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

Advanced Manufacturing Office and Potential Technologies for Clean Energy Manufacturing Innovation

October 8, 2014

DOE/DOD Planning Workshop– Fort Worth, TX

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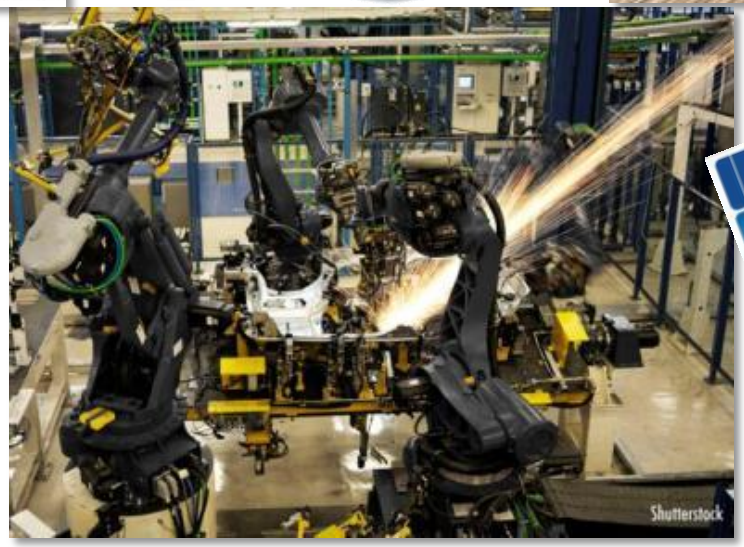
Director

Advanced Manufacturing Office

www.manufacturing.energy.gov

1. **Background on DOE and Manufacturing**
2. Technical Assistance
3. R & D Projects
4. Manufacturing R & D Facilities
5. Workshop Meta-Questions and Ground Rules

Status Quo: Products invented here, and made elsewhere



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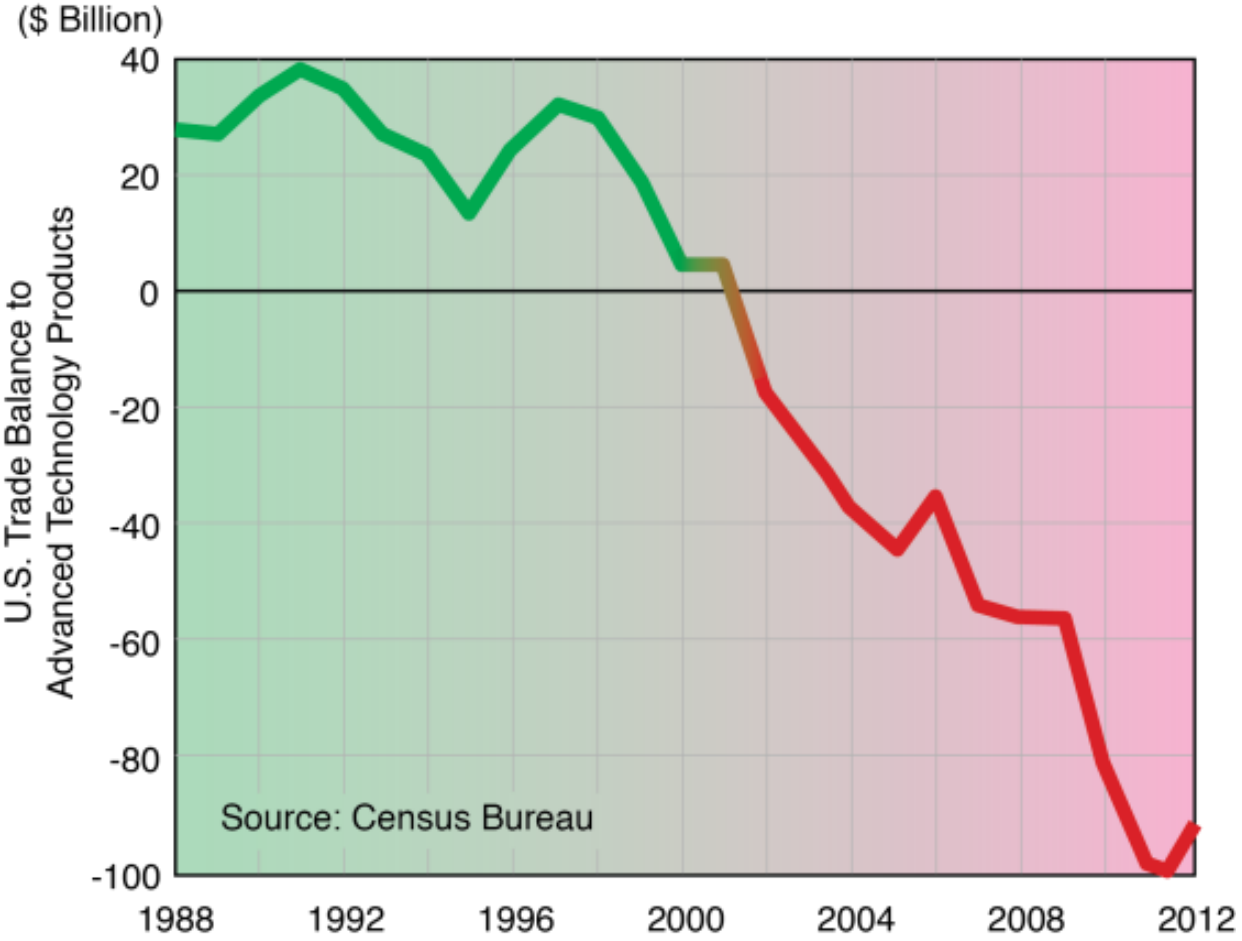
Significance of U.S. Manufacturing

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

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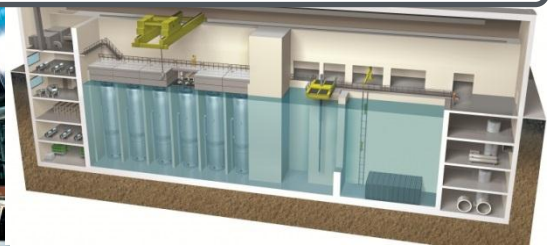
Clean Energy Manufacturing

Clean Energy Manufacturing:
Making things such that lifecycle sustainability is improved in the making, use, and full lifecycle of the product made.

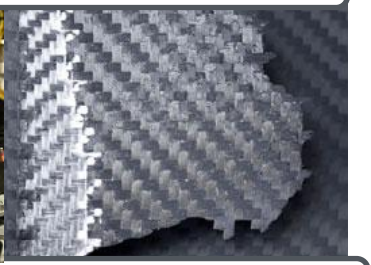
Advanced Manufacturing:
Making things in a manner such that technology provides a competitive advantage over practices widely in use

Products that generate clean energy

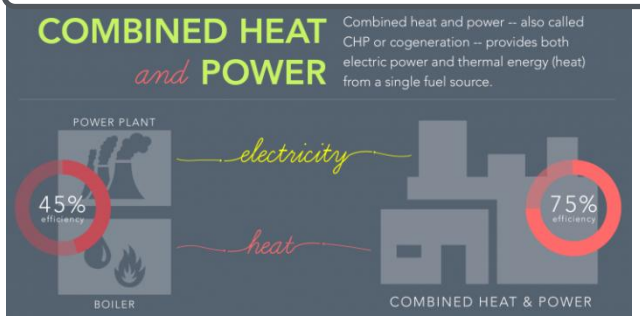




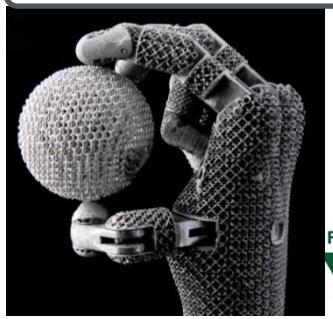
Products that save energy

Cleaner Energy and Saving Energy in Manufacturing



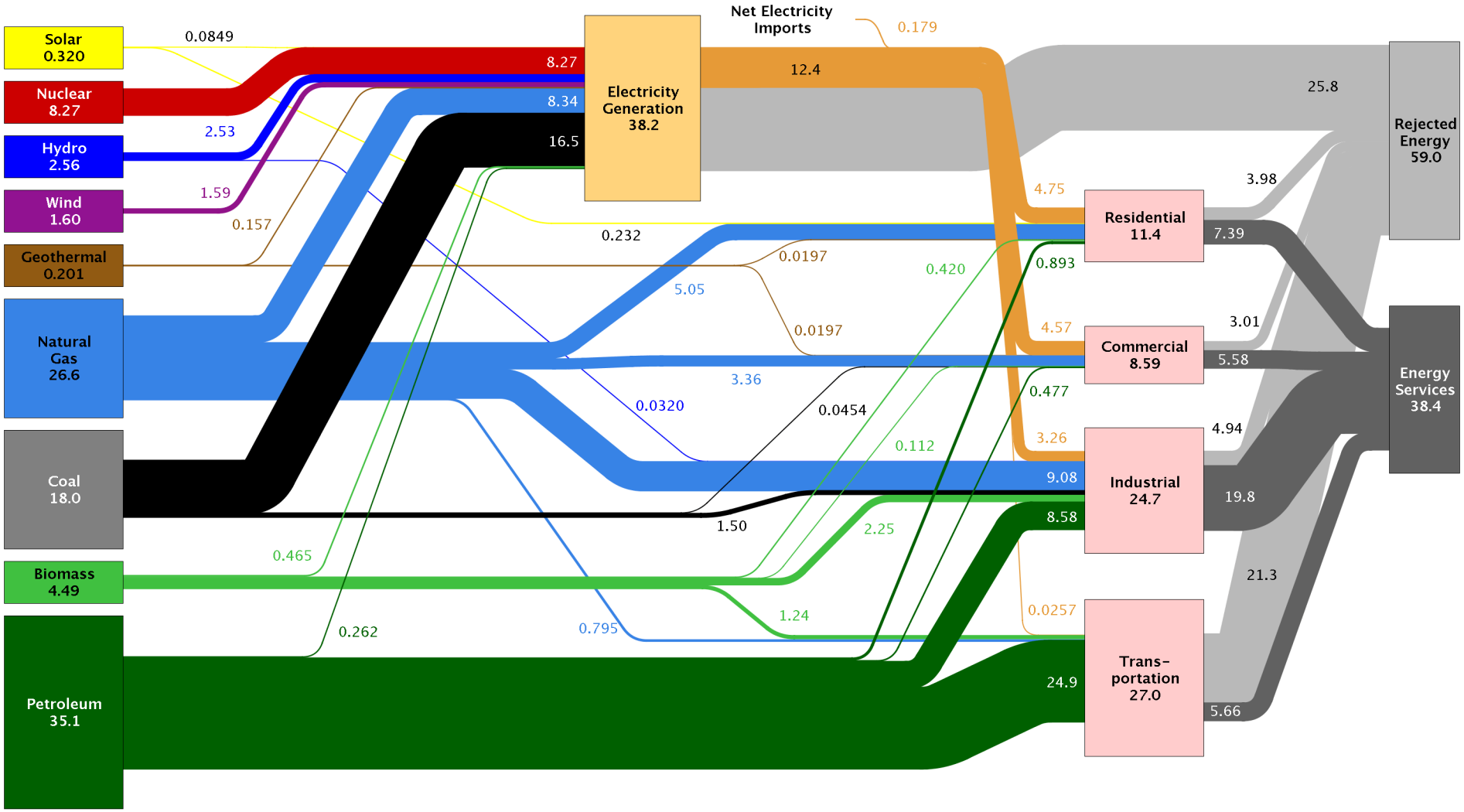
Advanced Manufacturing Technology




Energy Efficiency & Manufacturing Technology

Estimated U.S. Energy Use in 2013: ~97.4 Quads

Lawrence Livermore National Laboratory



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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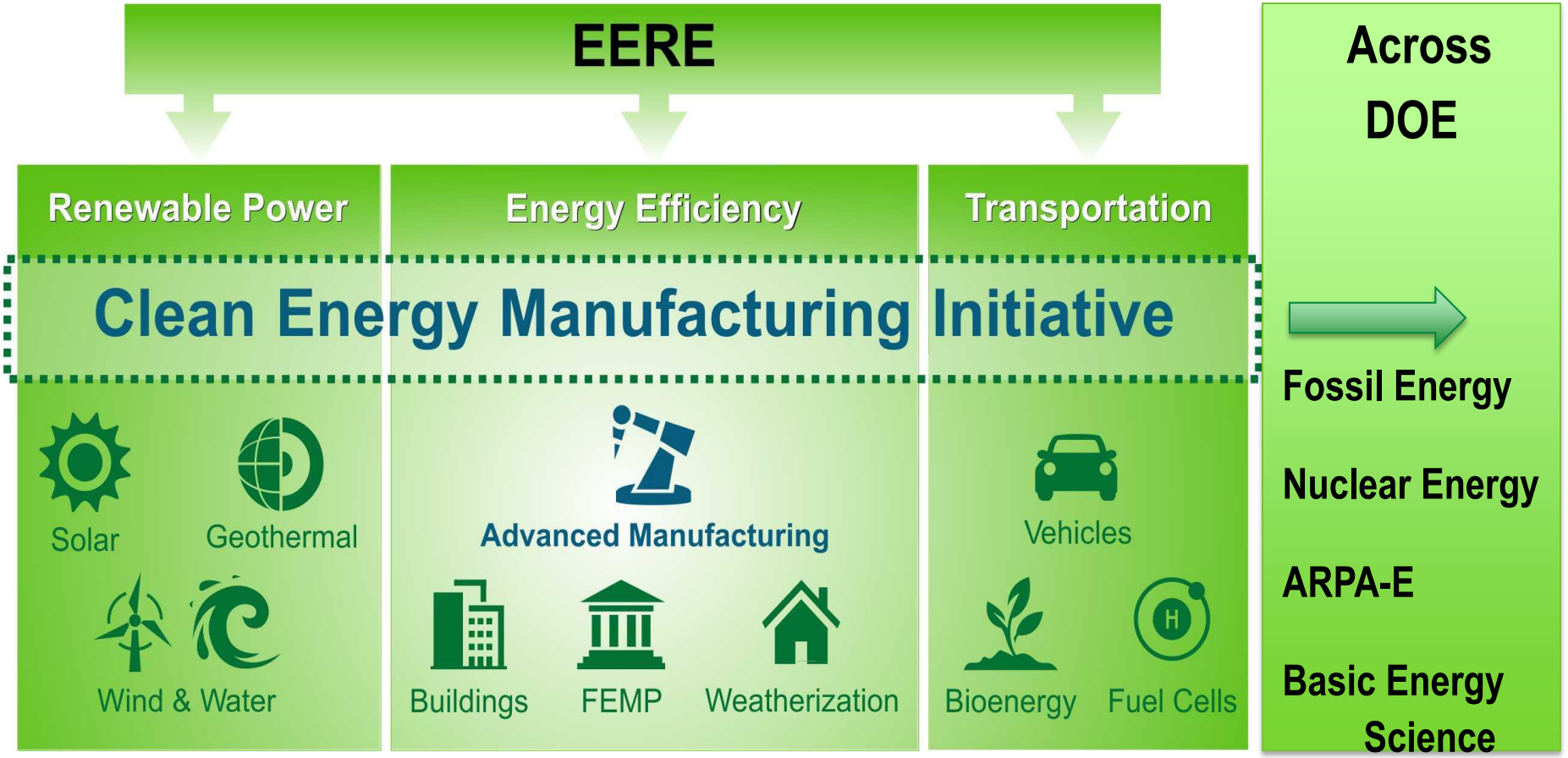
Clean Energy Manufacturing Initiative – DOE



Collaboration toward:

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

Coordination for:

- Comprehensive Strategy
- Collaborative Ideas

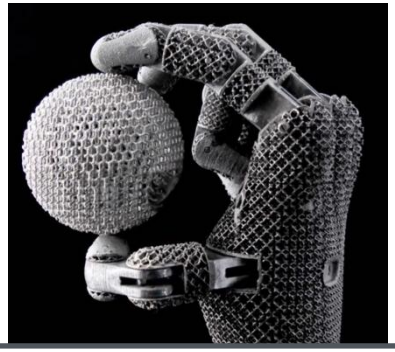
Clean Energy Manufacturing Initiative: 2 Objectives

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

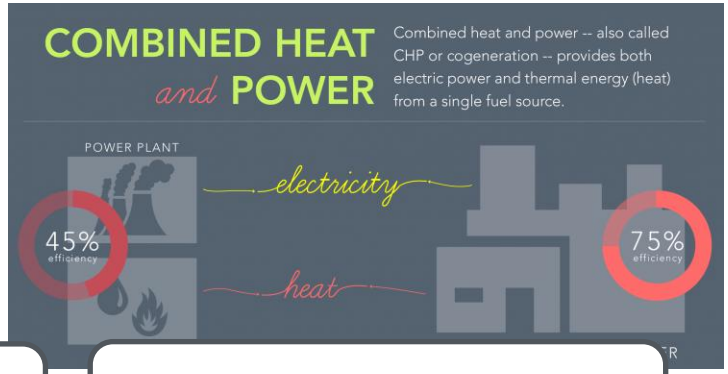
Products that generate clean energy

Products that save energy

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



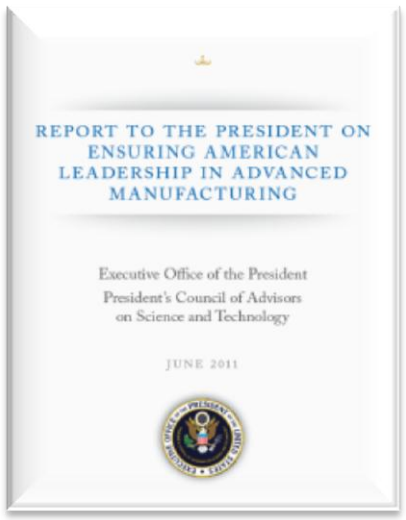
Advanced Manufacturing Technologies

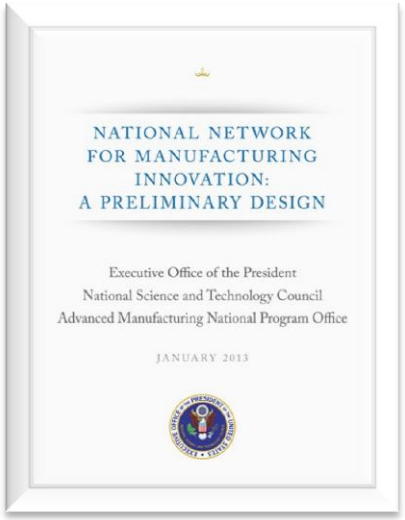


Combined Heat & Power

Industrial Energy Efficiency

National Manufacturing Policy & DOE's Role





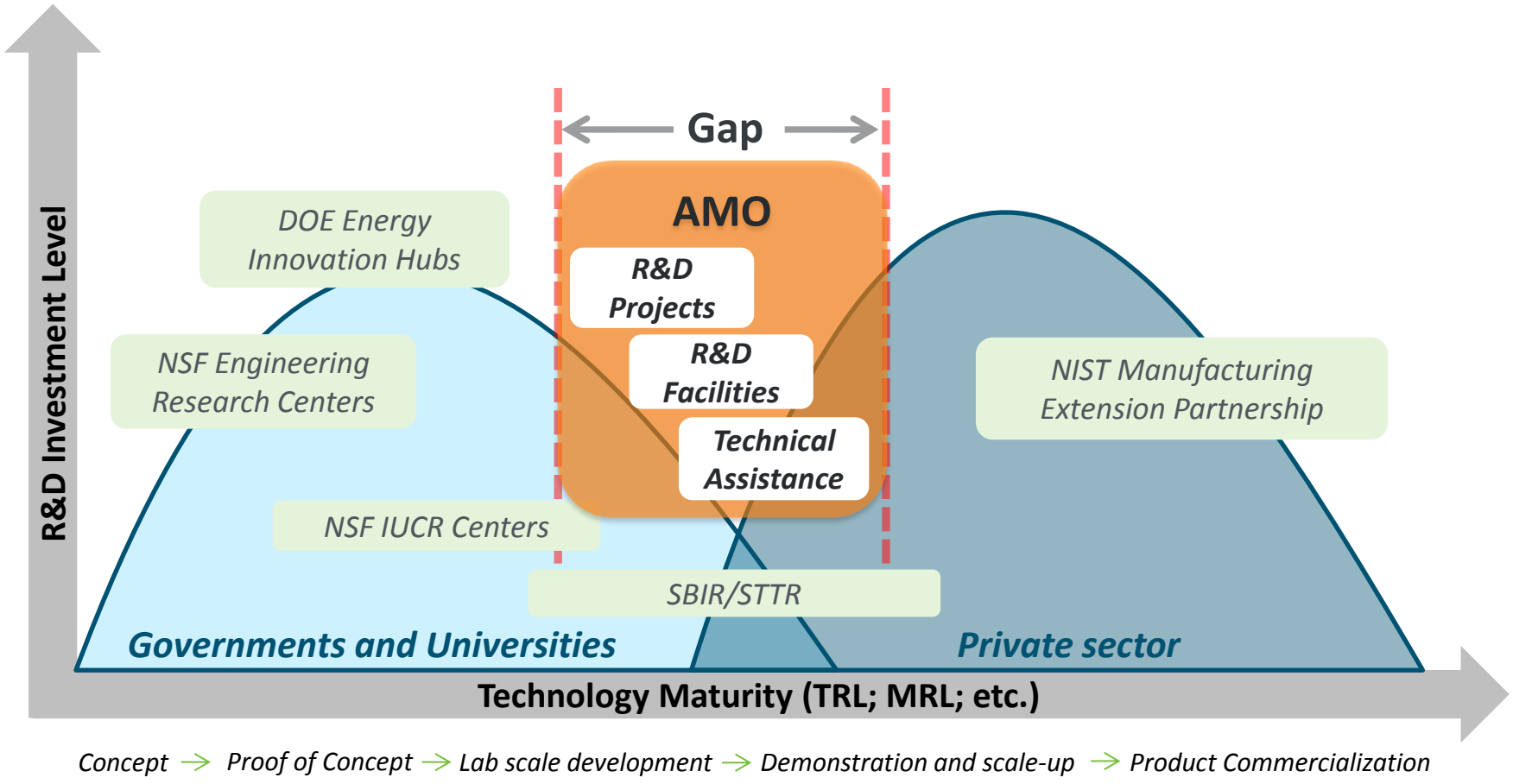
- DOE is active across the pillars of the Administration's Policy & in several resulting efforts
- DOE is a leader in **advanced manufacturing innovation** and implementing the **National Network for Manufacturing Innovation (NNMI)**

NNMI:

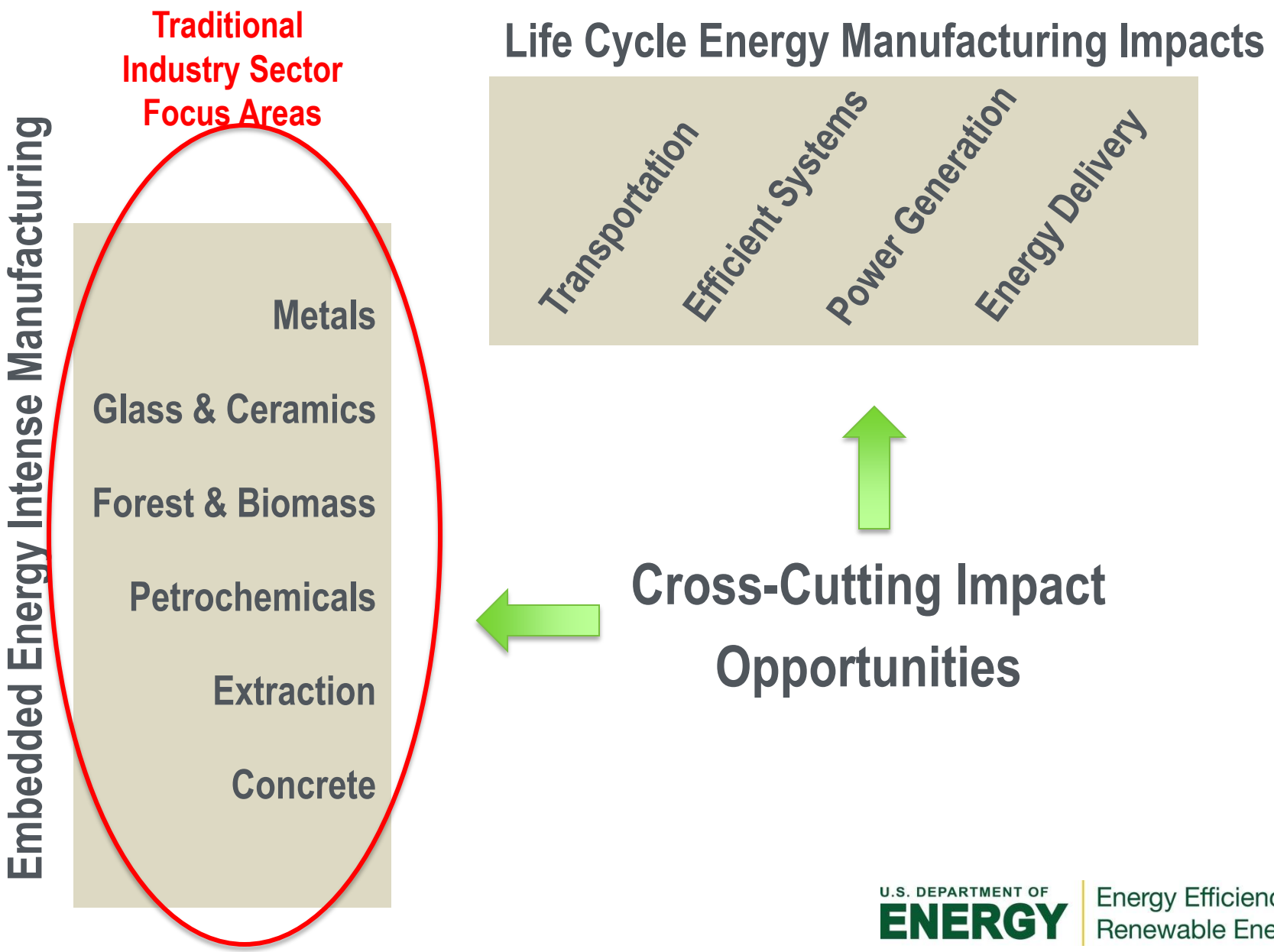
Energy Efficiency & Renewable Energy

Bridging the Gap to Manufacturing

AMO: Advanced Manufacturing Office



Manufacturing Sector Whitespace



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, Modeling and Platforms (ie. Smart Manf.)
  - Advanced Chemical Process Intensification
  - Grid Integration of Manufacturing (CHP and DR)
  - Sustainable Manufacturing (Water, New Fuels & Energy)
- **Emergent Topics in Manufacturing**

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Better Plants Program

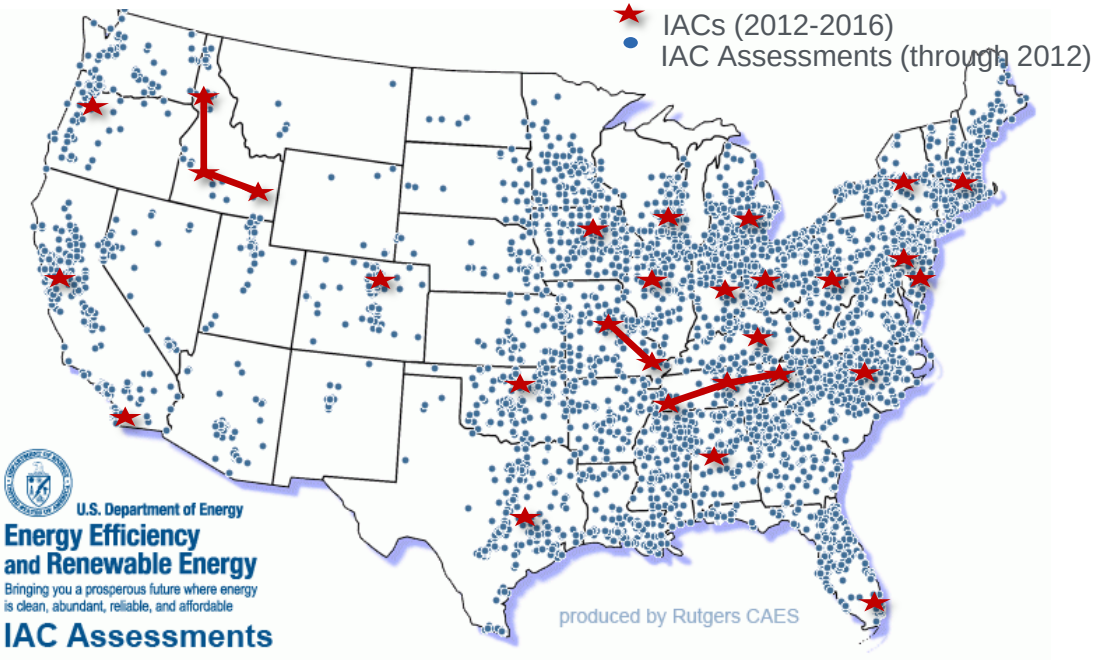
- Voluntary pledge to reduce energy intensity by 25% over ten years over all facilities
- Over 120 Program Partners, over 1,750 plants, ~8% of the total U.S. manufacturing energy footprint
- Partners implement cost-effective energy efficiency improvements that:
  - Save money
  - Create jobs
  - Promote energy security
  - Strengthen U.S. manufacturing competitiveness

Better Plants
U.S. DEPARTMENT OF ENERGY

- **Through the Better Plants Program, companies receive national recognition and technical support from DOE**

Industrial Assessment Centers (IACs)

- IAC Program: Targets Energy Savings in Small-Medium Size Firms
- 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



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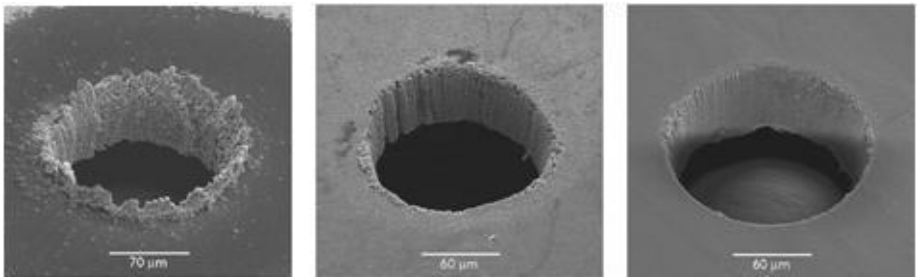
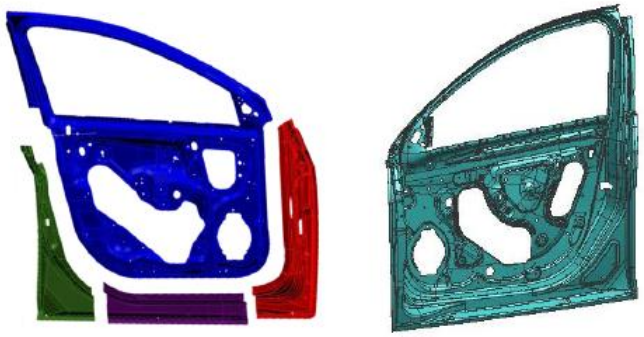
R&D Projects – Manufacturing Processes

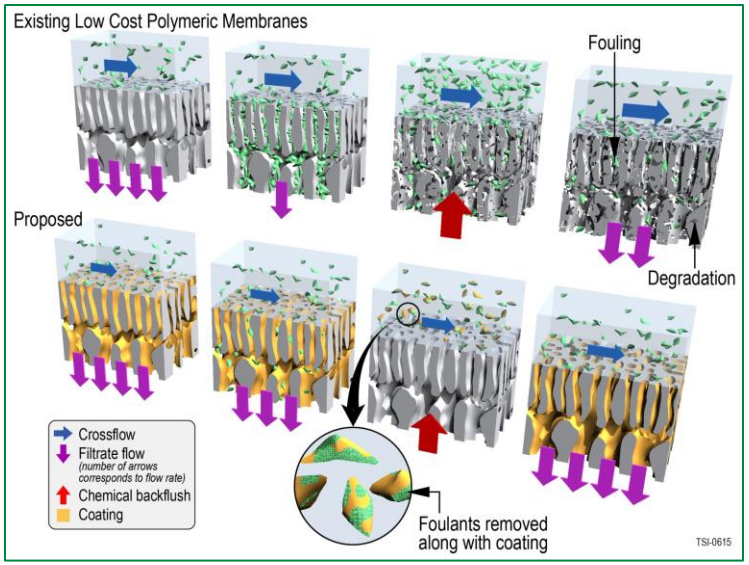


Ultrafast, femtosecond pulse lasers (right) will eliminate machining defects in fuel injectors.
Image courtesy of Raydiance.



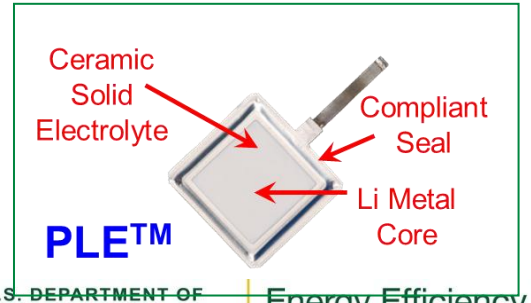
Energy-efficient large thin-walled magnesium die casting, for 60% lighter car doors.

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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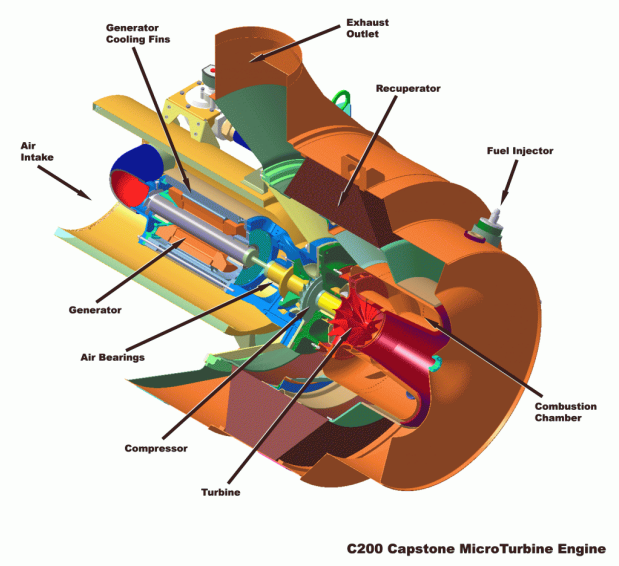
R&D Projects: Combined Heat and Power (CHP)

Advanced MicroTurbine System (AMTS) R&D Program

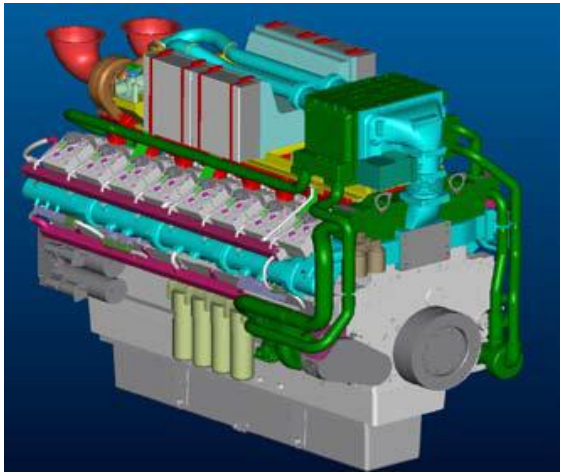


C200 Capstone MicroTurbine Engine

C200 MicroTurbine Engine

Capstone photos source: capstoneturbines.com

Advanced Reciprocating Engine Systems (ARES) R&D Program



QSK60G engine

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Shared R&D Facilities

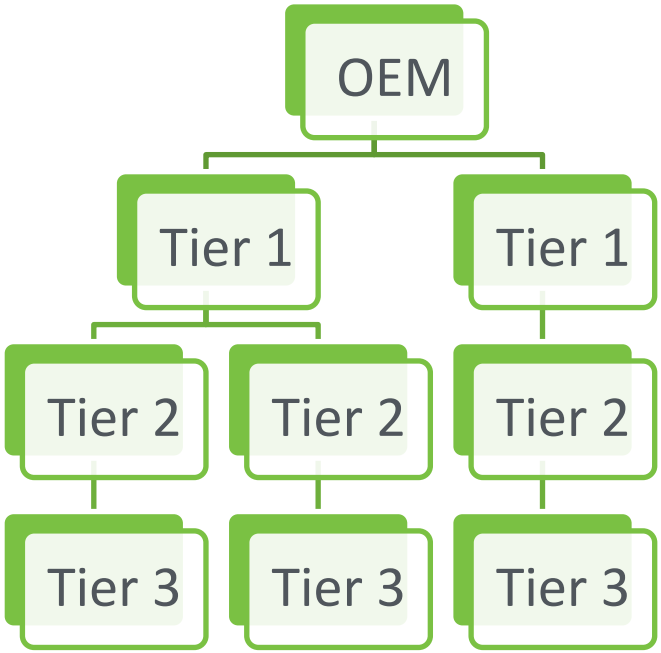
- Address market disaggregation to rebuild the industrial commons

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?**

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)

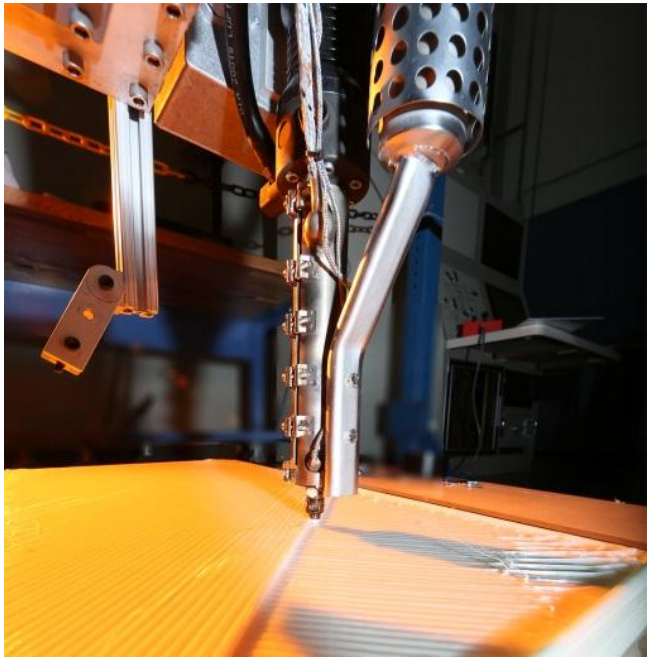
DOE Assistant Secretary David Danielson during ribbon cutting ceremony of the Carbon Fiber Technology Facility at Oak Ridge National Laboratory. Carbon fiber has the potential to improve the fuel efficiency of vehicles.

Photo courtesy of Jason Richards, Oak Ridge National Laboratory.

Manufacturing Demonstration Facility at Oak Ridge National Lab

Supercomputing Capabilities

Spallation Neutron Source



America Makes

Additive Manufacturing

Arcam electron beam processing AM equipment

POM laser processing AM equipment

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

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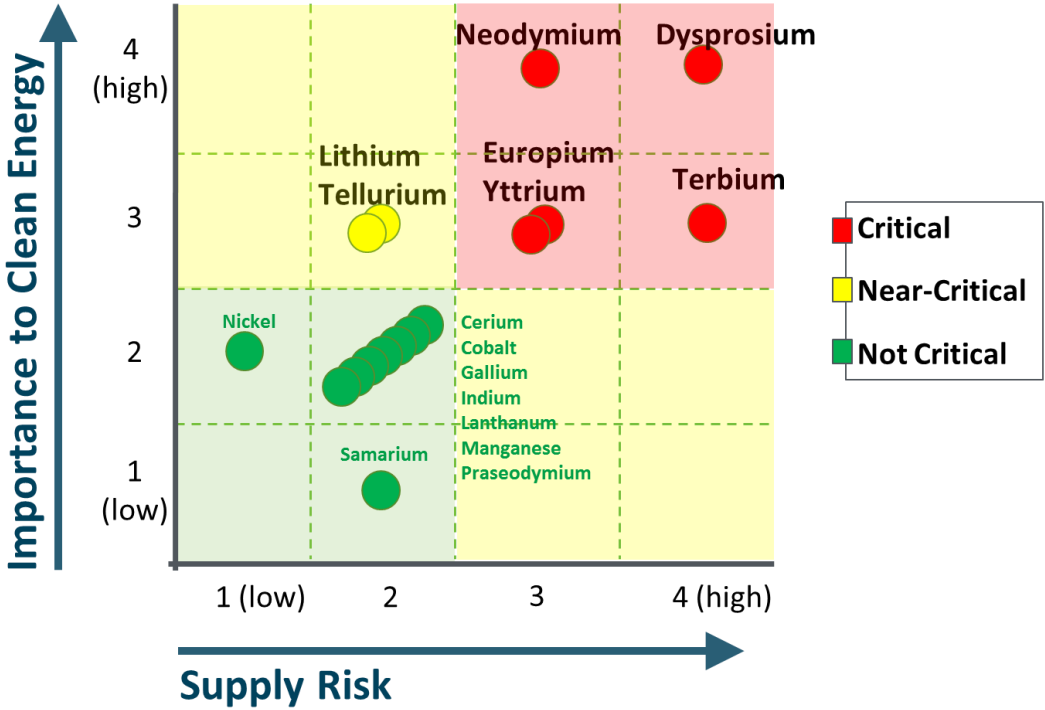
CMI Accelerating Energy Innovations

Critical Materials Institute

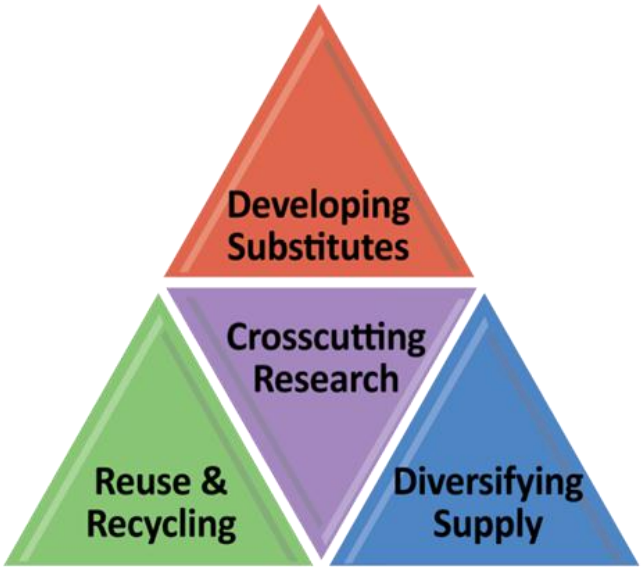
A DOE Energy Innovation Hub

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

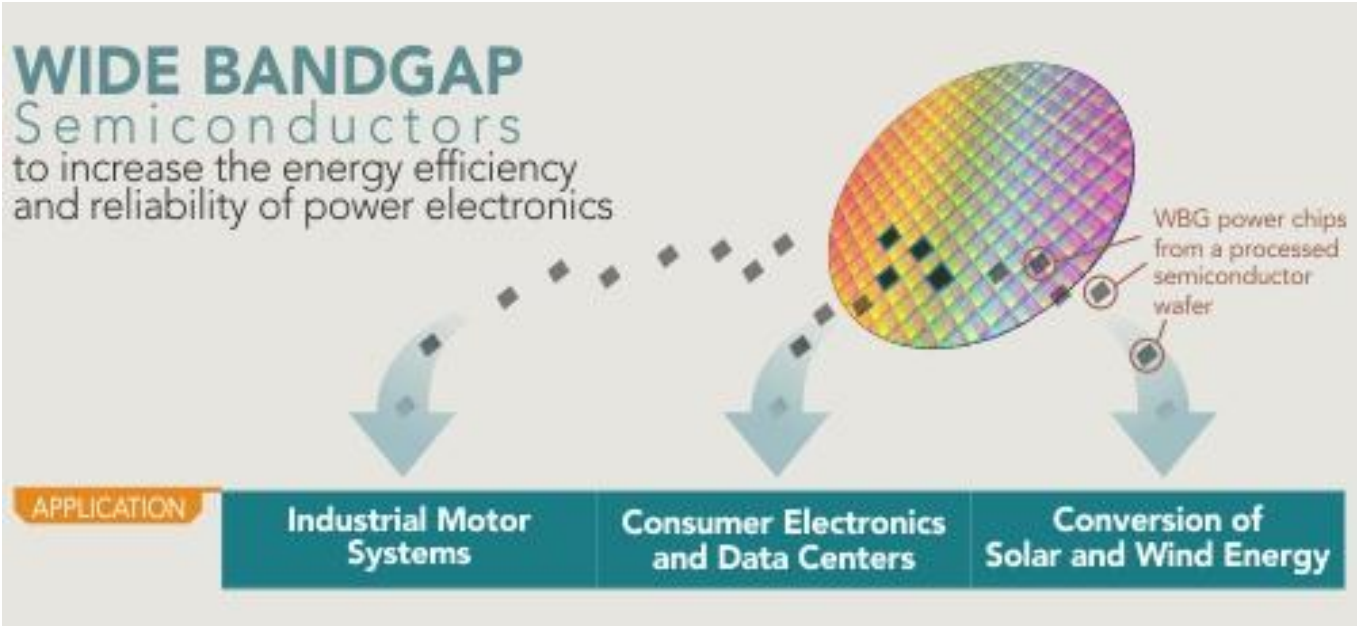


	Dy	Eu	Nd	Tb	Y	Li	Te
Lighting		✓		✓	✓		
Vehicles	✓		✓			✓	
Solar PV							✓
Wind	✓		✓				

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



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.

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  - Advanced Chemical Process Intensification
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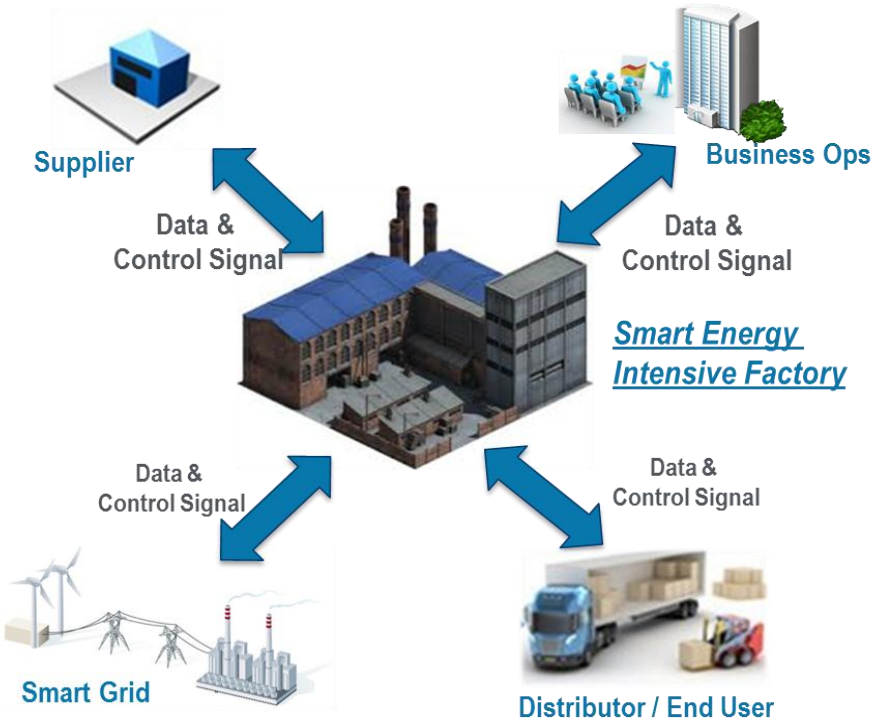
- **Emergent Topics in Manufacturing**

Advanced Controls, Sensors, Models & Platforms for Energy Intensive Process & Clean Energy Productivity



Smart factories will be interconnected with supply chain, distribution, and business systems.

- Encompass machine-to-plant-to-enterprise-to-supply-chain aspects of sensing, instrumentation, monitoring, control, and optimization
- Enable hardware, protocols and models for advanced industrial automation: requires a holistic view of data, information and models in manufacturing
- Leverage High Performance Computing for High Fidelity Process Models
- Significantly reduce energy consumption and GHG emissions & improve operating efficiency – **20% to 30% potential**
- Increase productivity and competitiveness across all manufacturing sectors: Special Focus on Energy Intensive Manufacturing Processes

Leverages AMP 2.0

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

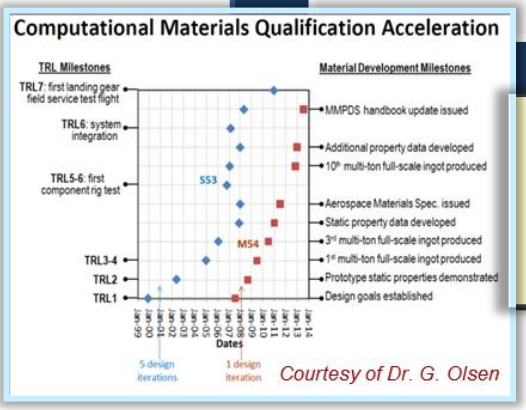
leveraging and expanding on the current MGI multi-physics, multi-scale computational base

feedback pathways

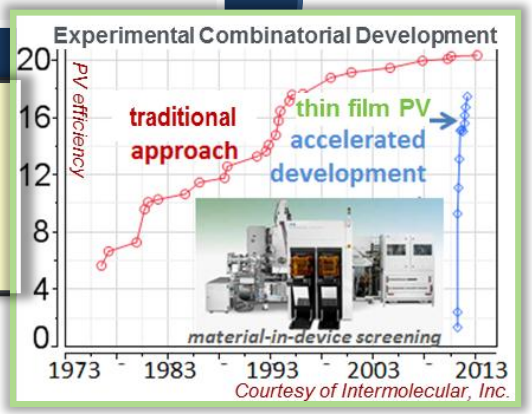
High Throughput Synthesis, Characterization & Analysis Capabilities

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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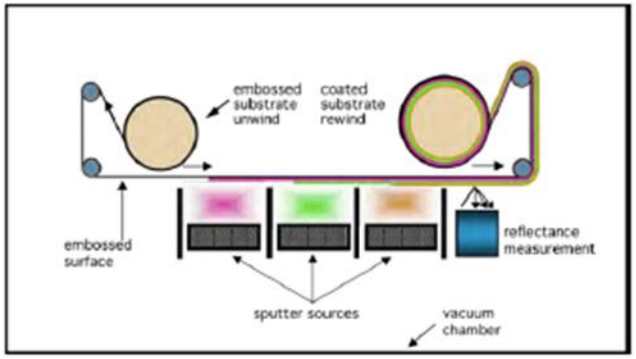
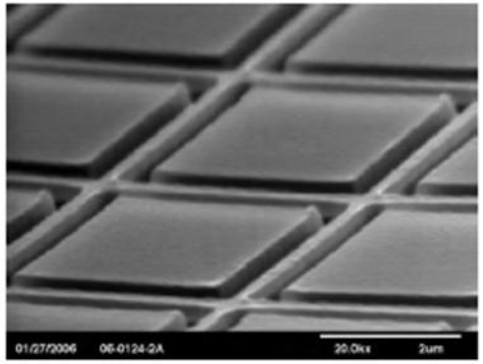
2D Fabrication / Advanced Roll-to-Roll Manufacturing

- **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**

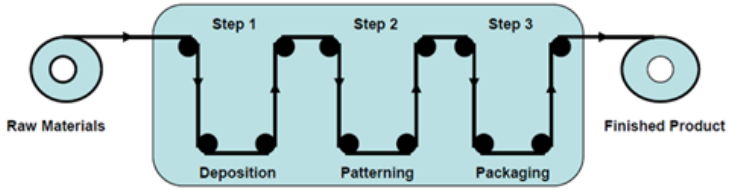
- **<u>Potential Energy Applications</u>:**

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





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



Idealized R2R Process Methodology

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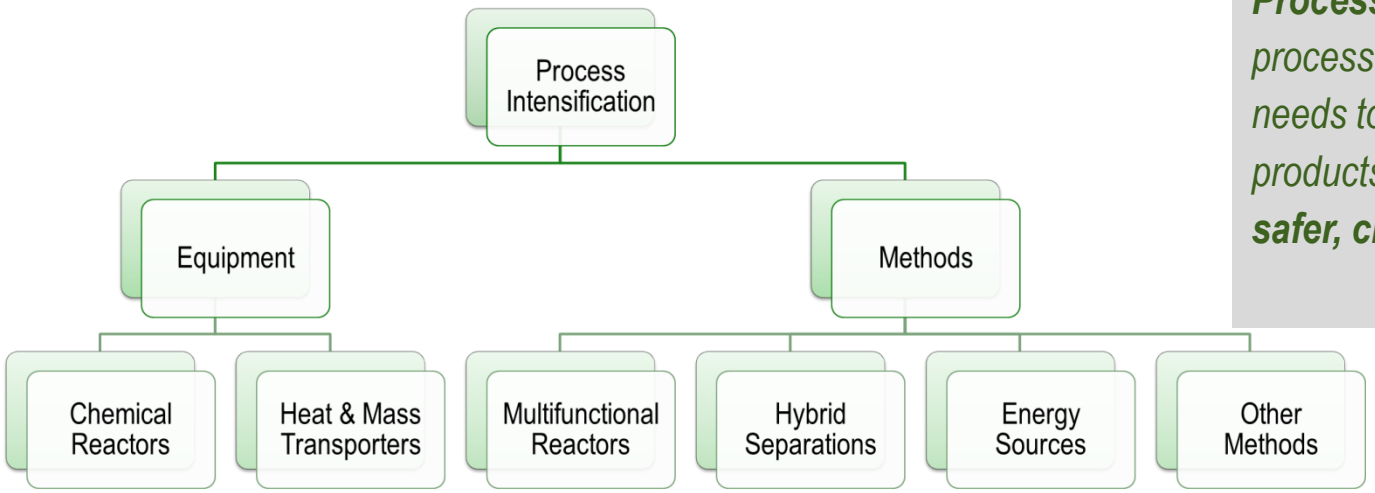
Modular Chemical Process Intensification



- 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, Power Generation, Sustainable Fuels

Technical Issue 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 Facility Structure?

Technical Issue Identification Criteria: High Impact

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?

- What is manufacturing challenge to be solved?
- If solved, how does this impact clean energy goals?
- If solved, who will care and why specifically?

Technical Issue Identification Criteria: Additionality

EERE Core Questions	Application to NNMI Topic Selection
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?

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- Who else might fund this mid-TRL development & how might EERE/AMO support catalyze this co-investment?

Technical Issue Identification Criteria: Openness

EERE Core Questions	Application to NNMI Topic Selection
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?

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- Is there Fertile low-TRL Scientific Base to Address the Challenge?
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Technical Issue Identification Criteria: Enduring Benefit

EERE Core Questions	Application to NNMI Topic Selection
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?

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- Is Industry Currently Trying to Identify Solutions?

Technical Issue Identification Criteria: Proper Role

EERE Core Questions	Application to NNMI Topic Selection
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?

- 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?

Technical Issue Identification Criteria: Modality

EERE Core Questions	Application to NNMI Topic Selection
+ Appropriate Mechanism	• Why is this specific mid-TRL Problem Best Addressed through a 5-Year, Multi-participant, Industry-oriented Facility Structure?

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Possible Metrics

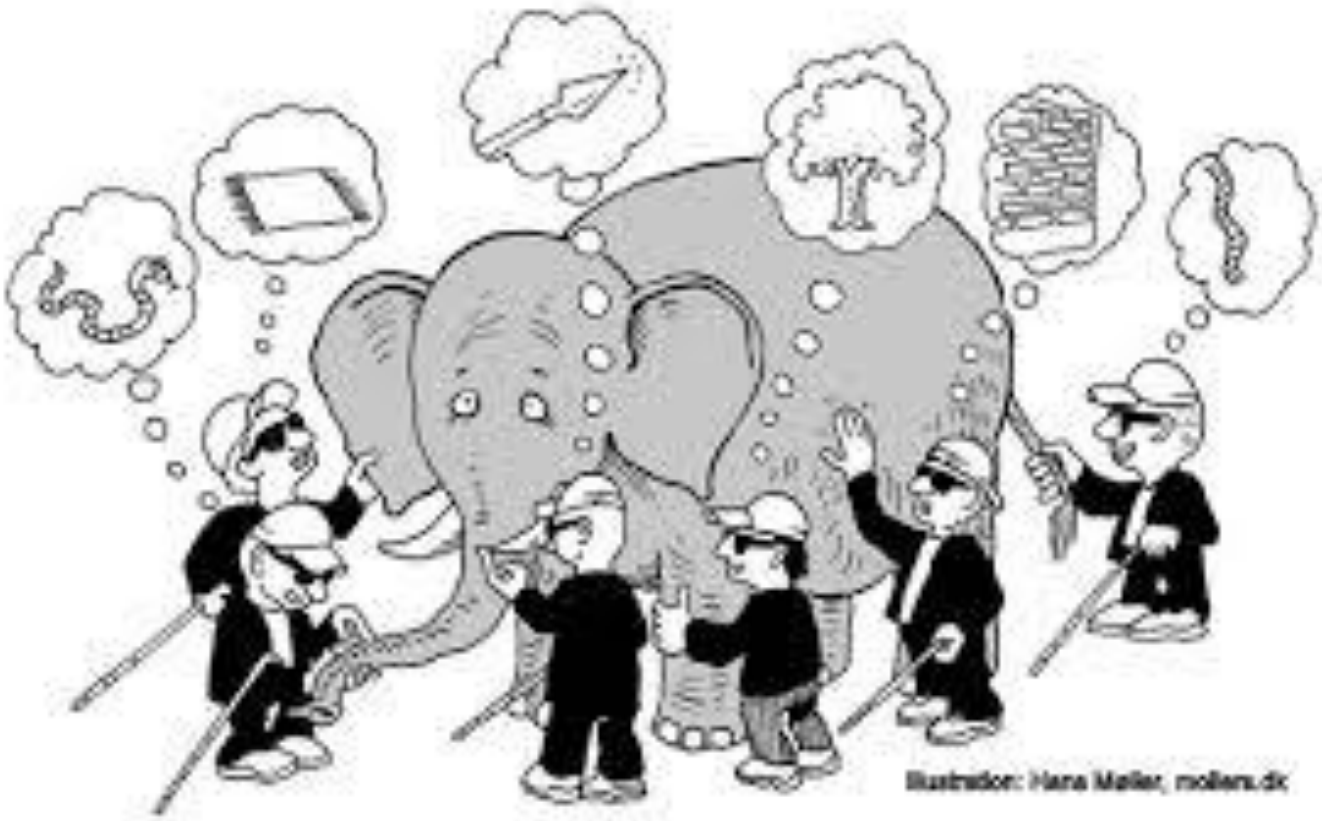
- Cost vs. Scale – bend scaling curve by x%
- Scale-up Costs Predictability and Technical Uncertainly
- Product Costs:
  - Product Transportation vs Supply Transportation
  - Capital Efficiency vs. Material/Energy Efficiency
- Non-Recurring Engineering Costs
  - First of Kind Demonstration – Test Beds
  - N-th of Kind Deployment
- Supply Chain / Ecosystem Uncertainty
- Specific Pre-Competitive Challenges
- Need Cost to Reach Parity: $/kW or $/kWh

Poor Metrics – In Isolation

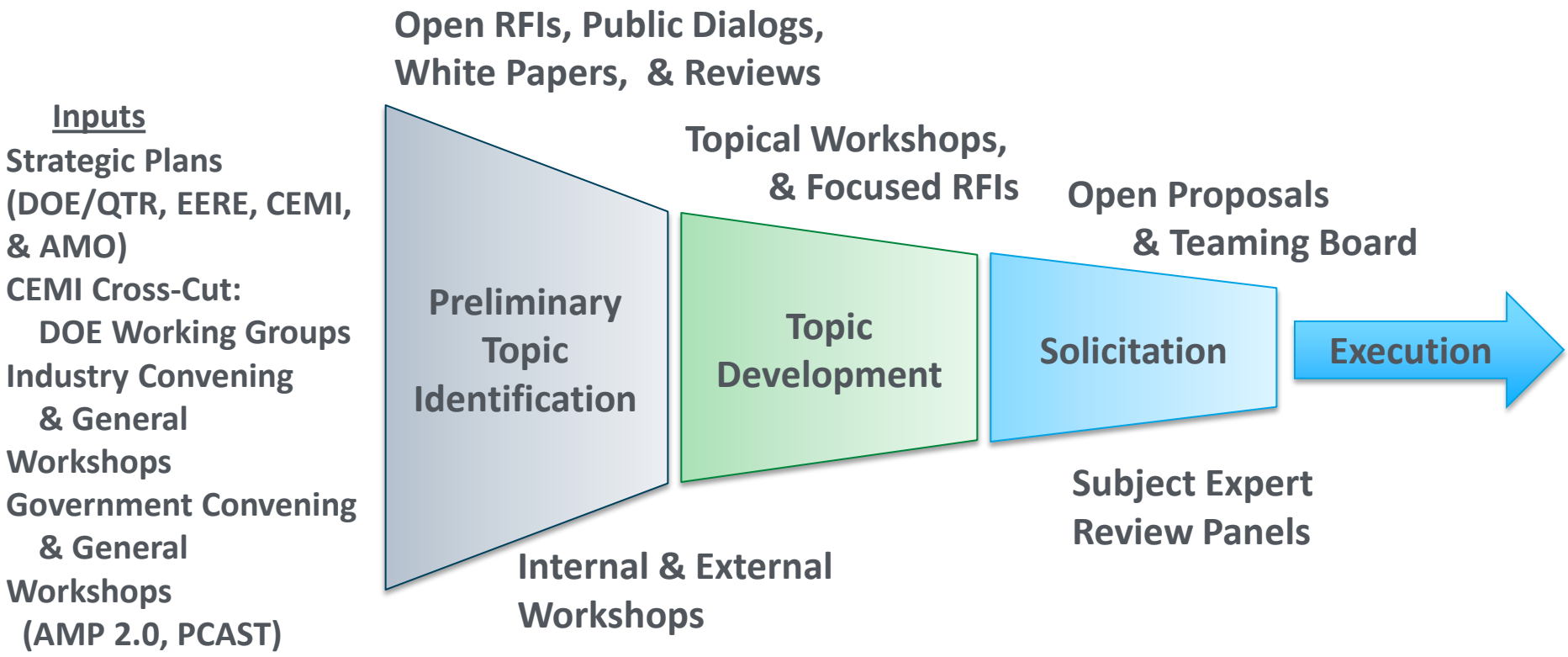
- This Problem is Risky
- This Problem is Expensive
- It is Hard to Find Financing
- An Industry is Interested in this Problem
- We will have Impact on the Market, next year!
- The Research is Done,

  All we need to do is go into Manufacturing
- There is a Report that Says this is Important

  I Just Can't Tell You How them Made this Conclusion
- ….


Illustrador: Hans Møller, møllers.dk

General Process : No Timeline



What does Success Look Like?

Energy Products Invented Here…

…And Competitively Made Here!

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

Additional Ground Rules

- Open Public Dialog on Technical Issues
- NO DISCUSSION of Active Solicitations or Actions
- NO Consensus Formation
- NO Policy Recommendations
- Everything in Public Domain

Thank You

Questions?