Advanced Manufacturing Office Overview and Clean Water R&D

2017 Clean Water Technology Workshop
Dallas, TX

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Director
Advanced Manufacturing Office
www.manufacturing.energy.gov

July 10th, 2017
Energy and Manufacturing Innovation Innovation Today

Advanced Manufacturing and Energy Innovation

Security
- Energy independence
- Stable, diverse energy supply

Environment
- Clean Air
- Clean Water

Economy
- Competitiveness by energy productivity
- Domestic jobs

Technology Innovation through Early-Stage Research and Development In Manufacturing and Energy is a Foundation for Economic Growth & Jobs
A little history: The Start of a pair of Revolutions

Lexington & Concord
1775

Watt, Boulton & Co.
1775
(intelligence: steam regulation for external combustion engines)
“… 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
Second Industrial Revolution

Electrification

Process Scaling
Energy & Materials

Standardization & Assembly Line
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
How will Manufacturing, Economy and Security of the Nation depend on Information, Computation, Actuation and Communication Technologies in the 21st Century?
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
Energy Use in the US Economy

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

- Solar 0.532 Quads
- Nuclear 8.34 Quads
- Hydro 2.39 Quads
- Wind 1.82 Quads
- Geothermal 0.224 Quads
- Natural Gas 28.3 Quads
- Coal 15.7 Quads
- Biomass 4.72 Quads
- Petroleum 35.4 Quads
- Electricity Generation 38.0 Quads
- Residential 11.3 Quads
- Commercial 8.71 Quads
- Industrial 24.5 Quads
- Transportation 27.7 Quads
- Rejected Energy 59.1 Quads

Lawrence Livermore National Laboratory

U.S. Department of Energy
Energy Efficiency & Renewable Energy
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
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 (Quads/year)
- Petroleum 35
- Natural Gas 25
- Coal 20
- Nuclear 8
- Geothermal 0.2
- Hydro 3
- Wind/Solar 1

Water (Billion gallons/day)
- Fresh Surface 284
- Saline Surface 57
- Fresh Ground 82
- Saline Ground 2

Electricity Generation 39
- Thermo-electric Cooling 196
- Transportation 27
- Residential 11
- Commercial 8
- Industrial 24
- Energy Services 37
- Dissipated Energy 60

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

7/13/2017
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
### Impact Areas of Cross-Cutting Efficiency Technology R&D for Energy Intensive Industry Sectors

<table>
<thead>
<tr>
<th></th>
<th>Chemicals &amp; Bio-chemicals</th>
<th>Petroleum Refining</th>
<th>Primary Metals</th>
<th>Forest &amp; Food Products</th>
<th>Clean Water</th>
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<tbody>
<tr>
<td><strong>SMART Manufacturing</strong></td>
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<td><strong>Process Intensification</strong></td>
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<td><strong>CHP &amp; Grid Integration</strong></td>
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<td><strong>Sustainable Manufacturing</strong></td>
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Early Stage R&D and Manufacturing Technology

Technology Readiness

Manufacturing Scale
Early Stage R&D and Manufacturing Technology

Technology Readiness

Research

Develop

Demo

Deploy

Manufacturing Scale

New Knowledge
Enabling Subsequent Deployment
• 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

Better Plants Snapshot

<table>
<thead>
<tr>
<th>Partnership Size</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Partner Companies</td>
<td>157</td>
</tr>
<tr>
<td>Approximate Number of Facilities</td>
<td>2,400</td>
</tr>
<tr>
<td>Percent of U.S. Manufacturing Energy Footprint</td>
<td>11.4%</td>
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Reported Savings through 2014

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<tr>
<td>Cumulative Energy Savings (TBtu)</td>
<td>457</td>
</tr>
<tr>
<td>Cumulative Cost Savings (Billions)</td>
<td>$2.4</td>
</tr>
<tr>
<td>Cumulative Avoided CO₂ Emissions (Million Metric Tons)</td>
<td>26.6</td>
</tr>
<tr>
<td>Average Annual Energy-Intensity Improvement Rate</td>
<td>2.1%</td>
</tr>
</tbody>
</table>

• 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
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
• 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.*

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*
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
Apply modeling and simulation capabilities to manufacturing challenges

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

A computer simulation of the virtual blast furnace. Image courtesy of Purdue University – Calumet.
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 CO2 enrichment, wind rate. Scaling code up to 2000 cores

**Team:** Purdue Calumet with LLNL
New Material Innovations for Clean Energy 2X Faster and 2X Cheaper
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

- VC
- Corp. M&A Licensing
- cyclotronroad
- CHAIN REACTION INNOVATIONS
- INNOVATION CROSSROADS
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R&D Facilities & Consortia

Address market disaggregation challenge to 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
- Workforce Development and Education
- Public-private Partnership to Scale
Manufacturing Technology Maturation

TRL 6/7: System Testing in Production Relevant Environment
MRL 6/7: System Components made in Pilot Environment

TRL 5/6: Hardware-in-Loop System Testing in Laboratory
MRL 5/6: Investigate Pilot Environment to Make Systems

TRL 4/5: System Technology Tested in Laboratory
MRL 4/5: Investigate Pilot Environment to Make Components

TRL 3/4: Enabling Technology Tested in Laboratory
MRL 3/4: Enabling Components Made in Laboratory

TRL 1-3: Foundational Science
MRL 1-3: Lab Facilities
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
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
PowerAmerica: Develop advanced manufacturing processes that will enable large-scale production of wide bandgap semiconductors.

WIDE BANDGAP SEMICONDUCTORS
To increase the energy efficiency and reliability of power electronics

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>Industrial Motor Systems</th>
<th>Consumer Electronics and Data Centers</th>
<th>Conversion of Solar and Wind Energy</th>
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</thead>
<tbody>
<tr>
<td>POWER ELECTRONIC SYSTEM</td>
<td>Variable Frequency Drive</td>
<td>Rectifier</td>
<td>Inverter</td>
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<tr>
<td>END USE</td>
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WBG power chips from a processed semiconductor wafer
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

Read More at: https://www.whitehouse.gov/blog/2016/04/04/depth-look-how-manufacturing-hubs-helped-business-innovate
Institute for Advanced Composite Material Manufacturing (IACMI): Develop and demonstrate technologies to produce carbon fiber composites at 50% the cost and 75% less energy.

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

• Advanced sensors and controls for real-time process management
Objective: Develop a set of technologies that bring significant reduction in equipment size, process complexity, cost or risk reduction that will result in...

- 2x Improved energy efficiency
- 20% Improved energy productivity
- 50% Decreased deployment cost
**REMADE: Reducing EMbodied-energy And Decreasing Emissions**

**Key Technical Goals:**

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

**Technology Focus Areas**

- **Design for Reuse/Disassembly**
- **Manufacturing Processes**
- **Remanufacturing / EOL Reuse**
- **Recycling & Recovery**

**Lead:** Sustainable Manufacturing Innovation Alliance (SMIA)

$70M public investment, $70M match
26 universities,
44 companies,
7 national labs,
26 industry trade associations and foundations
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.
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

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• Clean Water
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: 1 kWh / m³ (tonne)
    - 0.65 kWh (corresponding to 235m elevation change)
  
  - Environment: Approximate: 1 lb / m³ (tonne)
    - Based on 0.69 kg CO₂/kWh
  
  - Quality: 500 ppm TDS
  
  - Complimentary Cases: Desalination, Produced Water, Grey Water, etc.
Framework Cost for Desalination in Clean Water

Goal = $0.50/m3

Cost Decreases for Desalination

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

Technical Challenge Framework
Multi-disciplinary and Translational

Applications
- Fresh-Water
- Waste-Water
- Produced-Water

System Test-Beds
- Forward Osmosis
- Membrane Distillation
- Advanced RO
- Capacitive Separation
- Dew-vaporation

Enabling Technologies
- Resistant Materials
- Process Models
- Separation Membranes
- Ionic Liquids & Sorbents
- Flow/Heat Exchangers

Scientific Foundation
- Control Systems
- Multi-scale Simulation
- Other
- Biology
- Data/System Optimization
- New Materials Discovery

Qualified New Technologies
Technical Insight & Understanding

TRL 1-3 ➔ TRL 3-5 ➔ TRL 5-7

7/13/2017
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