Sustainable Manufacturing Workshop

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www.manufacturing.energy.gov
Clean Energy and Manufacturing: Nexus of Opportunities

Clean Energy Solutions

- Competitiveness in clean energy
- Domestic jobs

Security
- Energy self-reliance
- Stable, diverse energy supply

Environment
- Clean air
- Climate change
- Health

Economy

Clean Energy Manufacturing
- Making Products which Reduce Impact on Environment

Advanced Manufacturing
- Making Products with Technology as Competitive Difference
Bridging the Gap to Manufacturing

AMO: Advanced Manufacturing Office

Concept → Proof of Concept → Lab scale development → Demonstration and scale-up → Product Commercialization
Climate Action Plan
(EOP / CEQ / OSTP 2014)

Advanced Manufacturing Partnership (AMP2.0)
(NEC / PCAST / OSTP 2014)

Quadrennial Energy Review
(DOE / EPSA 2015)

Quadrennial Technology Review
(DOE / Science and Technology 2015)

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

2) Platform Materials & Processes Technologies for Manufacturing Clean Energy Technologies
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Advanced Manufacturing Topical Priorities

Efficiency Technologies for Manufacturing Processes (Energy, CO₂)
(1) Advanced Sensors, Controls, Modeling and Platforms (HPC, Smart Manf.)
(2) Advanced Process Intensification
(3) Grid Integration of Manufacturing (CHP and DR)
(4) Sustainable Manufacturing (Water-Energy, New Fuels & Feedstocks)

Platform Materials & Technologies for Clean Energy Applications
(5) Advanced Materials Manufacturing
   (incl: Extreme Mat’l., Conversion Mat’l, etc.)
(6) Critical Materials
(7) Advanced Composites & Lightweight Materials
(8) 3D Printing / Additive Manufacturing
(9) 2D Manufacturing / Roll-to-Roll Processes
(10) Wide Bandgap Power Electronics
(11) Next Generation Electric Machines (NGEM)

QTR Manufacturing Focus Areas Mapped to Advanced Manufacturing
Topical Areas for Technology Development
Modalities of Support

**Technology Assistance:** (Dissemination of Knowledge)

**Technology Development Facilities:** (Innovation Consortia)
Critical Materials Hub, Manufacturing Demonstration Facility (Additive), Power America NNMI, IACMI NNMI, CyclotronRoad, HPC4Manufacturing

**Technology Development Projects:** (Individual R&D Projects)
Individual Projects Spanning AMO R&D Space - University, Small Business, Large Business and National Labs. Each a Project Partnership (Cooperative Agreement).
AMO Elements

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

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

Address market disaggregation to rebuild the industrial commons

Then

Now

Ford River Rouge Complex, 1920s
Photo: Library of Congress, Prints & Photographs Division, Detroit Publishing Company Collection, det 4a25915.

How could we get innovation into manufacturing today?
- RD&D Consortia based Eco-Systems
- 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: Enabling Technology Tested in Laboratory
MRL 1-3: Enabling Components Made in Laboratory

End-Use Adoption

Technology Needs and Requirements

Industry Partnerships

Applied Research

Basic Research

Development Demonstration

Deployment

Foundational Science

Lab Facilities
Critical Materials Institute

A DOE Energy Innovation Hub

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

Program goal is to accelerate the manufacturing capability of a multitude of AM technologies utilizing various materials from metals to polymers to composites.
PowerAmerica:
Next Generation Power Electronics Manufacturing 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

¹Lux Research, 2012.
Objective
Develop and demonstrate innovative technologies that will, within 10 years, make advanced fiber-reinforced polymer composites at...

50% Lower Cost
Using 75% Less Energy

And reuse or recycle >95% of the material

*States are significant contributors
Focus on Real-Time For Energy Management

• Encompass machine-to-plant-to-enterprise real time sensing, instrumentation, monitoring, control, and optimization of energy (>50% improvement in energy productivity)

• Enable hardware, protocols and models for advanced industrial automation: requires a holistic view of data, information and models in manufacturing at Cost Parity (>50% reduction in installation cost)

• Significantly reduce energy consumption and GHG emissions & improve operating efficiency – (15% Improvement in Energy Efficiency)

• Increase productivity and competitiveness across all manufacturing sectors: Special Focus on Energy Intensive & Energy Dependent Manufacturing Processes

Leverage AMP 2.0 and QTR
National Network for Manufacturing Innovation (NNMI)

- Network of distinct regional Institutes, each with different technology focus
- Public-Private Partnerships focused on TRL 4-7
- $70-100 million in federal funding, with minimum 1:1 cost share
- 7 current DOE and DOD Institutes
- 2 pending, 15 total by end of 2016
National Network for Manufacturing Innovation (NNMI)

DOE Institutes
• PowerAmeica – Wide band gap power electronics
• IACMI—Advanced Composites
• (Pending)—Smart Manufacturing
• Two new institutes in 2016—Topics TBD

DOD Institutes
• AmericaMakes – Additive manufacturing
• DMDII—Digital Manufacturing
• LIFT—Lightweight metals
• AIM—Photonics
• FlexTech—Flexible Hybrid Electronics
• (Pending)—Revolutionary Fibers and Textiles
Topical Engagement with Industry

- **Advanced Materials**
  - Materials in Extreme Conditions
  - Sustainable Materials in Manufacturing

- **Process Intensification**
  - Process Intensification (Chemical)
  - Process Intensification (Thermal)

- **Roll-to-Roll Processing**
  - Functional Membrane Structures

- **Advanced Sensors, Controls, Models, Platforms**
  - Smart Manufacturing
Developing R&D priorities

• Will inform BOTH potential institute topic AND AMO’s broader R&D portfolio

• Other workshops:
  • Chemical Process Intensification (Oct. 2015)
  • Thermal Process Intensification (Oct. 2015)
  • Extreme Environment Materials (Nov. 2015)
  • High Value Roll-to-Roll Manufacturing (Dec. 2015)
  • Sustainable Manufacturing (Jan. 2016)
DOE QTR: Manufacturing Technology

**Efficiency Technologies**

1. Advanced Sensors, Controls, Modeling & Platforms
2. Process Heating
3. Waste Heat Recovery
4. Sustainable Manufacturing – Flow of Materials through Industry

**Enabling Platform Technologies**

5. Direct Energy Conversion Materials (Magnetocaloric, Thermoelectric, etc)
6. Critical Materials
7. Composite Materials
8. Additive Manufacturing
9. Roll-to-Roll Processing
10. Wide Bandgap Power Electronics
11. Materials for Harsh Service Conditions

**Information & Data**

- Energy & Resource Management
- Advanced Manufacturing Processes
- Materials Development
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QTR Manufacturing Focus Areas Mapped to Advanced Manufacturing Topical Areas for Technology Development
Sustainable Manufacturing

Connections to other QTR Chapters and Technology Assessments

- Grid
- Electric Power
- Buildings
- Fuels
- Transportation

Sustainable Manufacturing – Flow of Materials through Industry

- Combined Heat and Power
- Waste Heat Recovery Systems
- Advanced Sensors, Controls, Platforms & Modeling for Manufacturing
- Process Heating
- Roll-to-Roll Processing

Ch. 6: Sustainable Manufacturing Technology Assessment

Scope

- Supply chain issues, from resource extraction to end of life (Life Cycle Analysis)
- Flow diagrams to demonstrate supply chain issues
- Material efficiency: mechanisms for reducing demand for materials (e.g., lightweighting, scrap reduction, increased material longevity)
- Design for Re-use / Recycling

Aluminum material flows through the economy*

Key Extra-Chapter Connections

- Electric Power: management of water & energy resources
- Buildings: recycling and materials substitution/minimization

*Source: Internal analysis (DOE Advanced Manufacturing Office, 2013)
Circular Material Economy

Opportunities to reduce impacts
Why Sustainable Manufacturing at the Department of Energy?

**Motivation**

- An efficient supply chain that has minimal negative environmental impacts can enhance the competitiveness of the industrial sector
- As material consumption increases – we need to be more efficient with material, reduce emissions and waste to landfill, and reuse materials while optimizing their value and utility
- Significant energy is lost in inefficient system level processes – the entire supply chain must be engaged to uncover potential solutions

**Opportunity**

- Sustainable manufacturing technology development that improves energy-efficiency, reduces greenhouse gas emissions while improving the efficiency of material use throughout the manufacturing process. The focus could be:
  - Testing and demonstration of alternative feedstocks;
  - Reduction of waste throughout the manufacturing process;
  - Improve reuse and recycling of materials, water and energy within the manufacturing process and at the end of product life;
  - Validation and deployment of the tools, processes and technologies to enable sustainable design and assessment.
US Material Consumption & Imports Increasing

Demand for aluminum, paper, steel, plastic and cement is predicted to continue to increase thru 2045

Price of materials and embodied energy of materials.

\[ y = 19x^{1.196} \]

\[ R^2 = 0.93 \]
Potential Energy Savings from Recycling

Energy Savings (Btu) per ton of recycled material (compared to landfiling)

- Al cans: 153.3
- Al ingot: 114.4
- Copper wire: 83.4
- Mixed Metals: 67.2
- HDPE: 50.9
- PET: 32.6
- PCs: 29.8
- Carpet: 22.1
- Steel Cans: 20.5
- Tires: 4.2
- Glass: 2.7
- Asphalt Concrete
- Concrete

EPA Waste Reduction Model
March, 2015

US Municipal Solid Waste Management 2010 (EPA)

- Discarded: 54%
- Recovery: 34%
- Waste to Energy: 12%
Analysis on Cradle-to-Gate Energy Consumption of Li-ion Batteries

![Energy consumption diagram](image)

- **Energy consumption without recycling**

<table>
<thead>
<tr>
<th>Recycled Component</th>
<th>Energy Consumption (MJ/kg battery)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiMn$_2$O$_4$</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
</tr>
</tbody>
</table>

- **Hydrometallurgical**
- **Intermediate Physical**
- **Direct Physical**

DOI: 10.1021/es302420z
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Workshop Purpose & Goals

• Purpose is to gather input from stakeholders on
  – Future opportunities and technical challenges facing development of transformative technologies, processes, and equipment for sustainable manufacturing
  – Input on performance metrics
  – Key problems to be addressed identified and quantified
  – Critical crosscutting barriers that, if successfully addressed, could enable step change impacts beyond the current state of the art

• Technology development should be focused on the gap between lab-scale development and deployment and scale-up
  – QUANTITATIVE GOALS ARE NECESSARY

• Specific goals include:
  – To identify high value opportunities and manufacturing challenges to improve energy efficiency, reduce material/water use, and enable increased recycle & reuse
  – To discuss promising technologies and manufacturing systems that increase sustainability in manufacturing at the unit operations, facility, and system level
  – To strategize how best to leverage R&D among the public sector, industry, and academia
  – To encourage discussion and networking among leaders in the field
LIKE QUANTIFICATION OF POSSIBLE REQUIREMENTS, NEEDS & GAPS
Example Outcomes from Workshop

• **What are ambitions and inspiring metrics for success?**
  – Reducing possible waste / scrap by an order of magnitude while maintaining cost and energy use
  – Increasing reuse capacity by order of magnitude while maintaining throughput and cost

• **What are the technical pathways needed to achieve this?**
  – Technologies that enable low-cost reuse and recycling of multi-material products
  – Equipment that reuse manufacturing wastes (e.g., depolymerization)

• **Where are the gaps?**
  – Industry won’t invest in new sustainable technologies / infrastructure
  – Novel processes have high capital cost limiting investment in scale-up
Workshop Structure: Breakout Sessions

• 5 Sessions
  – Developing and Using Alternative Feedstocks
  – Reduction of Waste in Manufacturing Processes
  – Sustainable Design and Decision-Making
  – End of Life Product Management
  – Materials, Water and Energy Management

• Staff will take real-time notes

• Results of each breakout session will be presented in a plenary session for each day
Types of information

• Be Specific
• Be Candid—Chatham House Rules (notes non-attributed)
• Give Quantifiable Metrics
  – What are the most important variables)?
  – For the most important variables, what are the game changer metrics for parameters like material usage, water consumption, cost, and energy consumption?
  – What are the actual numbers (e.g., 80% reduction, 100% recovery, etc.)?
• Provide High Level of Detail
  – What specific technologies are needed to meet these game changer metrics?
  – Why hasn’t the private sector made more of these investments?
  – What specific form of public-private partnership would best accelerate sustainable manufacturing? What would be counterproductive?
Thank You!