freedom
- Reduced waste
- Cost savings
- Agile and shorter supply chains

Challenges

- Limited material selection
- Build speed can be slow
- Surface roughness
- Extensive testing, validation
- Build size

EERE Technology Areas That Benefit:
Automotive
Fuel cells
Hydro (prototypes)
Tooling – all industries
CHP turbines
Geothermal

Additive Manufacturing Saves Energy and Material

8.72 kg → *Conventional Machining - Buy-to-Fly Ratio 8:1* → 1.09 kg

0.57 kg → *Additive Manufacturing - Buy-to-Fly Ratio 1.5:1* → 0.38 kg

Process	Ingot Consumed (kg)	Final Part (kg)	Raw mat'l (MJ)	Manuf (MJ)	Transport (MJ)	Use phase (MJ)	Total energy per bracket (MJ)
Machining	8.72	1.09	8,003	952	41	**217,949**	**226,945**
EBM (Optimized)	**0.57**	**0.38**	**525**	**115**	**14**	**76,282**	**76,937**

Source: MFI and LIGHTEnUP Team

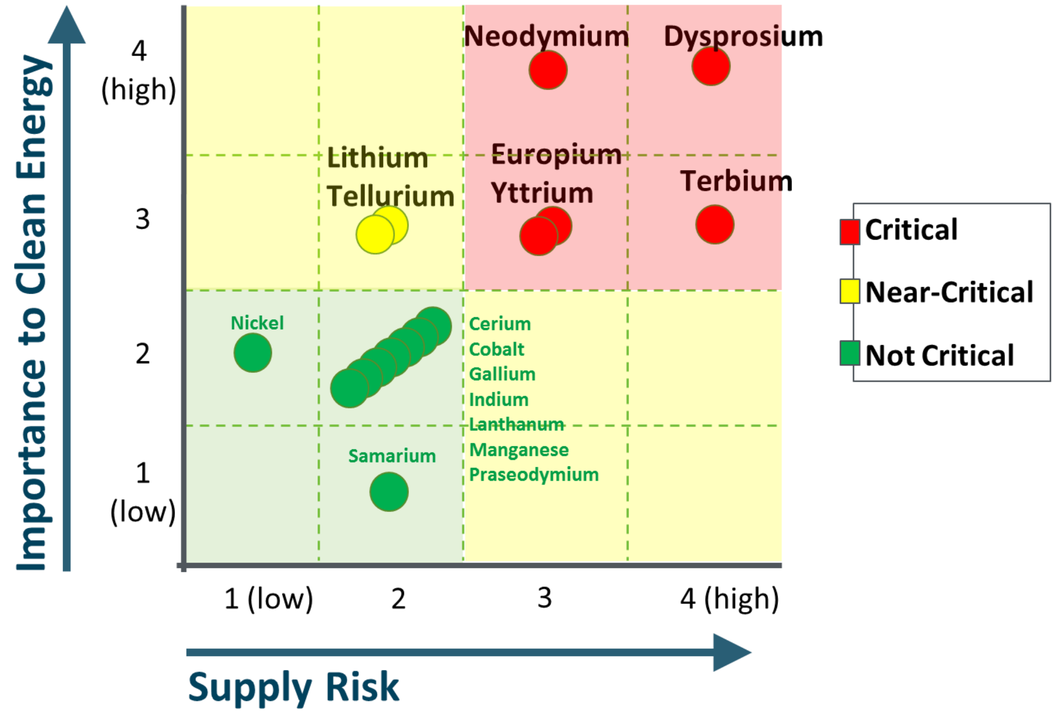
Key assumptions:

- Ingot embodied (source) energy 918 MJ/kg (255 kWh/kg)[5]
- Forging 1.446 kWh/kg[5] , Atomization 1.343 kWh/kg[6,7,8], Machining 9.9 kWh/kg removed[9], SLM 29 kWh/kg[10, 11], EBM 17 kWh/kg[10]
- 11 MJ primary energy per kWh electricity
- Machining pathway buy-to-fly 33:1[15], supply chain buy point = forged product (billet, slab, etc.)
- AM pathway buy-to-fly 1.5:1, supply chain buy point = atomized powder
- Argon used in atomization and SLM included in recipes but not factored into energy savings in this presentation

Critical Materials Institute

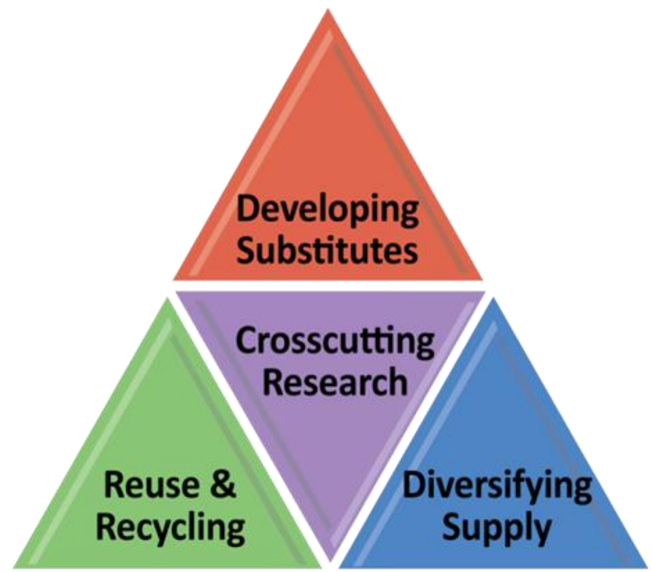
A DOE Energy Innovation Hub

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

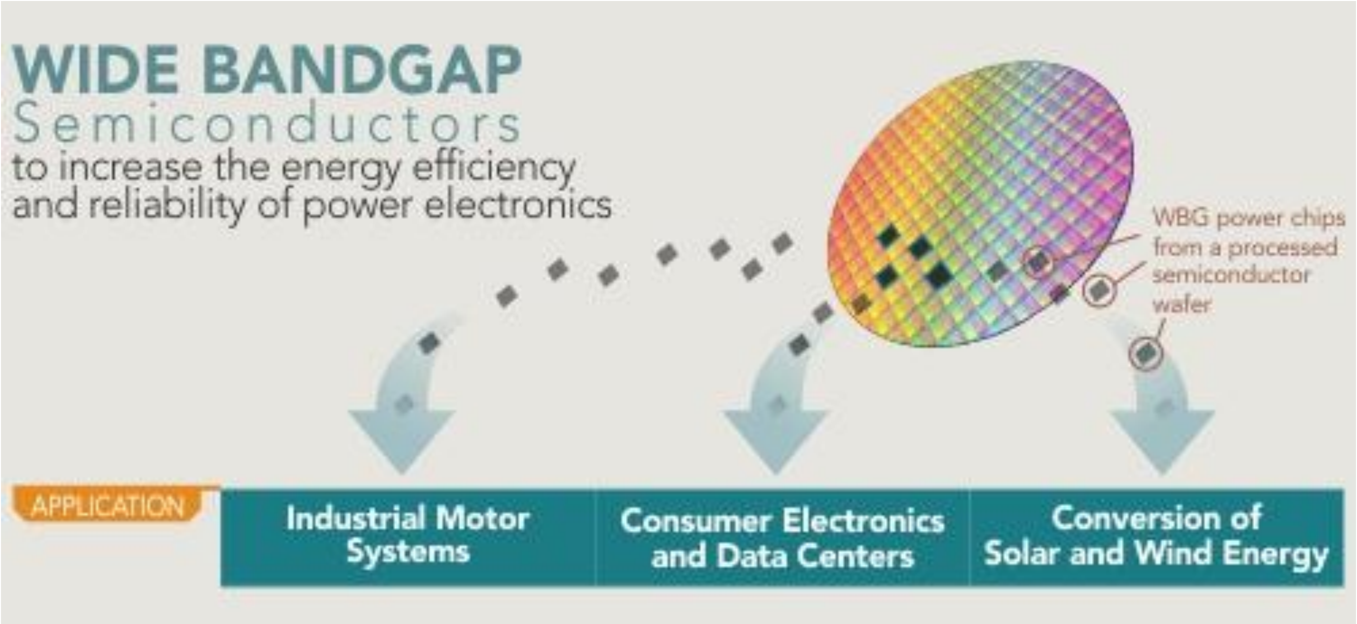


	Dy	Eu	Nd	Tb	Y	Li	Te
Lighting		✓		✓	✓		
Vehicles	✓		✓			✓	
Solar PV							✓
Wind	✓		✓				

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



Next Generation Power Electronics Manufacturing Innovation 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.

NNMI Topic Identification Criteria

EERE Core Questions	Application to NNMI 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 Dialog?
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?

Broad Topical Areas / Tech-Team Working Groups

Manufacturing Materials and Technologies

- Scale-up and Application of Nanomaterials and Materials Genome
- Advanced Roll-to-Roll / 2D / Surface Engineered Materials
- Biomaterials as Feedstock or Fuel in Manufacturing
- Advanced Composites
- Critical Materials
- Wide Bandgap Semiconductors
- Additive Manufacturing

Process Technologies and Energy in Manufacturing

- SMART Manufacturing / Big Data / HPC for Energy Intense Processes
- Process Intensification and Scale-up
- Water-Energy and Manufacturing
- Grid Integration (DR, CHP, etc) and Manufacturing
- Changing Fuels and Feedstocks (Natural Gas) and Manufacturing

Emergent Topics

- Other (metrology, low thermal-budget processes, robotics, etc)

RFI Closes: May 20, 2014

AMO Elements

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

1. **Research and Development Projects -** to support innovative manufacturing processes and next-generation materials
2. **Shared R&D Facilities**
3. **Technical Assistance**

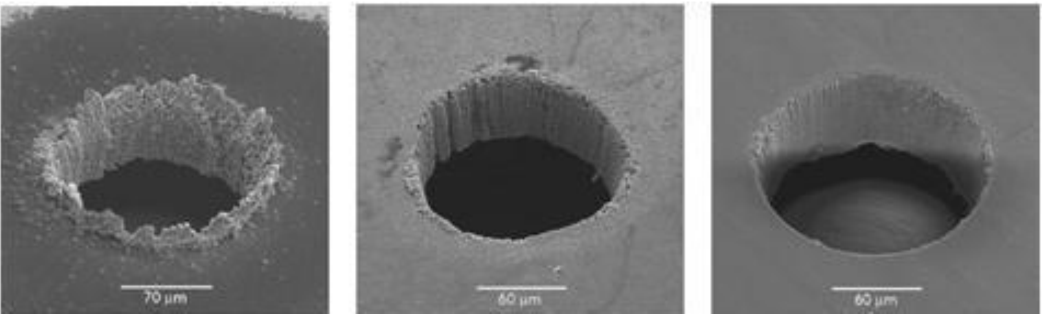
AMO Active R&D Projects

Innovative Manufacturing Initiative (2012 FOA)

- **Goal:** Enable a **doubling of energy productivity** in U.S. industry
- **Approach:** Each project is a public-private partnership to accelerate commercialization of new product or process technologies at industrially relevant scales
- **Focus:** Cross-cutting, foundational manufacturing technologies
- **Co-Investments:**
  - 13 starts in FY12 ($54M DOE / $17M industry)
  - 5 starts in FY13 ($23.5M DOE / $8M industry)

www1.eere.energy.gov/manufacturing/rd/innovative_manufacturing.html

R&D Project Examples

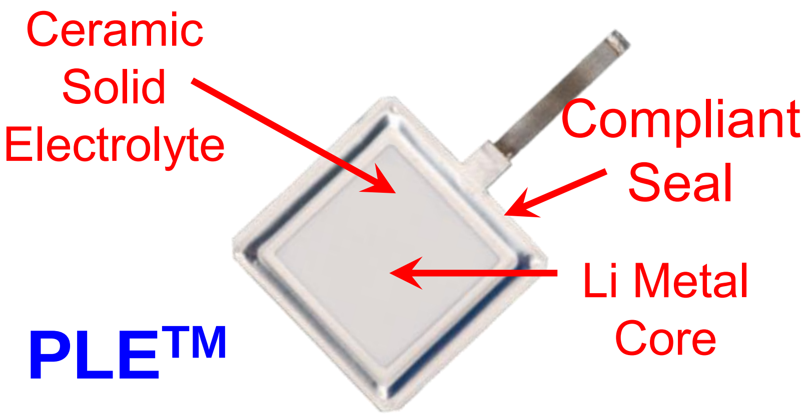


Ultrafast, femtosecond pulse lasers

(right) will eliminate machining defects in fuel injectors.

150 µm diameter holes cut in a 50 µm thick silicon wafer via nano (left), pico (center), and femtosecond (right) pulse lasers.

Image courtesy of Raydiance.



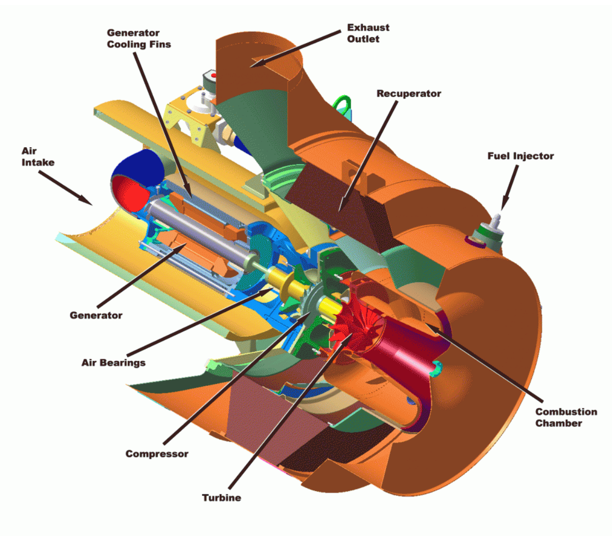
A water-stable protected lithium electrode.

Being developed along with a solid electrolyte and a scaled up manufacturing process for high energy density lithium batteries.

Courtesy of PolyPlus

R&D in Combined Heat and Power (CHP)

Advanced MicroTurbine System (AMTS) R&D Program

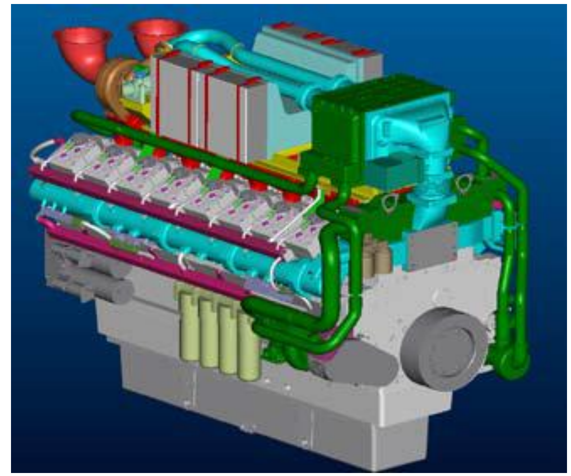


C200 Capstone MicroTurbine Engine

C200 MicroTurbine Engine

Capstone photos source: capstoneturbines.com

Advanced Reciprocating Engine Systems (ARES) R&D Program



QSK60G engine

What Does Success Look Like?

Advanced Manufacturing Office *Investments in Innovative R&D*

Advanced R&D Facilities *(DOE $)*

- Manufacturing Demonstration Facility (*$50M*)
  - Additive Manufacturing
- Critical Material Hub (*$120M*)
- National Additive Manufacturing Innovation Institute (*$10M*)

Next Generation R&D Projects

- 18 IMI R&D Projects
- Focused on foundational technologies crosscutting multiple industries
- DOE Investment: $75M

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

Energy Products Invented Here…

…And Made Here!

Excellence Requires Culture of Continuous Improvement and Examination with Execution

- Program Peer Review is not a Project Review
- Learn from Each Other
- Provide Feedback
- Baseline for Program Comparison over Time
- Identify Prossible Course Correction and New Direction