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

Advanced Manufacturing Office Overview and Clean Water R&D

2017 Clean Water Technology Workshop
Dallas, TX

July 10th, 2017

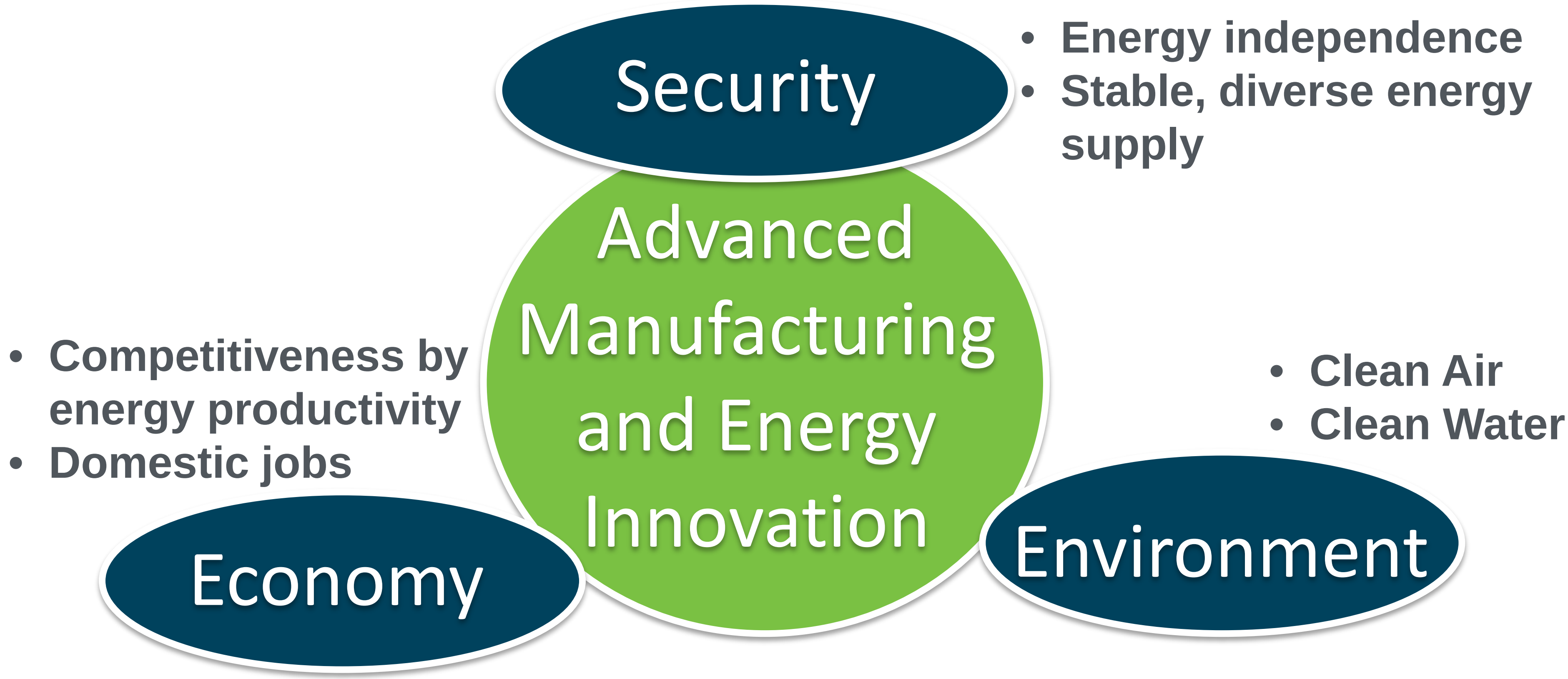
Mark Johnson

Director

Advanced Manufacturing Office

www.manufacturing.energy.gov

Energy and Manufacturing Innovation Today



Technology Innovation through Early-Stage Research and Development
In Manufacturing and Energy is a Foundation for Economic Growth & Jobs

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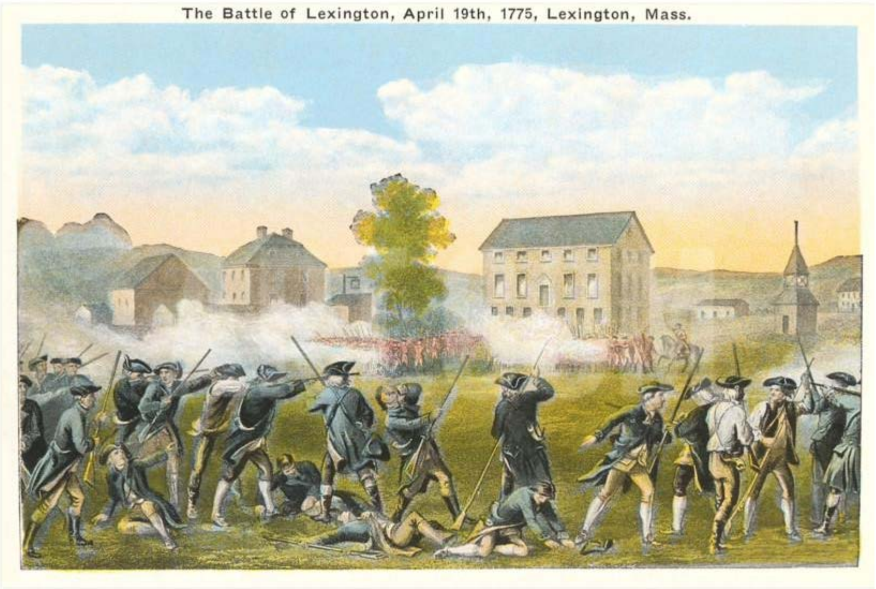
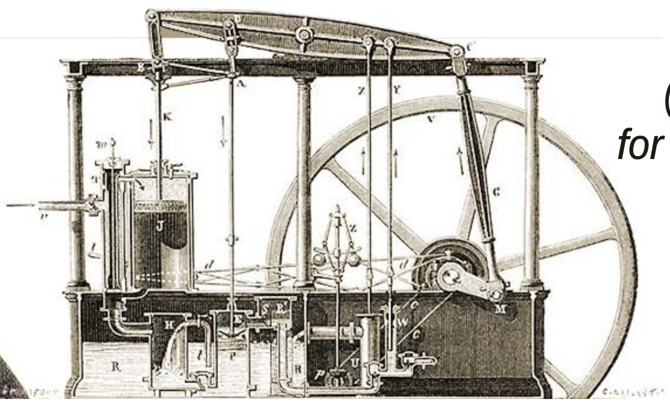
A little history: The Start of a pair of Revolutions



Lexington & Concord

1775

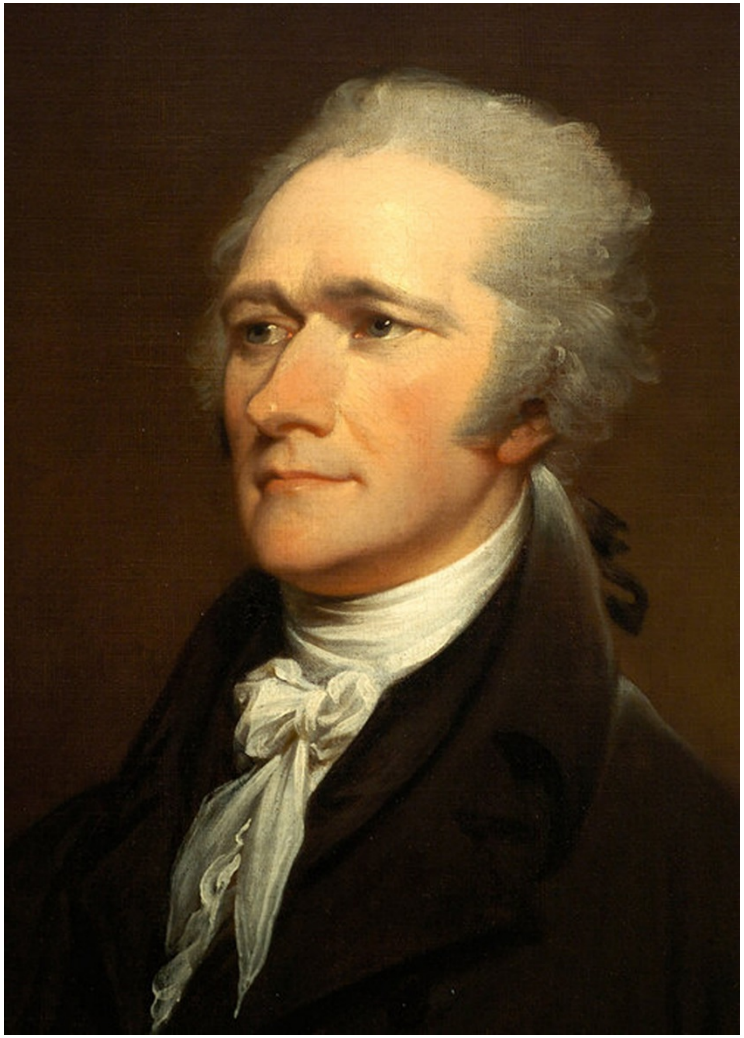


Watt, Boulton & Co.

1775

(intelligence: steam regulation
for external combustion engines)

US Manufacturing Strategy for First Industrial Revolution



"… the encouragement of manufactures is the interest of all parts of the Union."

"Not only the wealth; but the independence and security of a country, appear to be materially connected with the prosperity of manufactures."

"… it is the interest of a community with a view to eventual and permanent economy, to encourage the growth of manufactures."

- Alexander Hamilton
US Treasury Secretary (1789-1795)

Reports to Congress

First Report on the Public Credit - 1790
Second Report on Public Credit - 1791
Report on the Subject of Manufactures - 1791

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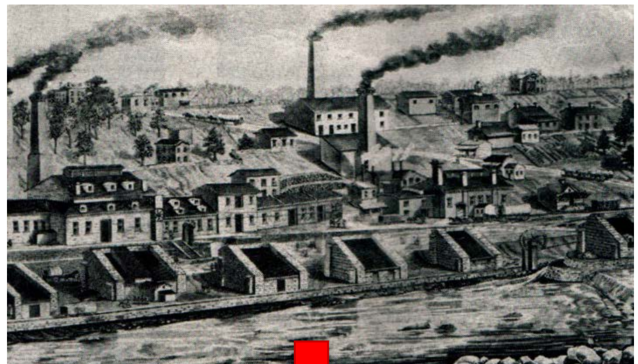
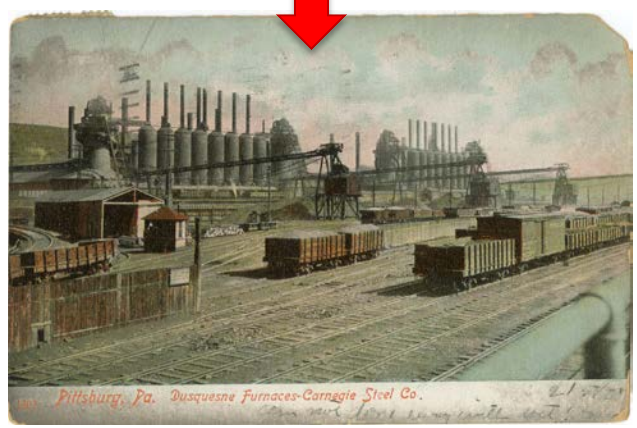
Second Industrial Revolution

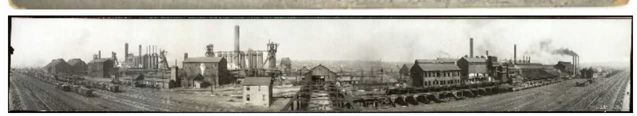
Electrification

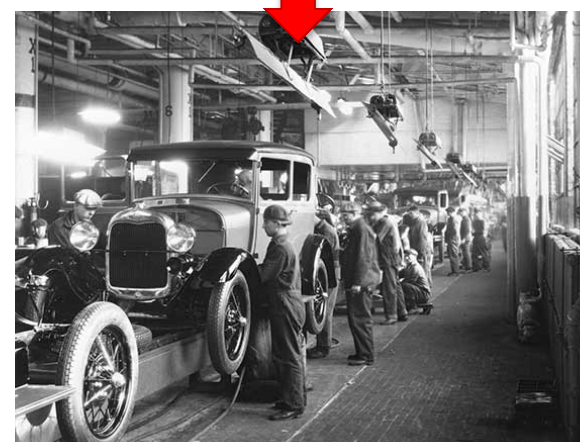
Process Scaling Energy & Materials

Standardization & Assembly Line









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Energy Intensive Industries -Today

Primary Metals
1608 TBTU

Petroleum Refining
6137 TBTU

Chemicals
4995 TBTU

Wood Pulp & Paper
2109 TBTU

Glass & Cement
716 TBTU

Food Processing
1162 TBTU

Other Manufacturing
~1600 TBTU

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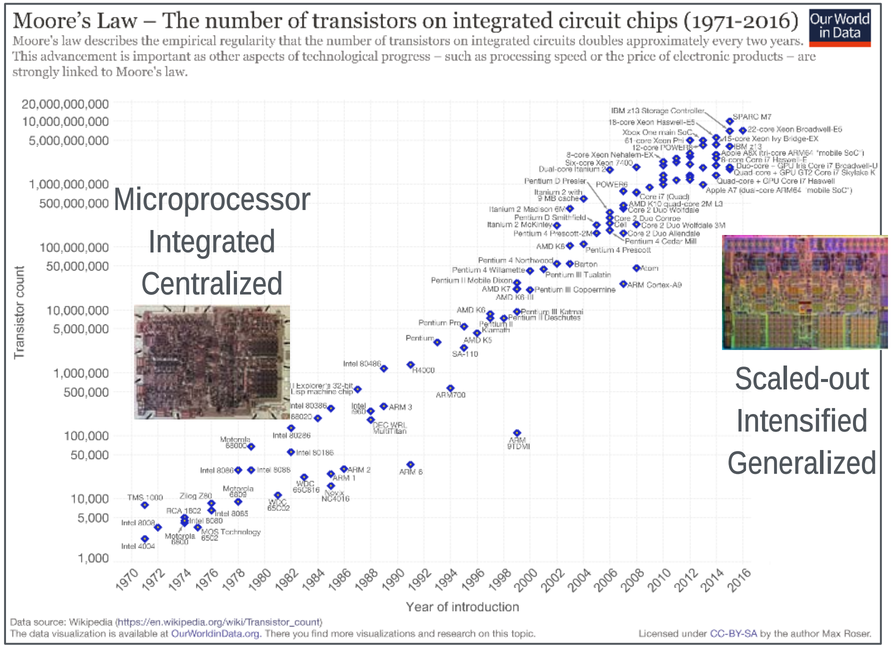
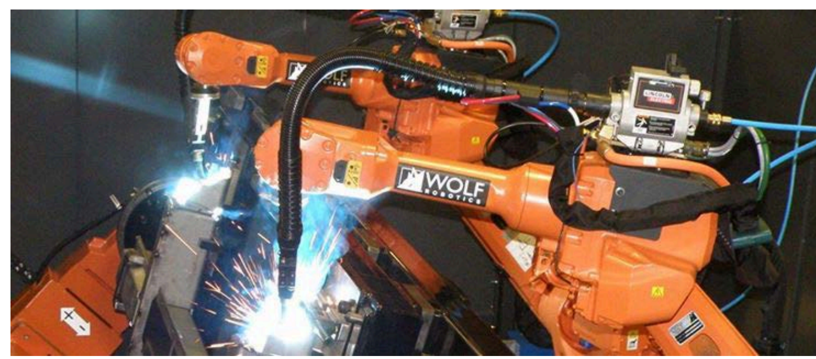
Third Industrial Revolution - Today





How will Manufacturing, Economy and Security of the Nation depend on Information, Computation, Actuation and Communication Technologies in the 21st Century?

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Processes for Clean Energy Materials & Technologies

Energy Dependence: Energy Cost Considered in Competitive Manufacturing

Solar PV Cell

Carbon Fibers

Light Emitting Diodes

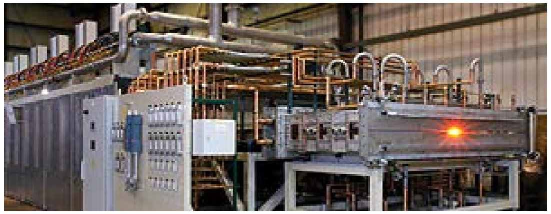
Electro-Chromic Coatings

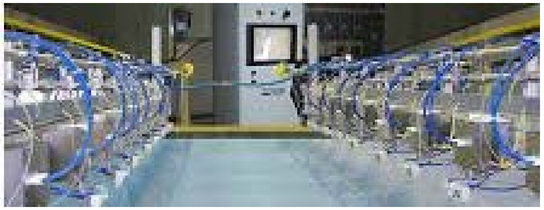
Membranes

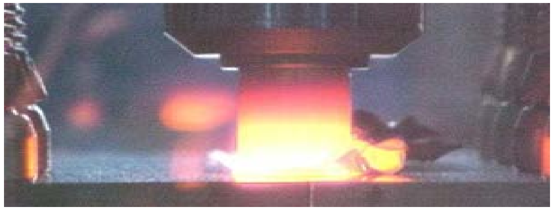
EV Batteries

Multi-Material Joining

Water Desalination







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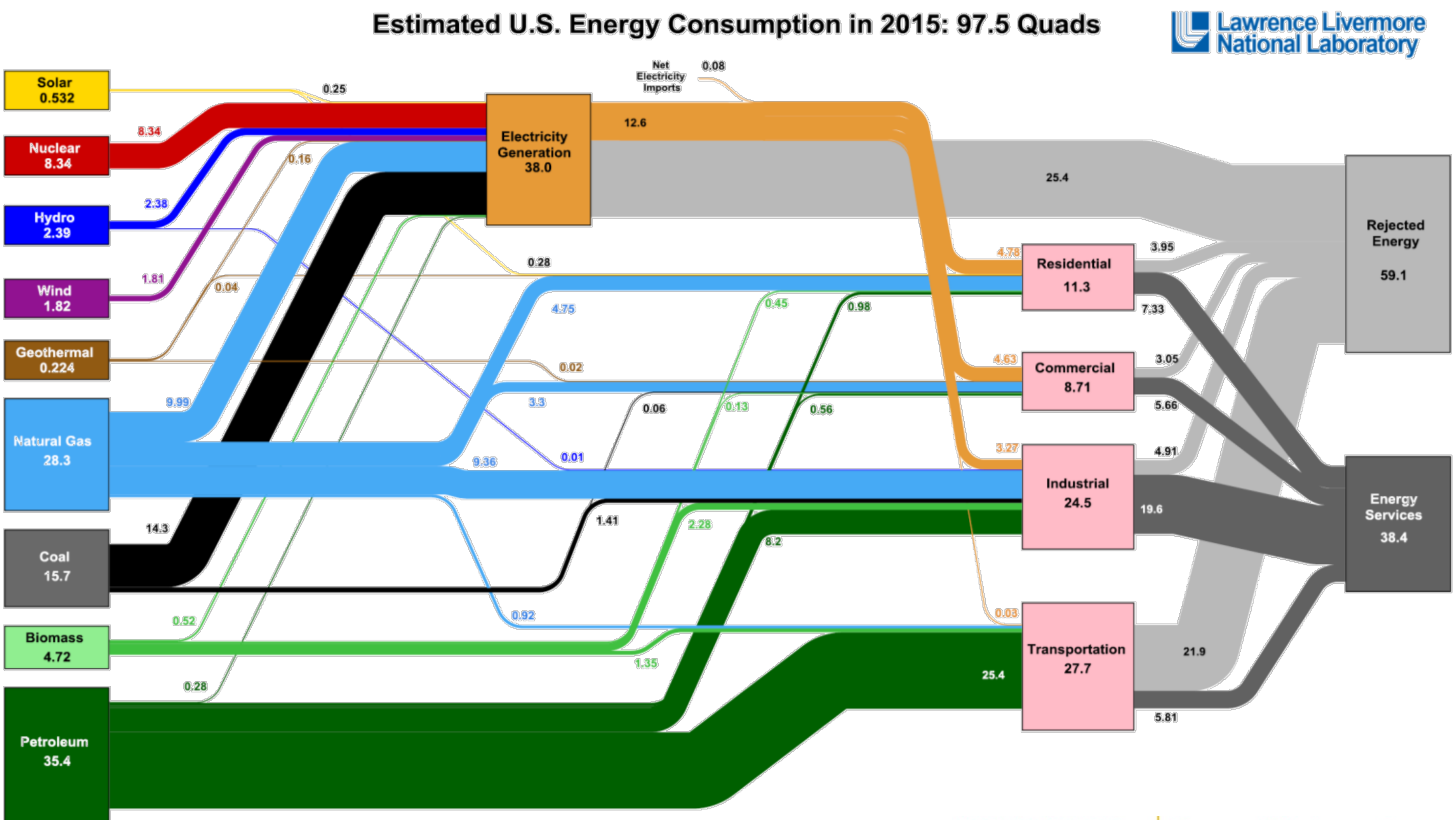
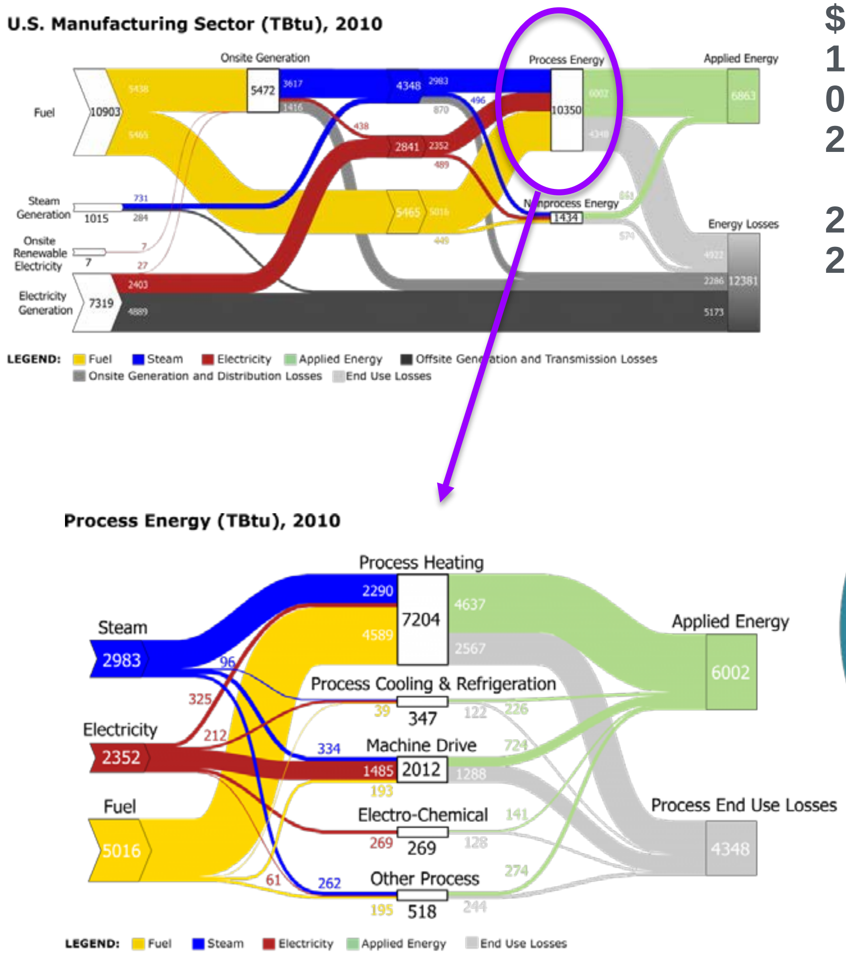
Energy Use in the US Economy



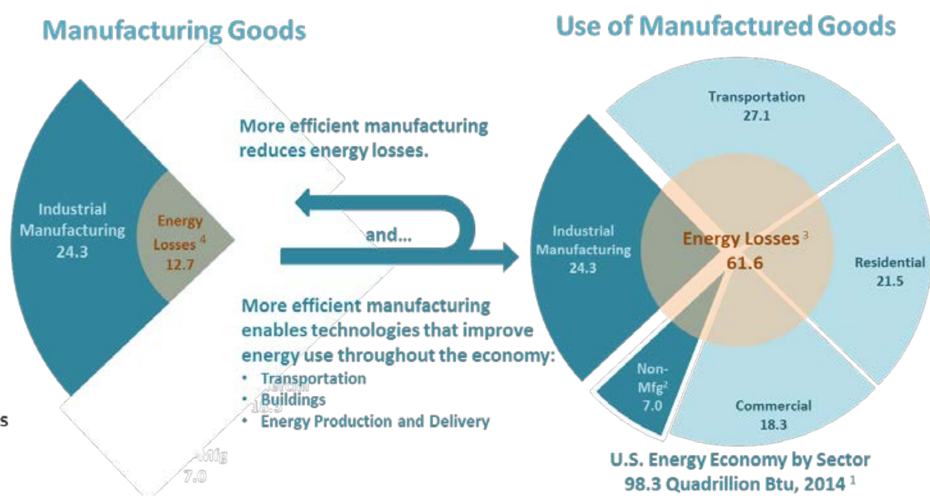
Advanced Manufacturing -- Opportunity

Technology Innovation through Early Stage R&D in Advanced Manufacturing and Energy is a Foundation for Economic Growth and Jobs in the US



$2T Manufacturing GDP
12.4M Manufacturing Direct Employment Jobs
0.8 / 1.0 – Indirect / Direct Jobs - All Manufacturing
2.2 / 1.0 – Indirect / Direct Jobs - Advanced Sub-Sectors

24 QBTU (25% of National Total) – Manufacturing
2/3 Manufacturing Energy is in Intensive Sectors



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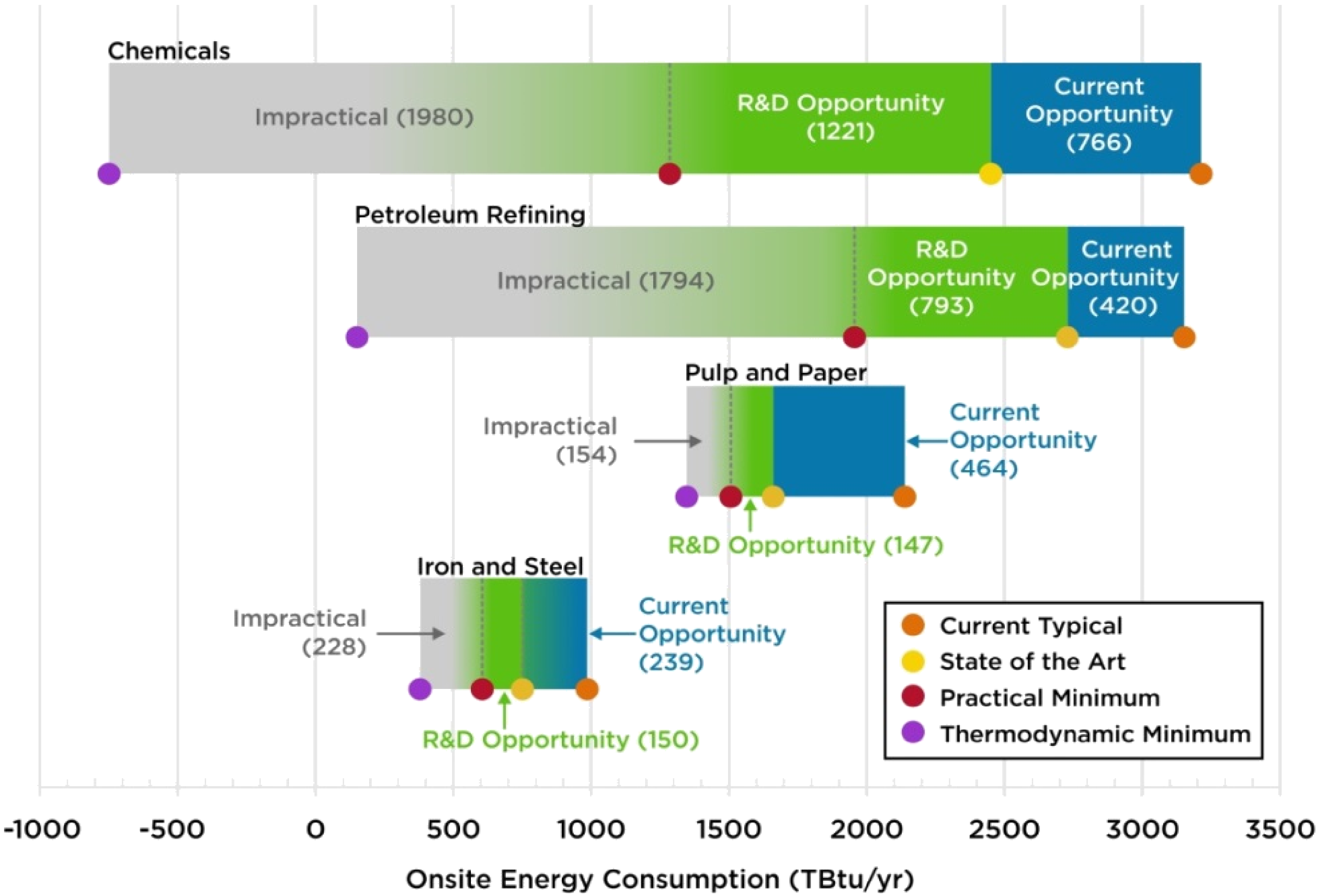
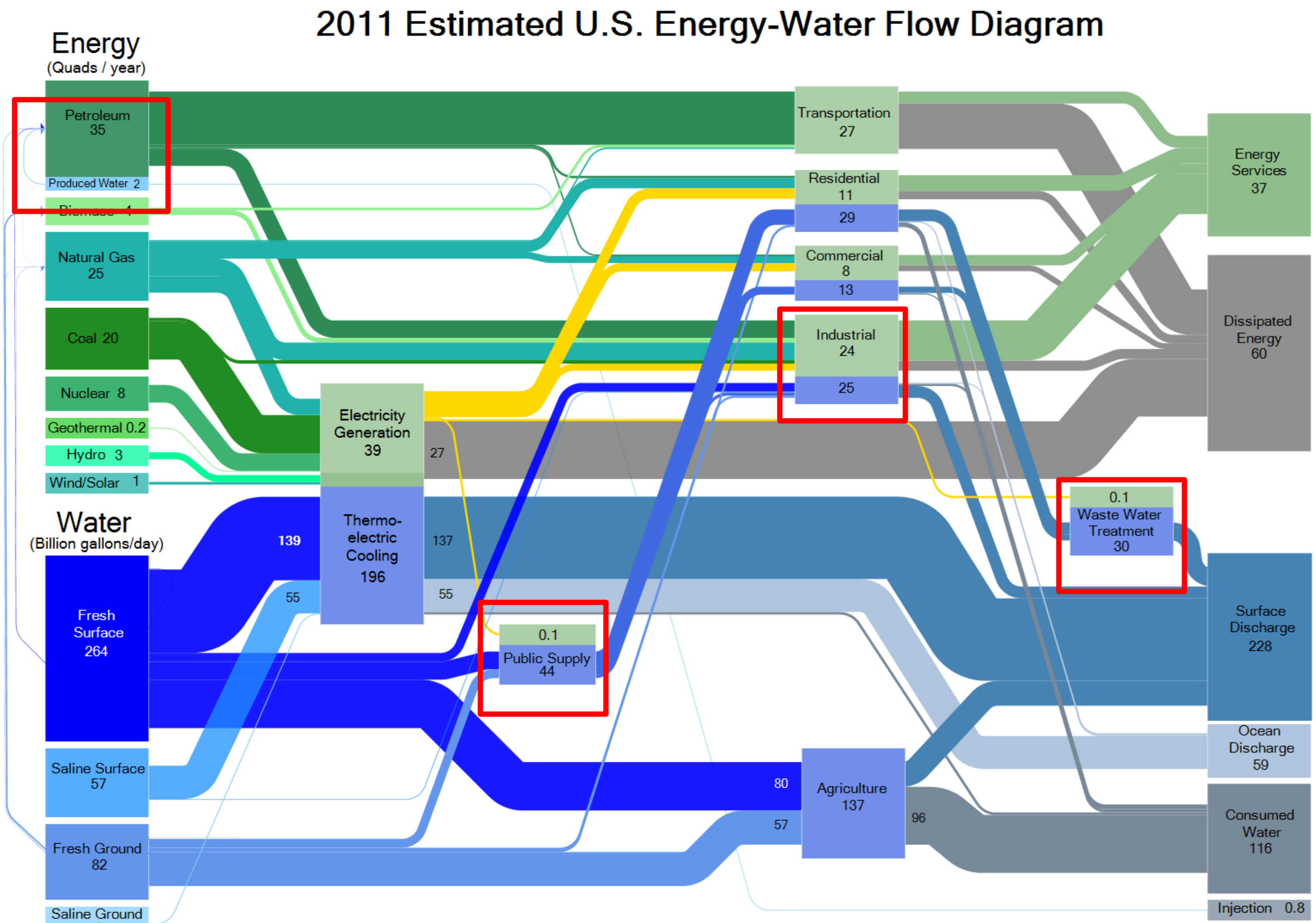
QTR, 2015

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

Clean water challenges are Energy challenges



Energy reported in Quads/year. Water reported in Billion Gallons/Day.

7/13/2017

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Advanced Manufacturing Office Framework

Focus on Early Stage Applied Research and Development

Technology Areas with Knowledge Gaps Applicable to Manufacturing and Energy

Merit-based R&D at National Laboratories, Universities, Companies (for profit and not for profit) and Consortia

Partner with Private Sector to Identify Technical Knowledge Gaps and Transfer Learning for Subsequent Adoption

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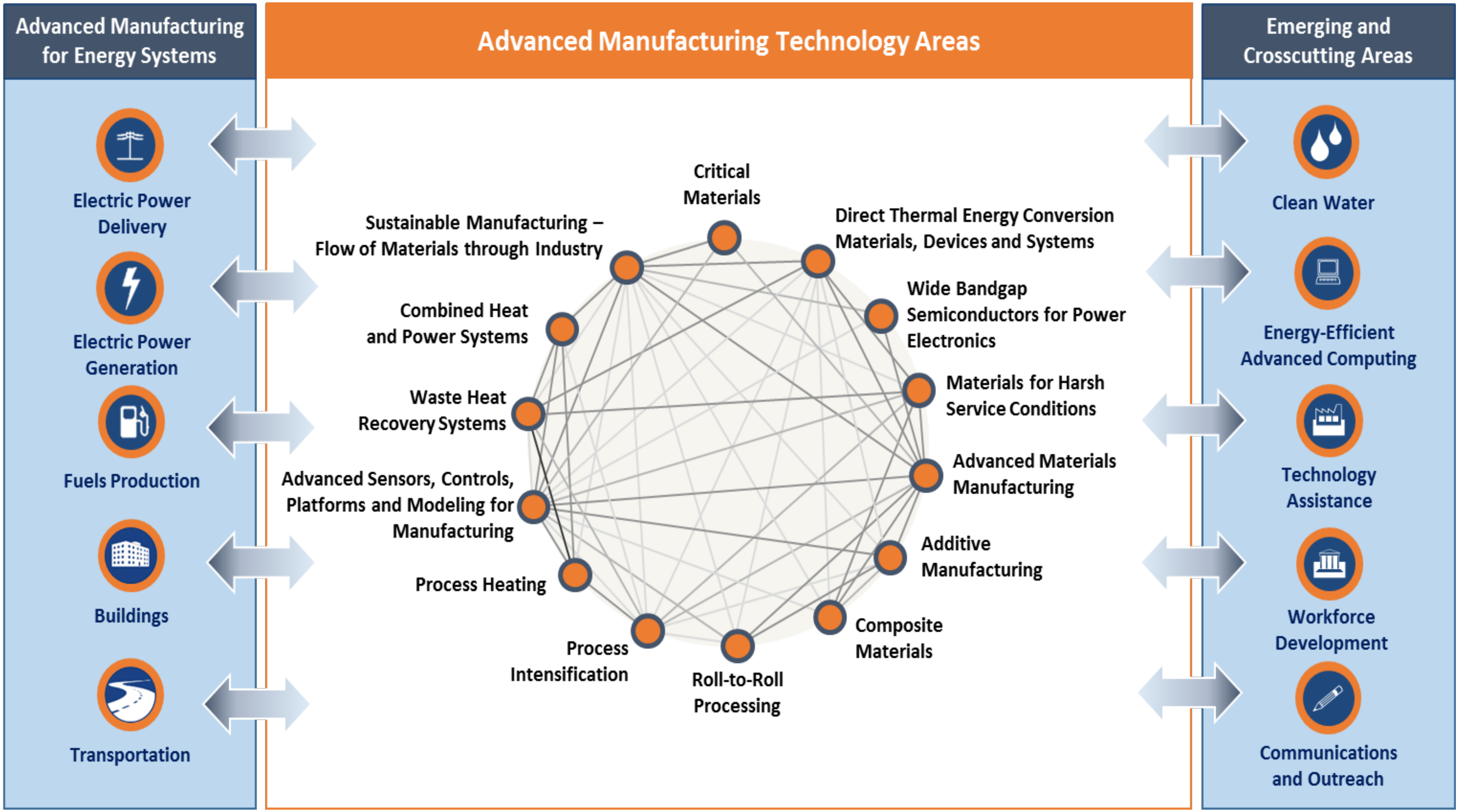
AMO Technical Focus Areas (2017 MYPP / DRAFT)



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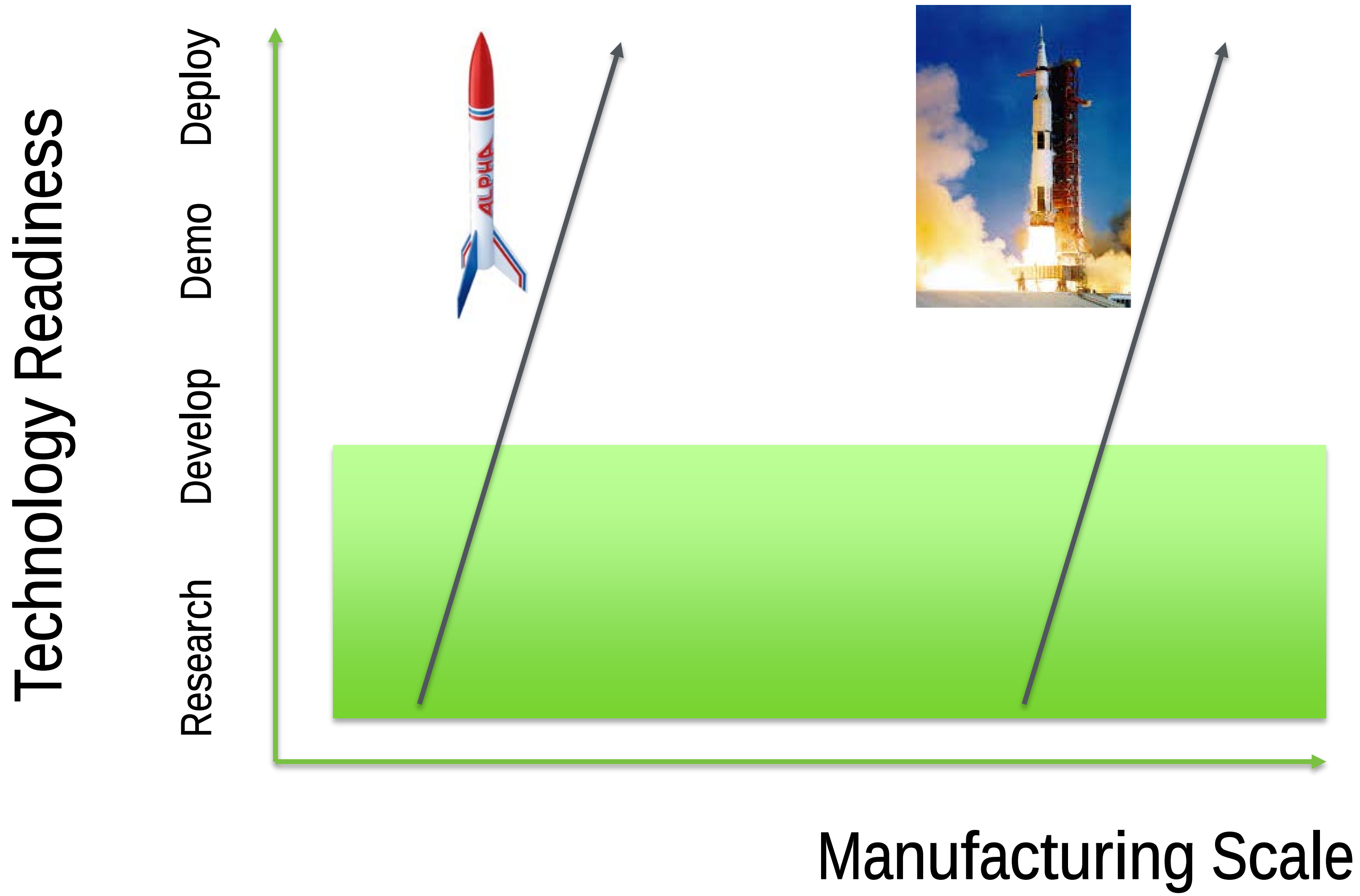
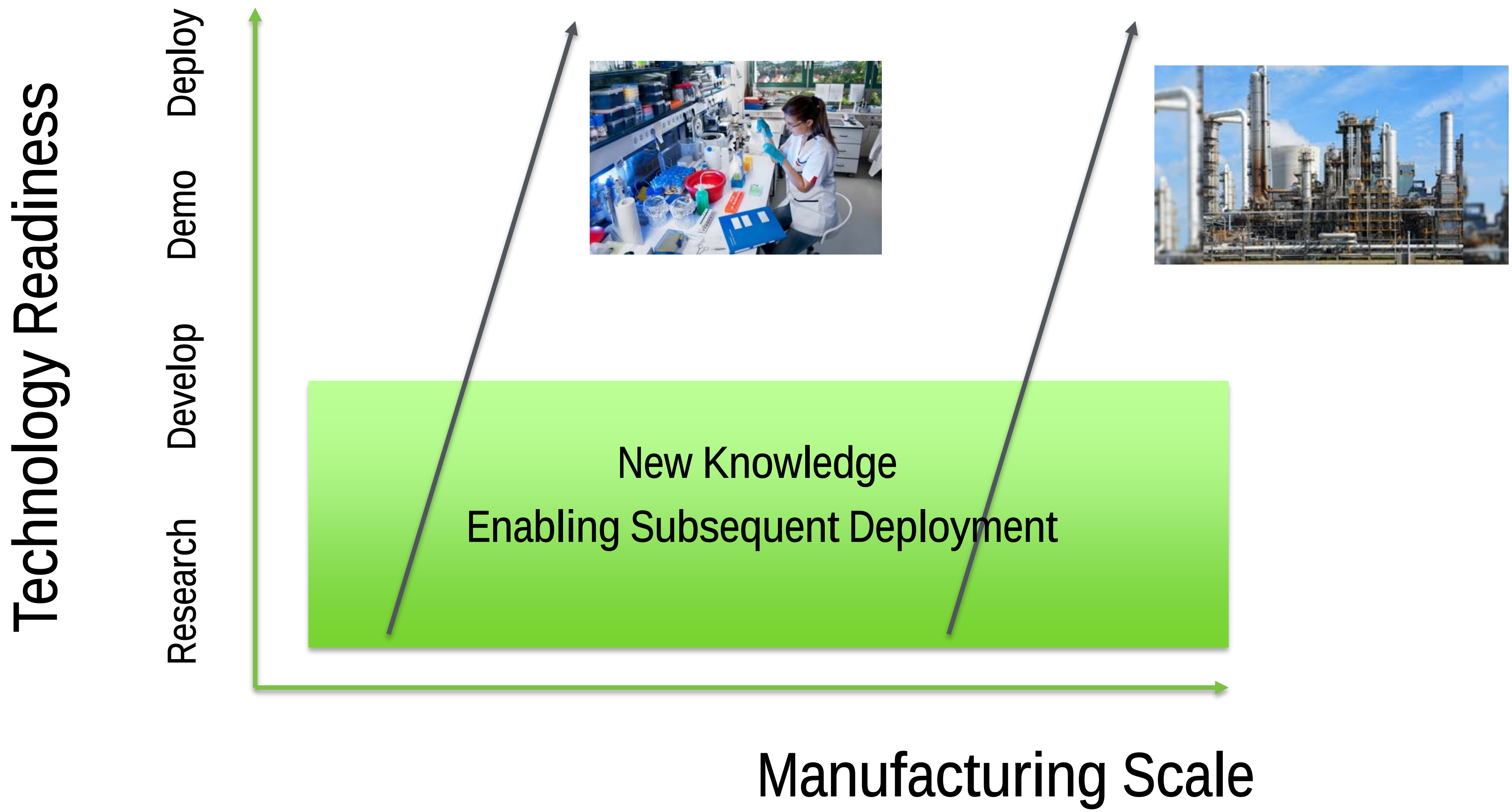
Impact Areas of Cross-Cutting Efficiency Technology R&D for Energy Intensive Industry Sectors

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

Early Stage R&D and Manufacturing Technology



Early Stage R&D and Manufacturing Technology

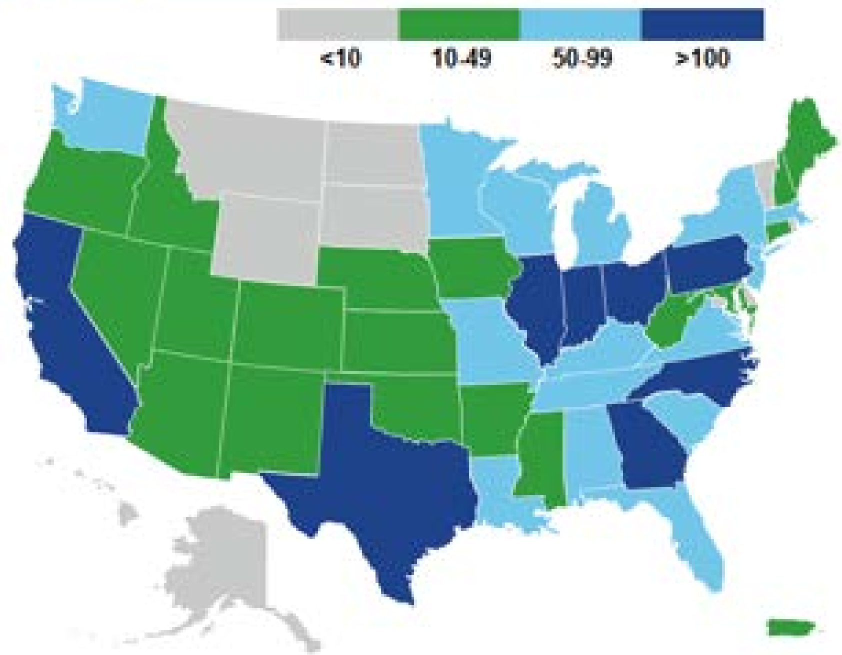


- Overview of DOE Advanced Manufacturing Office
- Technology Assistance Partnerships
- Research and Development Projects
- Research and Development Consortia
- Clean Water

Technical Assistance: Better Plants Program

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

Regional Distribution of Better Plants Facilities



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%

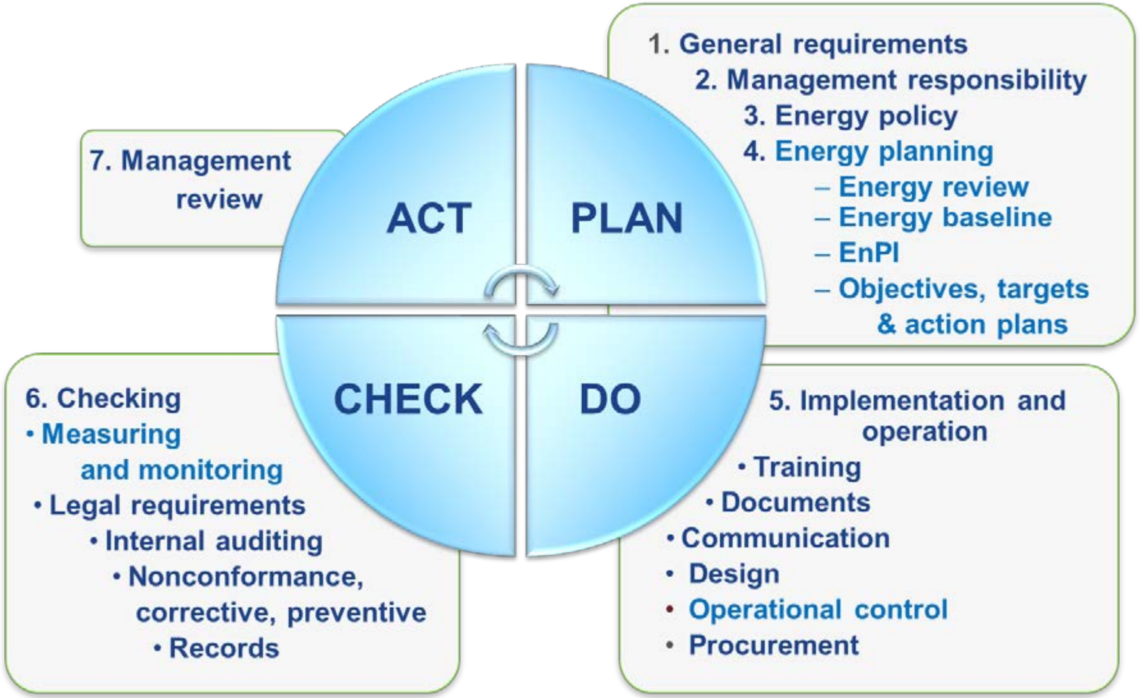
- To date, Better Plants Partners have reported **$2.4 billion in cumulative energy costs** (more than 0.45 Quads of energy)

ISO 50001–Energy Management Systems (EnMS)

International standard that draws from **best practices around the world**. Developed with input from 56 countries, many countries now adopting it as a national standard.

ISO 50001 specifies requirements for establishing, implementing, maintaining and improving an EnMS.

It does not prescribe specific energy performance improvement criteria.



Light blue text represents new data-driven sections in ISO 50001 that are not in ISO 9001 & ISO 14001

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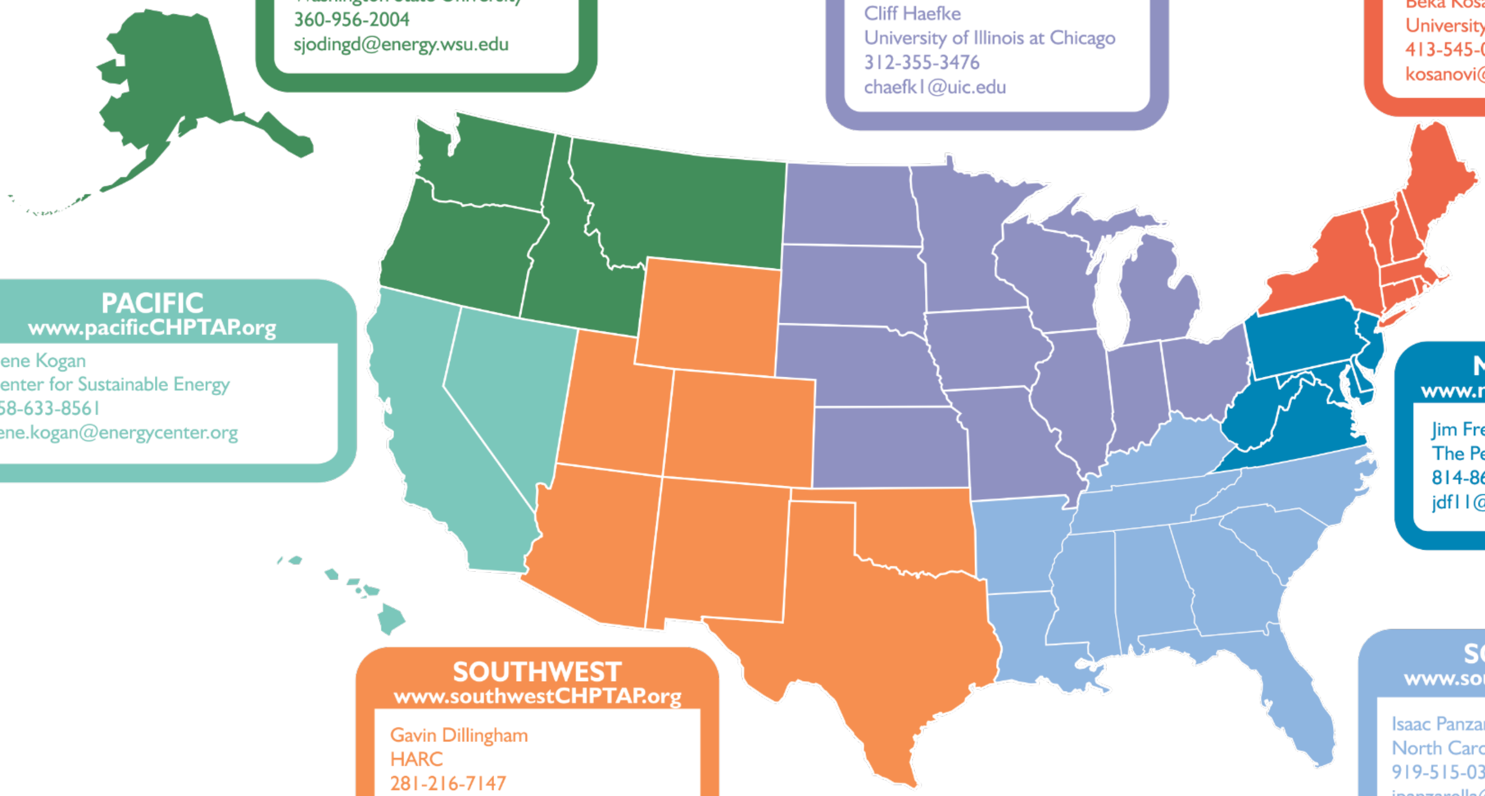
Combined Heat and Power, Technical Assistance Partnerships (CHP-TAPs)



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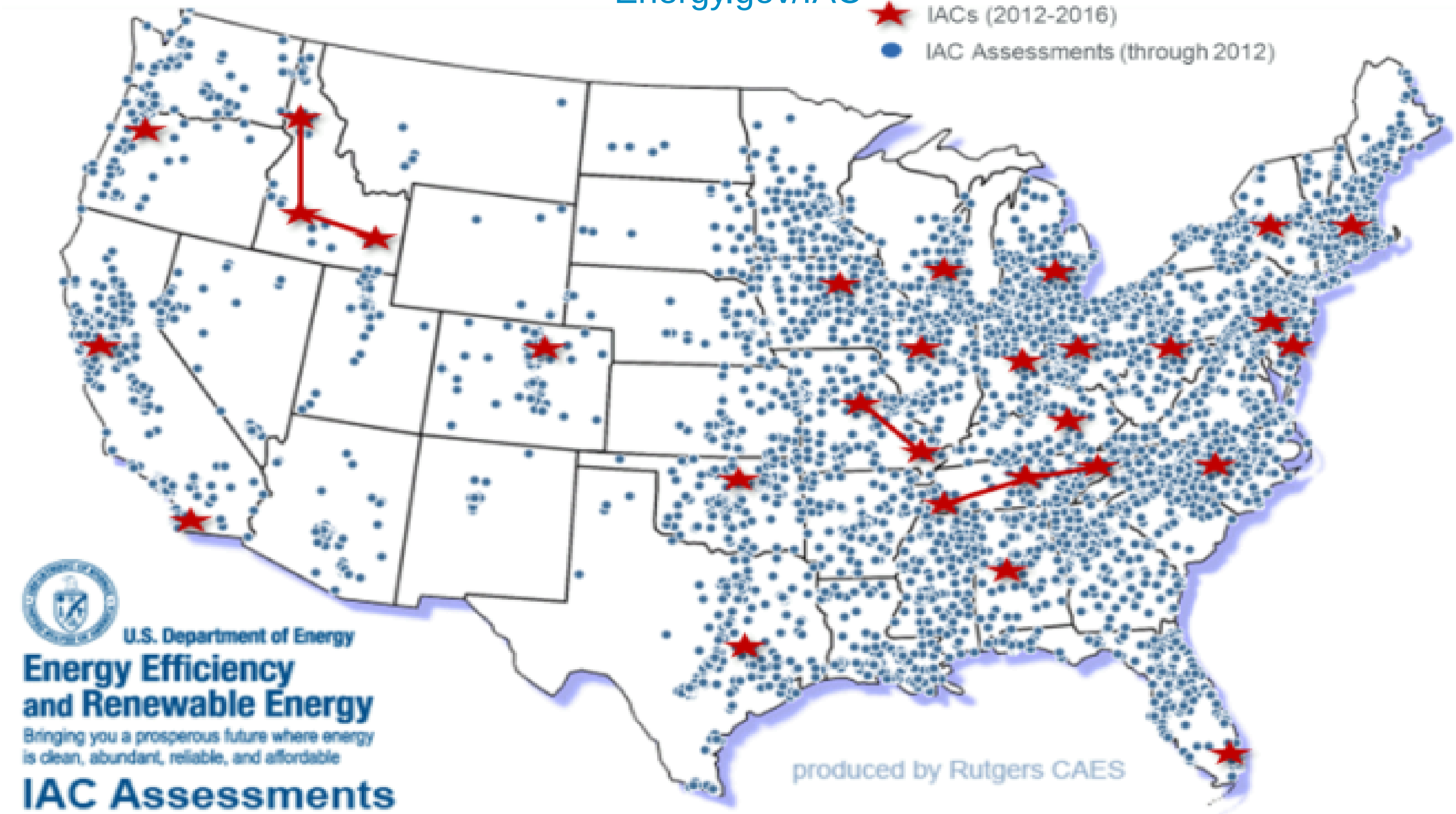
Technical Assistance: Industrial Assessment Centers

Energy Assessments & Student Training

University-based Industrial Assessment Centers

Support for small/medium sized manufacturing

Energy.gov/IAC



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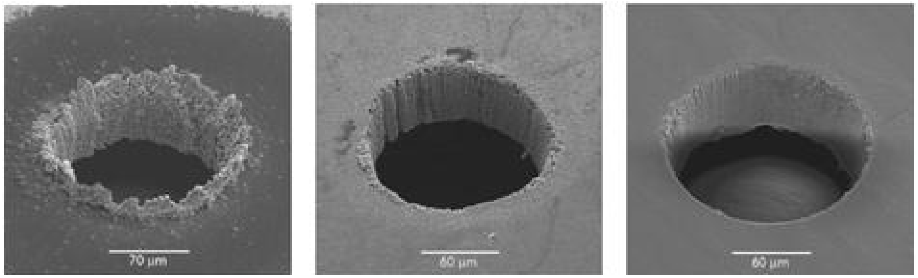
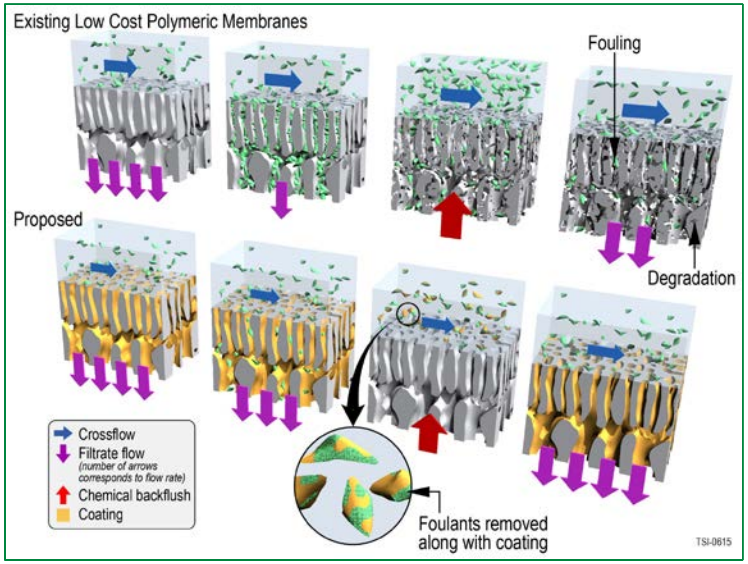
- Overview of DOE Advanced Manufacturing Office
- Technology Assistance Partnerships
- **Research and Development Projects**
- Research and Development Consortia
- Clean Water

R&D Projects: Manufacturing Processes



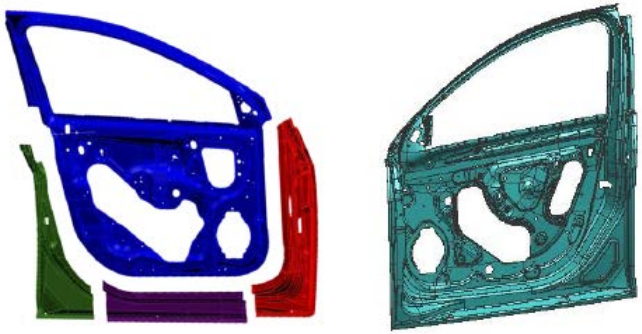
Ultrafast, femtosecond pulse lasers (right) will eliminate machining defects in fuel injectors.

Image courtesy of Raydiance.



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

Image courtesy of Teledyne

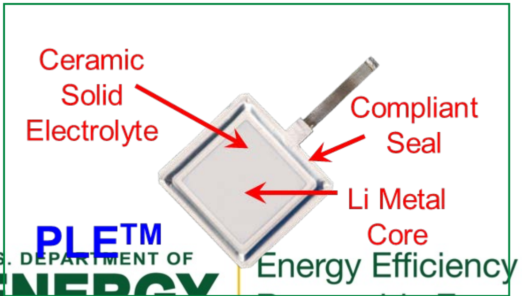


Energy-efficient large thin-walled magnesium die casting, for 60% lighter car doors.

Graphic image provided by General Motors.

A water-stable protected lithium electrode.

Courtesy of PolyPlus



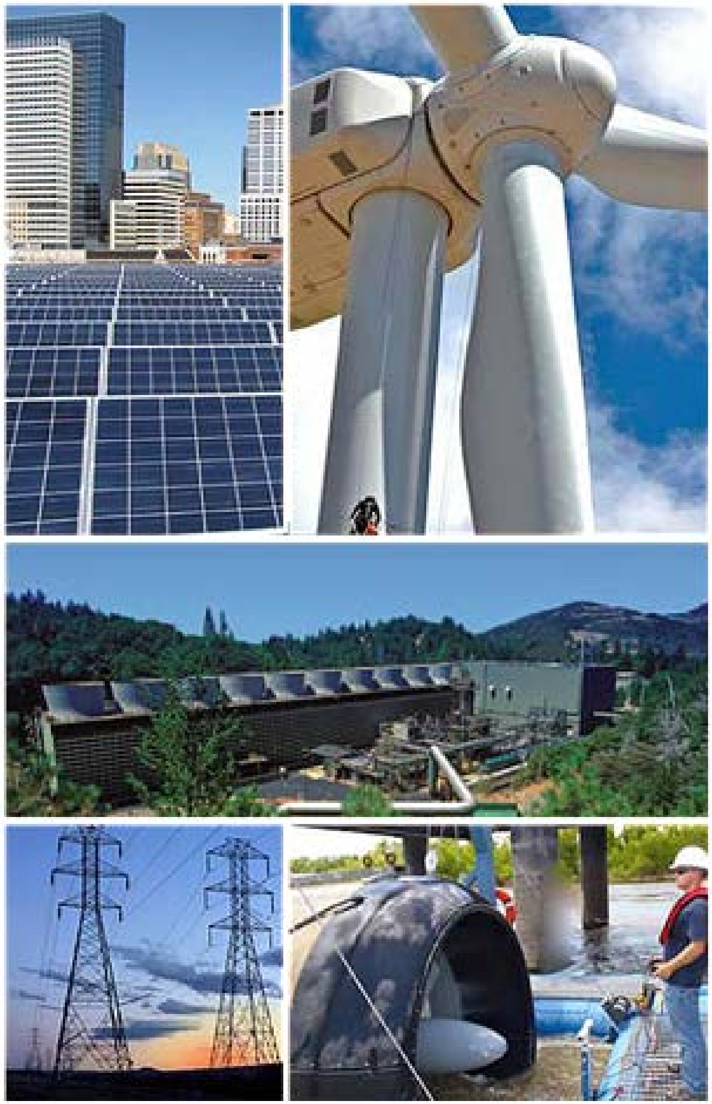
R&D: Next Generation Electric Machines (NGEM)

- 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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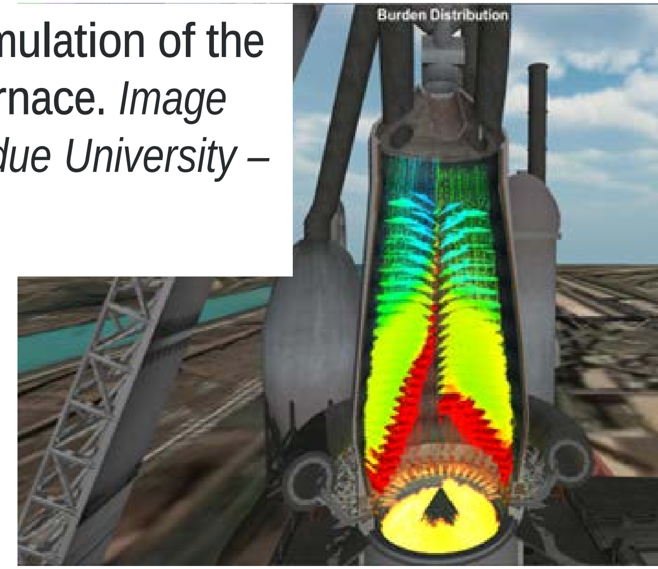
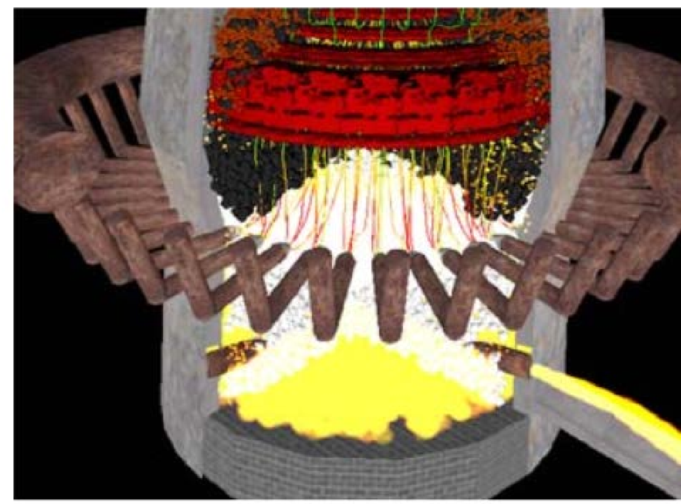
High Performance Computing for Manufacturing

Apply modeling and simulation capabilities to manufacturing challenges

A computer simulation of the virtual blast furnace. *Image courtesy of Purdue University – Calumet.*



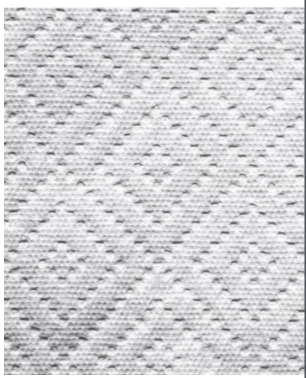


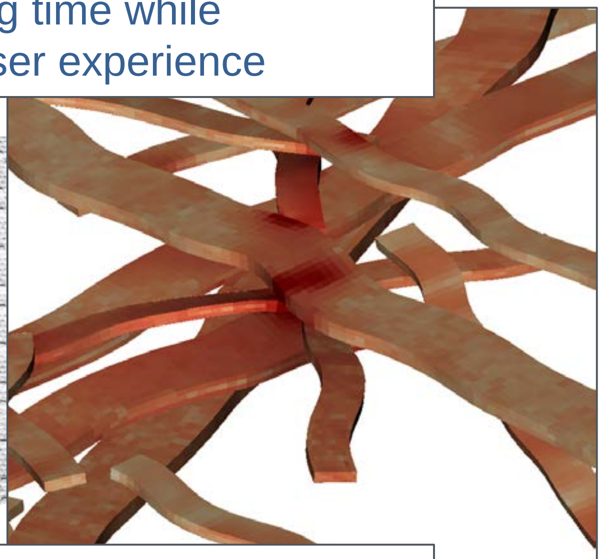
- Industry defined challenges
- Partner with National Labs to Address R&D Using HPC
- Streamlined partnering process

HPC has been used to design better processes in a variety of industries

Paper Towel Manufacturing

Goal: Use HPC to evaluate different microfiber configurations to optimize drying time while maintaining user experience



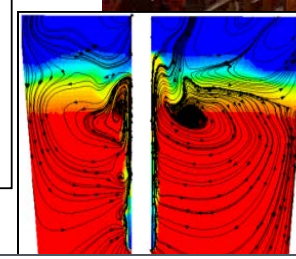


Results to date: New mesh tool reduces product design cycle by 2X cycle; additional cores by another 8X; largest non benchmark run of Paradyn code at LLNL

Team: Proctor and Gamble with LLNL

Reducing Coke Usage in Steel

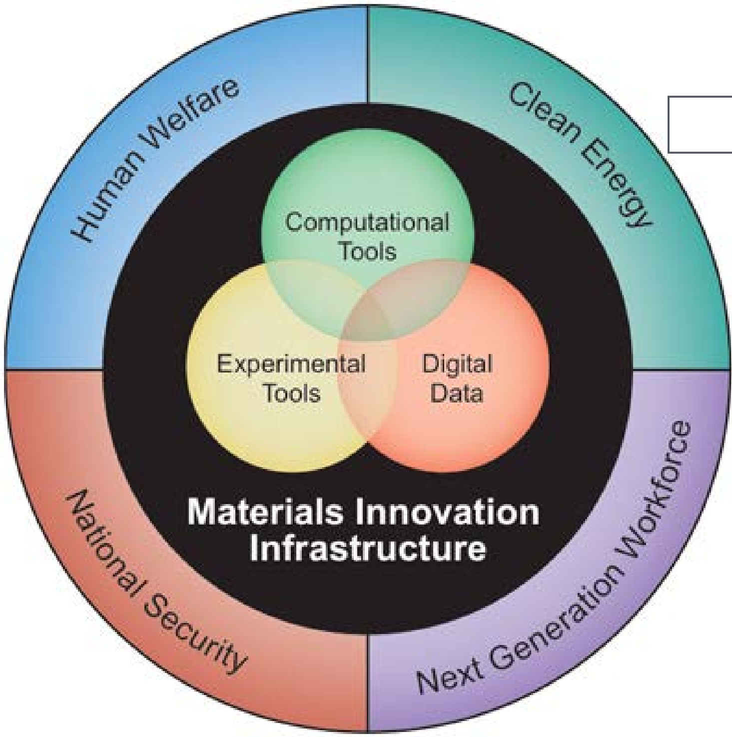
Goal: Use models of complex reacting flows HPC to optimize blast furnace processes to reduce carbon loads and coke usage; savings up to $80M/yr if successful



Results to date: 1000X improvement in computational speed of parametric studies to examine factors such as CO_2 enrichment, wind rate. Scaling code up to 2000 cores

Team: Purdue Calumet with LLNL

Applied R&D for 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

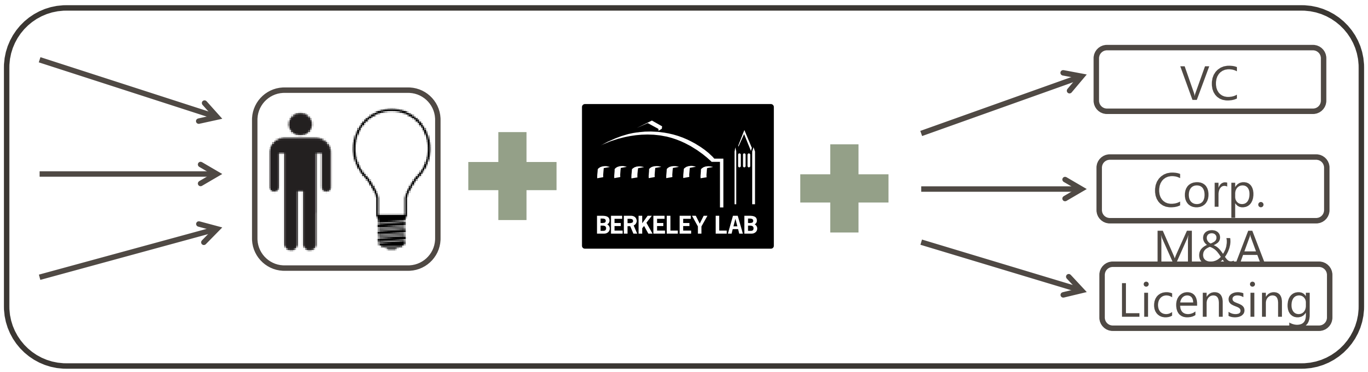
Materials Design & Synthesis → **Functional Design** → **Process Scale-Up & Qualification**

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

Post-Doc Innovation Accelerator at National Laboratories

Lab Embedded Accelerator Model:

Post-Doc innovators "spin in" to national labs for R&D



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

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- Overview of DOE Advanced Manufacturing Office
- Technology Assistance Patrnerships
- Research and Development Projects
- Research and Development Consortia
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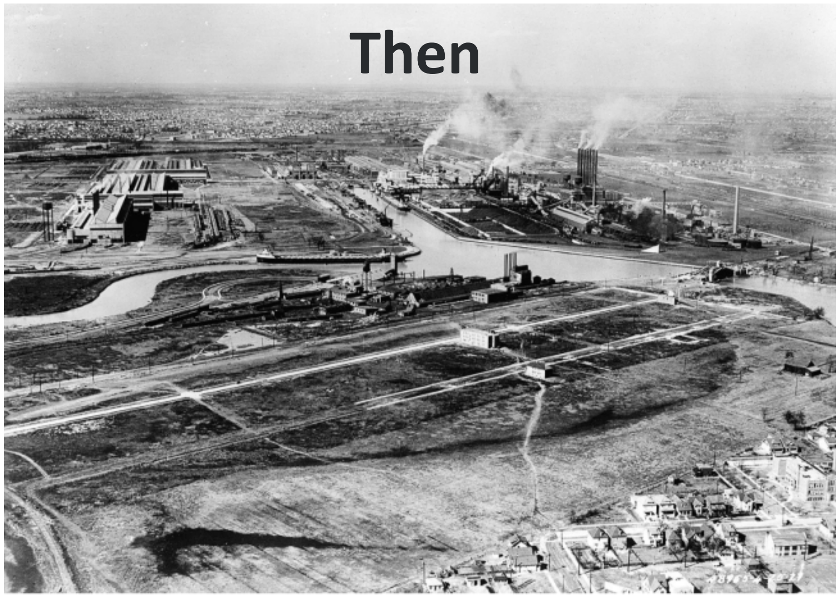
R&D Facilities & Consortia

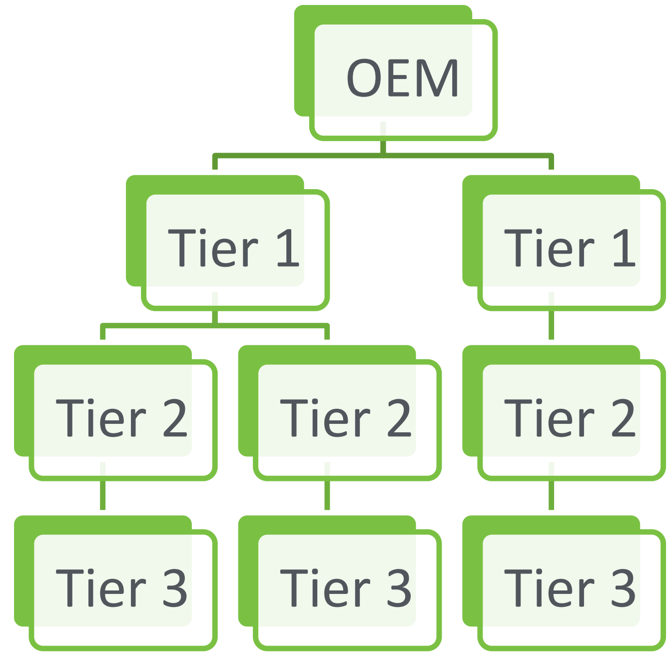
Address market disaggregation challenge to the industrial commons



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**
- **Workforce Development and Education**
- **Public-private Partnership to Scale**

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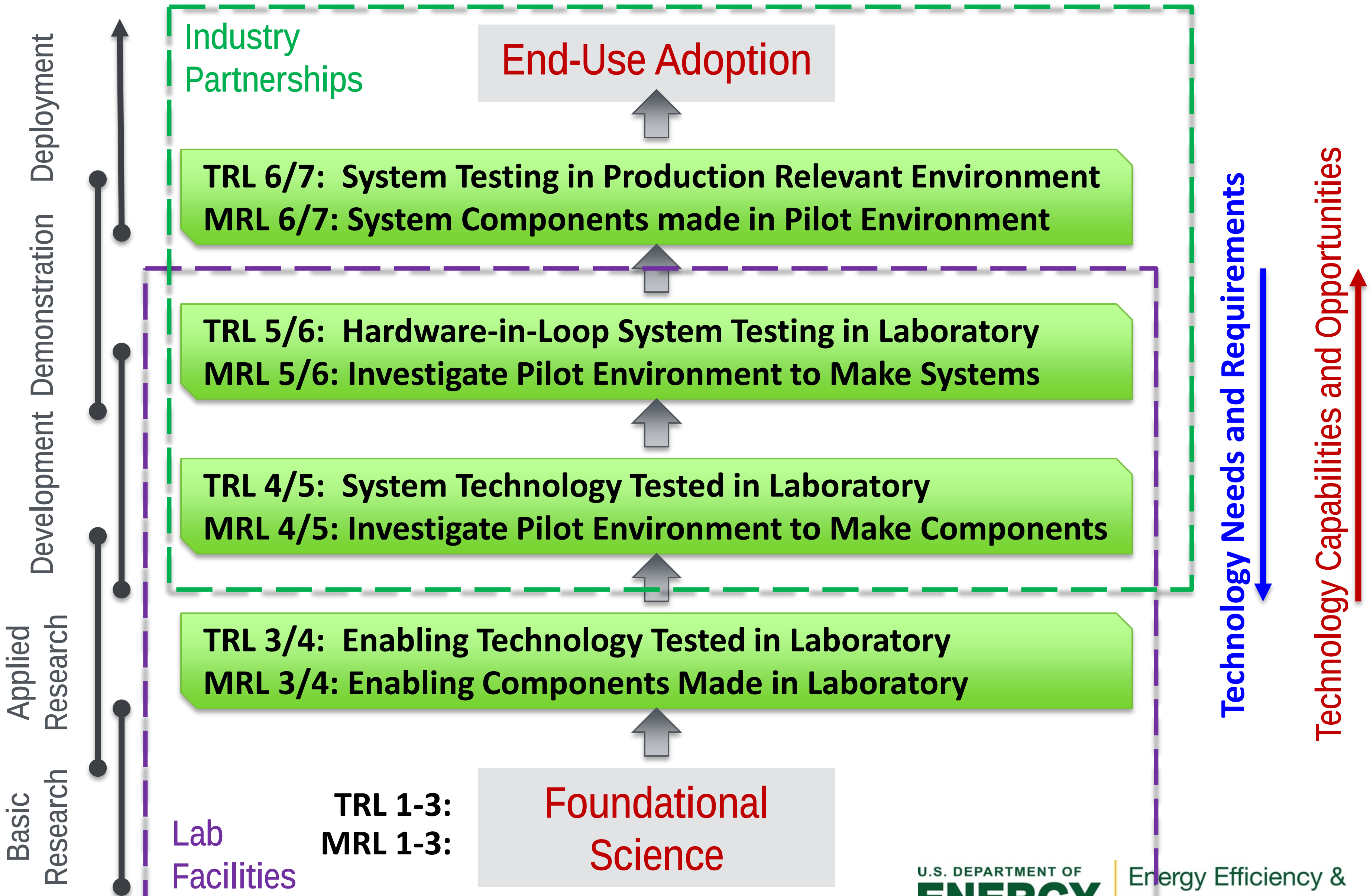
Manufacturing Technology Maturation



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Critical Materials Institute

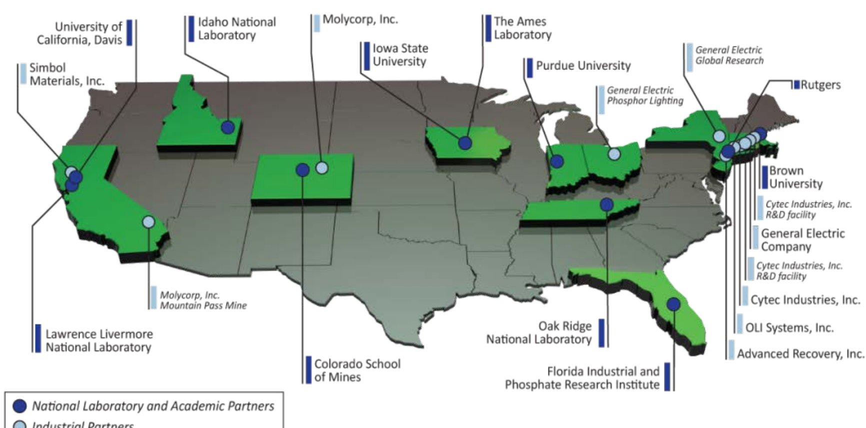
Eliminate materials criticality as an impediment to the commercialization of clean energy technologies for today and tomorrow.

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

Initial Support

- $120M for R&D June 2013-June 2018



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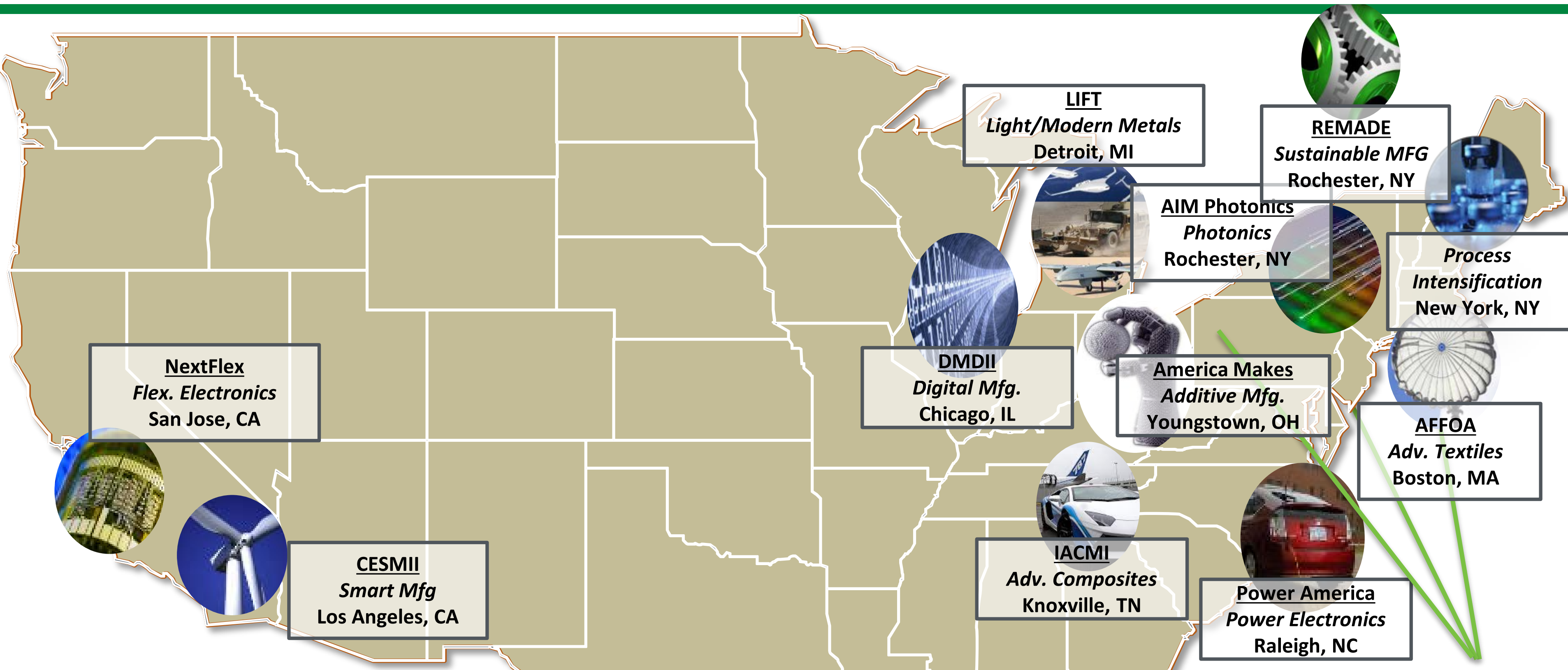
14 Manufacturing Innovation Institutes launched to date



- Over $800 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

Manufacturing USA

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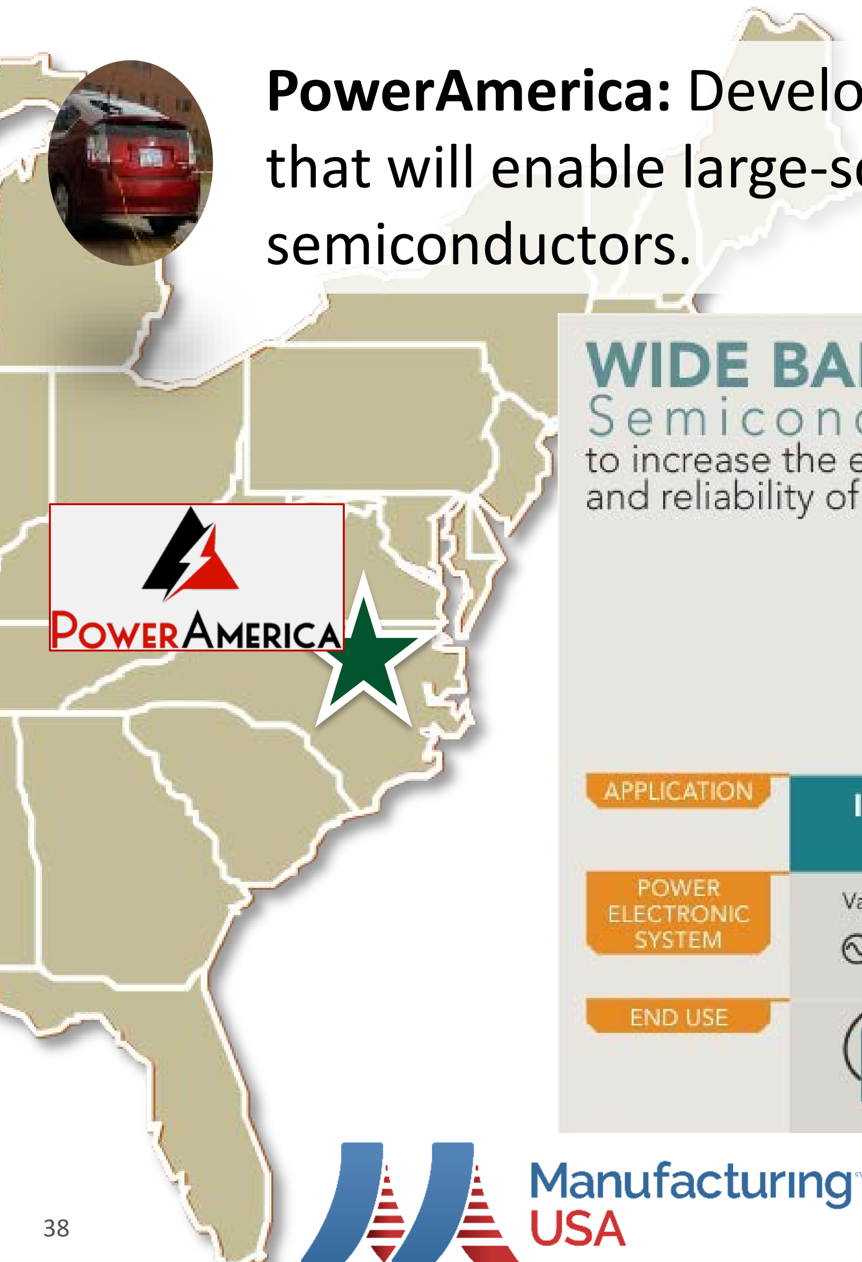
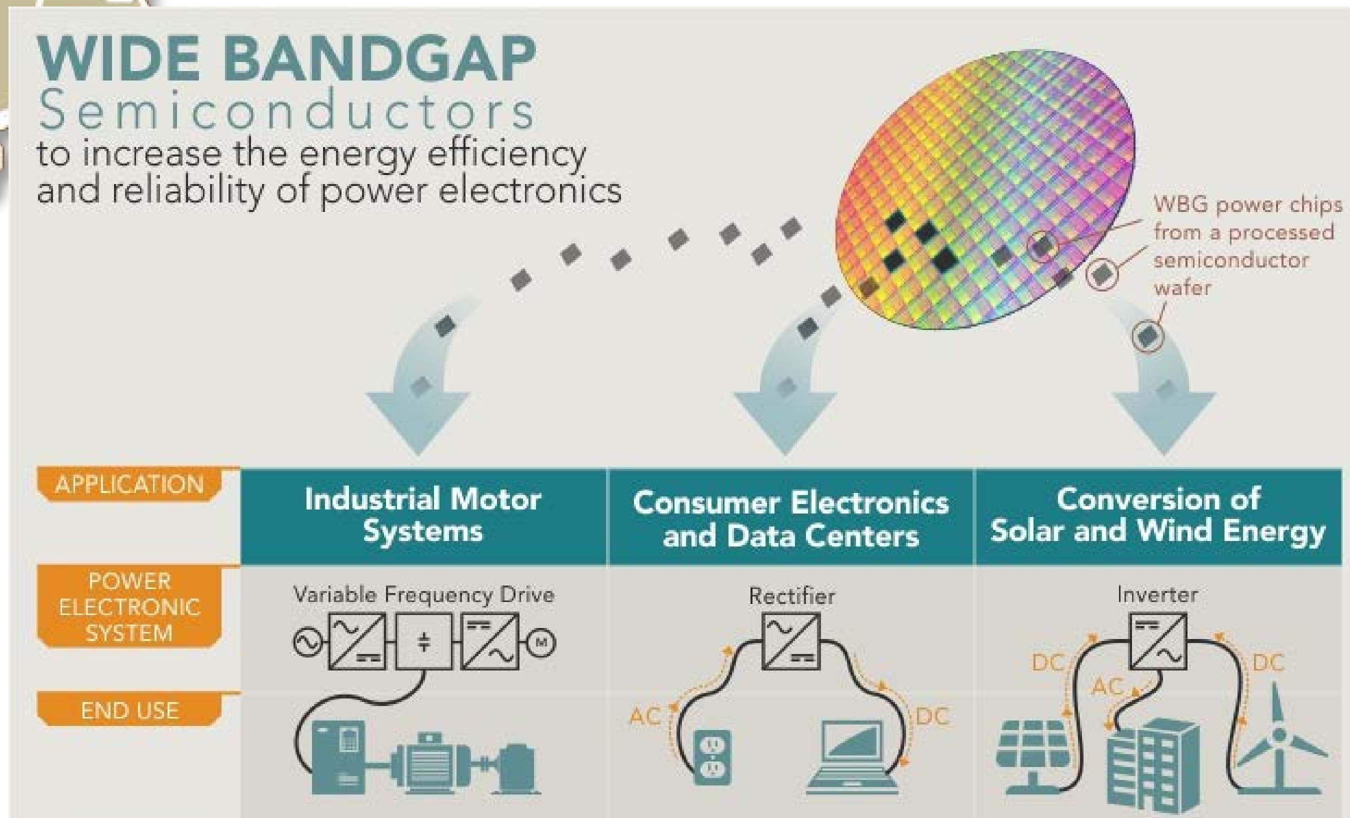
DOE Manufacturing USA Institute #1: PowerAmerica (Raleigh, NC)

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





Manufacturing USA

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Highlights: X-Fab Texas launches SiC Merchant Foundry

X-Fab Texas

- Using existing Si fab line, launched first available "merchant" SiC line
- Will dramatically reduce cost of SiC wafers for global power electronics market
- Supports 400 jobs in Lubbock, TX and will produce first device fall 2016

PowerAmerica

Manufacturing USA

Read More at: https://www.whitehouse.gov/blog/2016/04/04/depth-look[illegible]-manufacturing-hubs-helped-business-innovate

DOE Institute #2 – Carbon Fiber Composites (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.

THE COMPOSITES iacmi INSTITUTE

Institute for ADVANCED Composites Manufacturing INNOVATION

- Launched in January 2015
- $70 million Federal support matched by $180 million non-Federal
- 94 Total members including 72 industry members, 14 universities, and 2 national labs
- 46 Small and medium-sized industry partners

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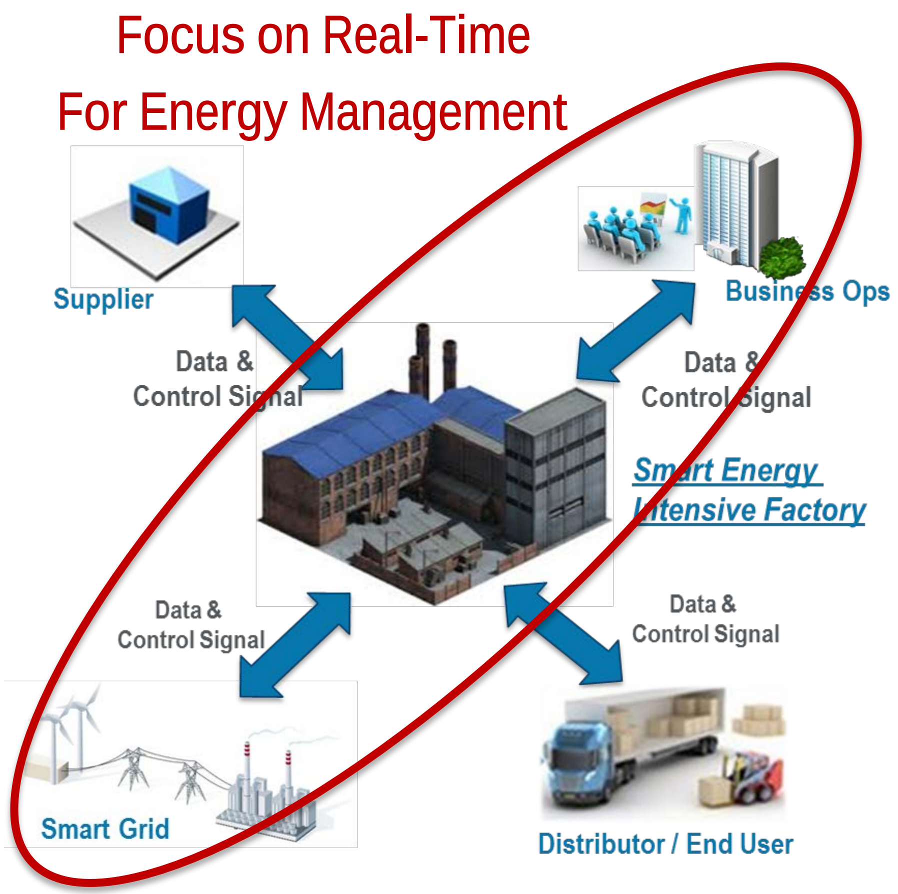
Institute for Advanced Composite Materials Innovation (IACMI)

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

DOE NNMI Institute #3 – Smart Manufacturing (Los Angeles, CA)

- 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

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

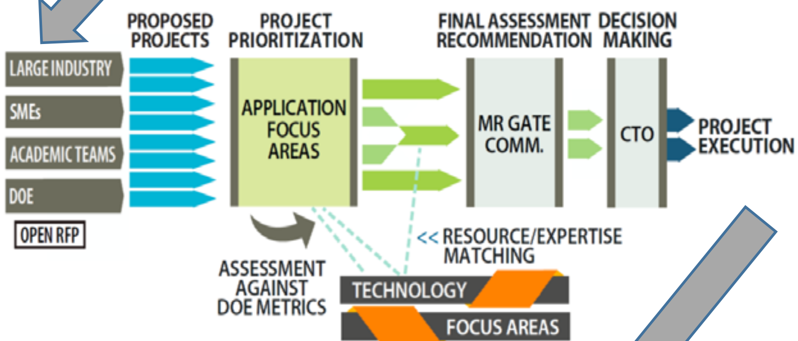
Objective: Develop a set of technologies that bring significant reduction in equipment size, process complexity, cost or risk reduction that will result in…

Test Bed Challenges

- Modeling/Simulation/Optimization & Control for Existing PI Processes
- Low Energy Separations for Existing Processes
- Material & Chemistry Intensification for Existing Processes
- Module Manufacturing for PI and MCPI
- Modular Decentralized Scale Out Processing

- 2x Improved energy efficiency
- 20% Improved energy productivity

- 50% Decreased deployment cost



- Technology Solutions
- Standards/ Design Tools/ Design Specs Available
- Work Force Trained

Capital Investment/ Commercial Deployment

IMPACT

800,000 Jobs Created

1100 TBtu Energy

82 MT CO_2

1900 Trained/Yr

Design Tools

>120 Industry Partners

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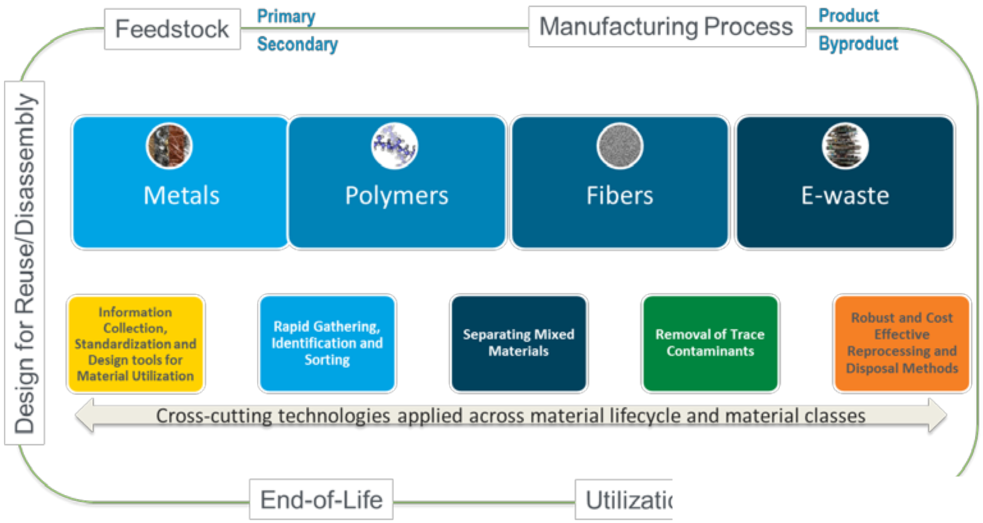
DOE NNMI Institute #5 – REMADE (Rochester, NY)

REMADE: Reducing EMbodied-energy And Decreasing Emissions

REMADE INSTITUTE



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

Lead: Sustainable Manufacturing Innovation Alliance (SMIA)
$70M public investment, $70M match
26 universities,
44 companies,
7 national labs,
26 industry trade associations and foundations

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.

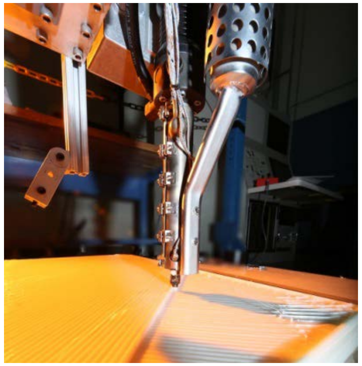
Manufacturing Demonstration Facility: National Lab Consortia

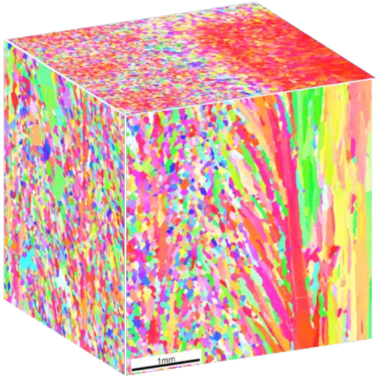
Supercomputing Capabilities

Spallation Neutron Source

MDF
Manufacturing Demonstration Facility

America Makes





Additive Manufacturing

Arcam electron beam processing AM equipment

POM laser processing AM equipment

Research in partnerships at MDF can provide validation and feedback to further research in AM technologies utilizing various materials from metals to polymers to composites.

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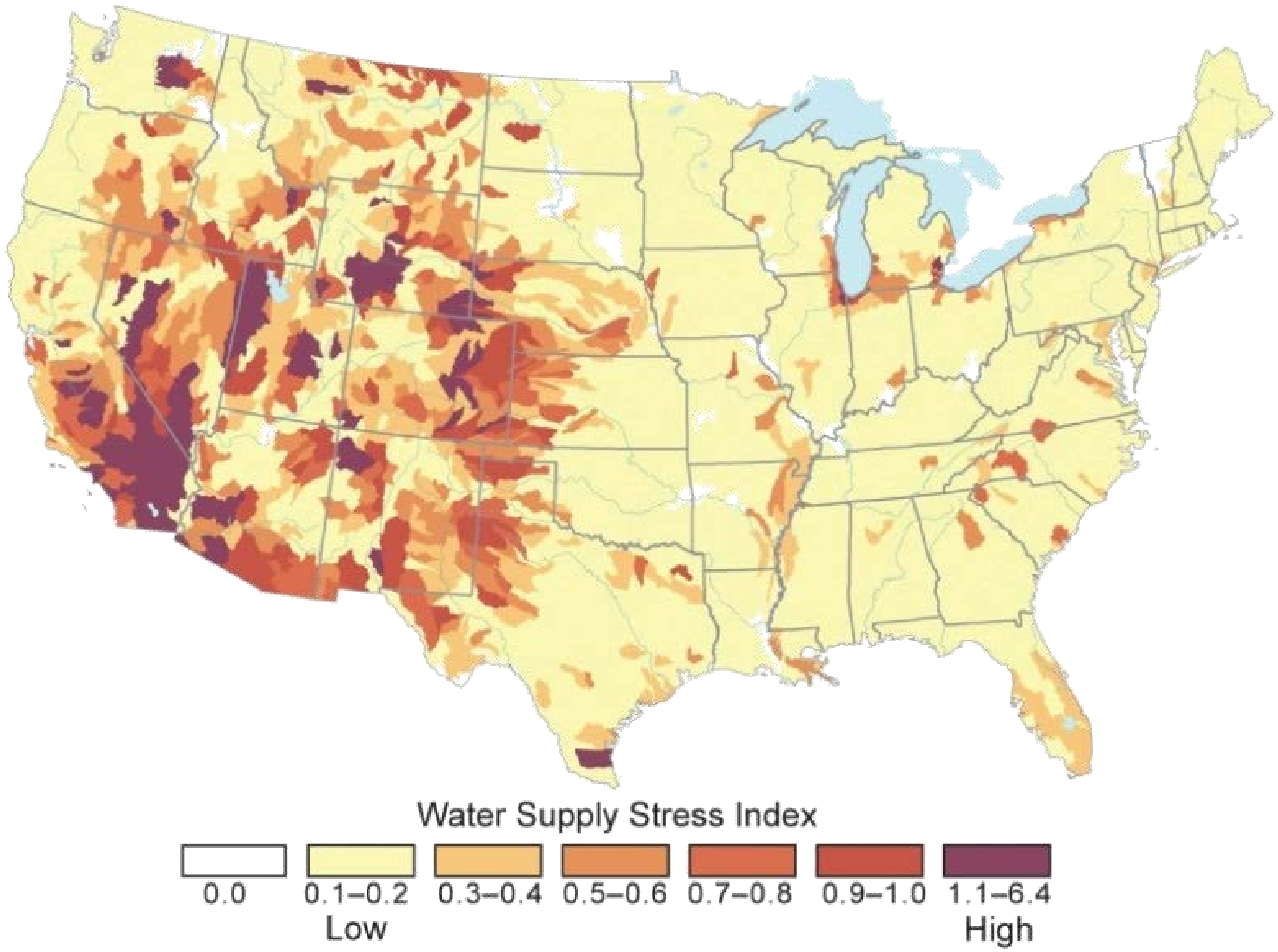
Collaborative R&D Project: AMO partnership with Wind

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
- Potential copper metal casting projects

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

Water Stress in the U.S.



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What is 'Pipe Parity' for Clean Water

- Deliver Water with equivalent Economic & Energy cost
  - Price: Approximate $0.50 / m3 (tonne)
    - Ranges from $0.10 to $1.00 nationally
  - Energy: Approximate: 1kWh / m3 (tonne)
    - 0.65 kWh (corresponding to 235m elevation change)
  - Environment: Approximate: 1lb / m3 (tonne)
    - Based on 0.69kg CO_2/kWh
  - Quality: 500 ppm TDS
  - Complimentary Cases: Desalination, Produced Water, Grey Water, etc.

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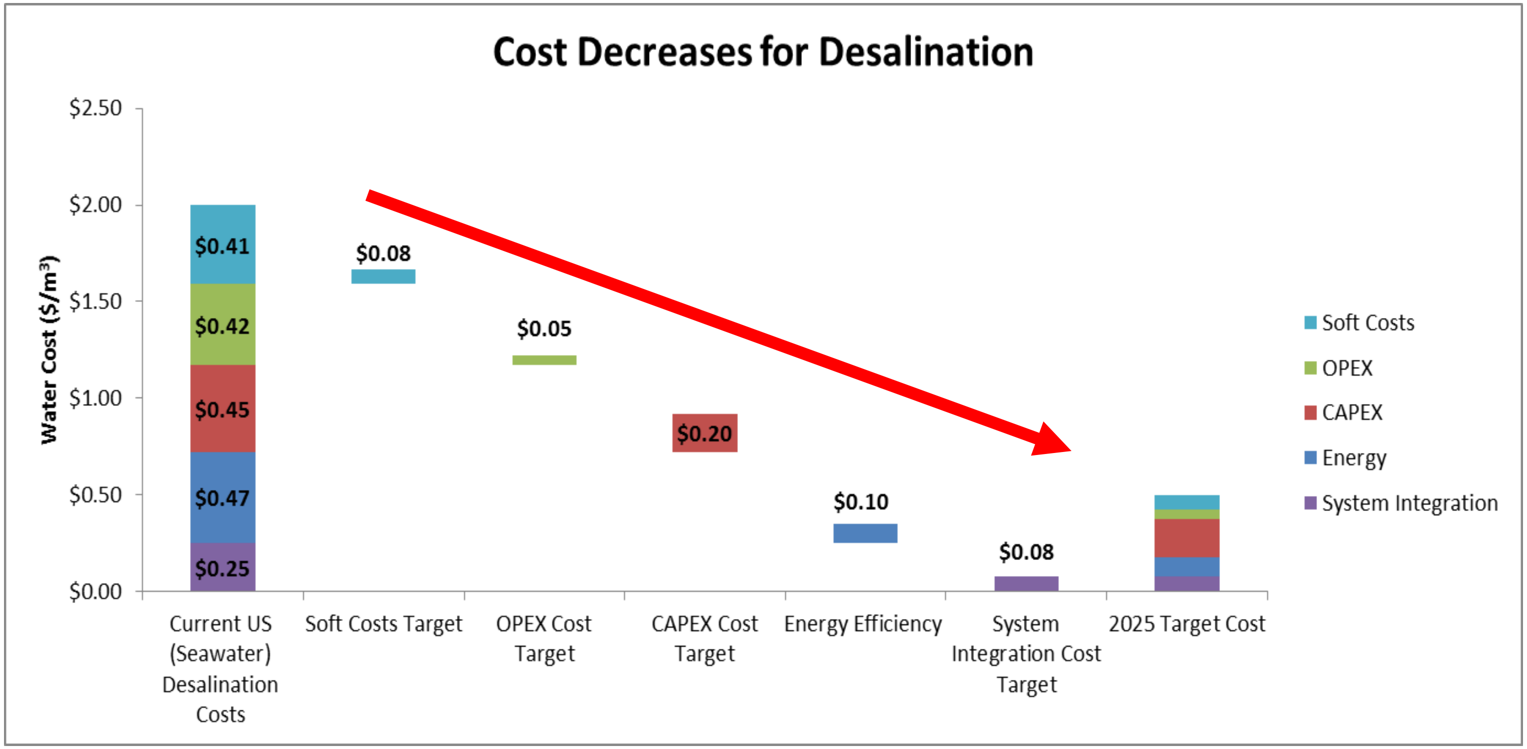
Framework Cost for Desalination in Clean Water

Goal = $0.50/m3



What are the technology R&D pathways that get us there?

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Some Possible Areas for Opportunity

- Operating Costs: Chemical additives (anti-bacterial, longer lasting membranes), Disposal / Post-processing of saline brines
- Capital Costs: Low-cost heat exchangers for thermal processes, Cost Effective membranes, Balance of Plant Equipment, Small Modular System Footprint
- Energy: Improve pressure energy recovery, utilize low-cost thermal energy
- System Integration: Intelligent design of water networks to minimize connection costs, Real-time Control and Sensor Systems
- Soft Costs: Workforce, Supply Chain, Expertise and Environmental Considerations

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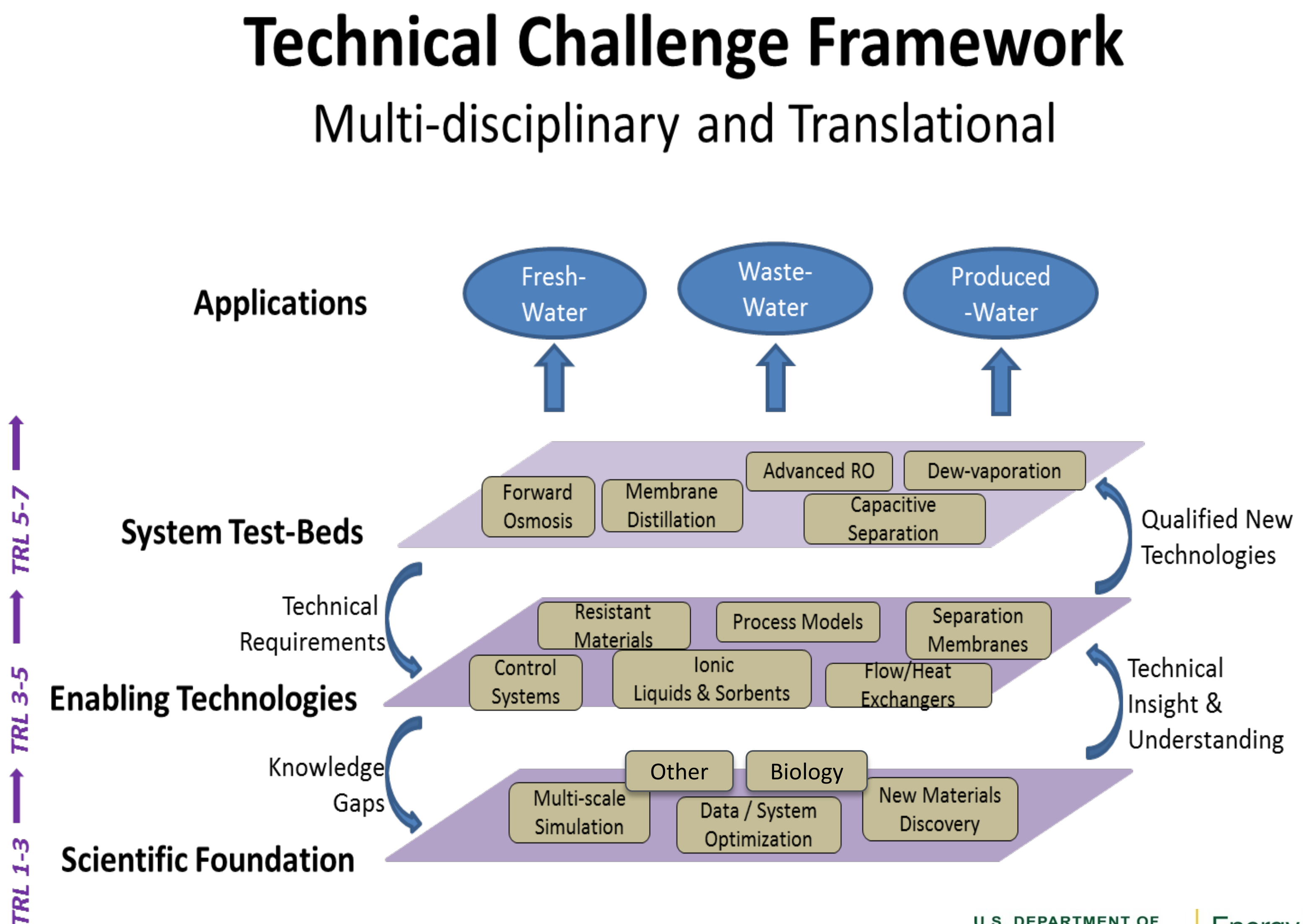
Where are the possible gaps?



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Goals for workshop

- What technology advancements needed to hit cost target?
- What ancillary and associated technology advancements (membranes, pumps/valves, etc.) are needed to make desalination pipe-parity competitive?
- Identify the most effective R&D needs for DOE in advancing these technologies.
- Discuss pathways to accelerate R&D of promising clean-water approaches at lower energetic, economic, and environmental costs relative to existing technologies

Thank You