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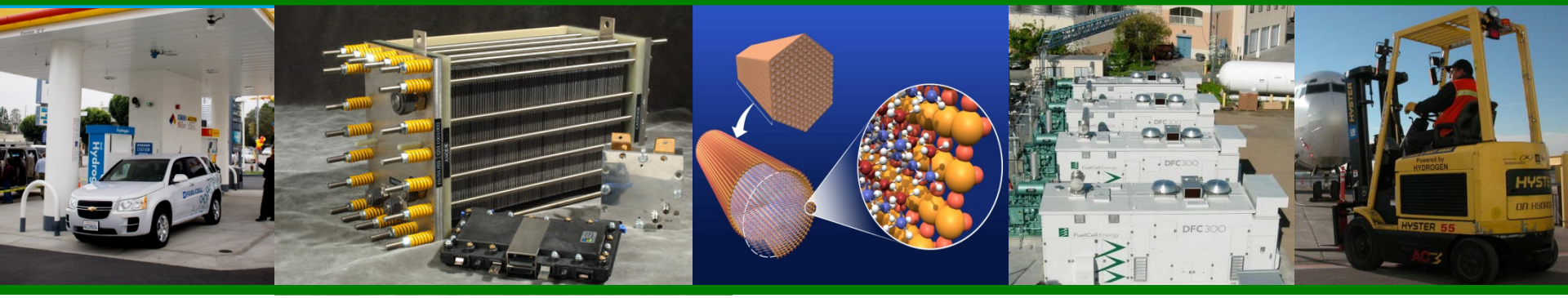

Manufacturing R&D Program Area
-Plenary Presentation-

Nancy L. Garland

Fuel Cell Technologies Office

2014 Annual Merit Review and Peer Evaluation Meeting

June 16 - 20, 2014

Goal and Objectives

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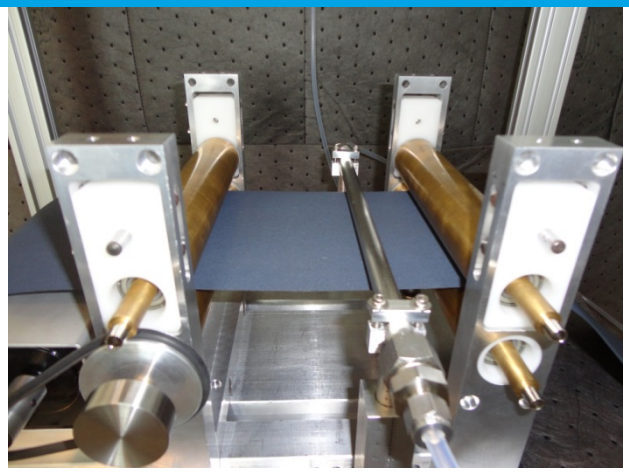
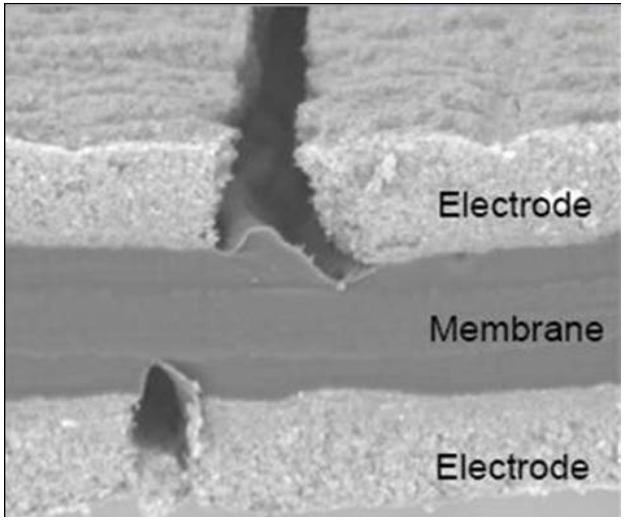
Goal: Research, develop, and demonstrate technologies and processes that reduce the cost of manufacturing hydrogen production, delivery, storage, and fuel cell systems.

Objectives:

- Develop manufacturing techniques to reduce the cost of automotive fuel cell stacks at high volume (500,000 units/year) from the 2008 value of $38/kW to $20/kW by 2020.*
- Develop fabrication and assembly processes to produce onboard vehicle hydrogen storage systems achieving: 1.8 kWh/kg (5.5 wt% H_2) and 1.3 kWh/L (40 g H_2/L) at a cost of $12/kWh ($400/kg H_2 stored) or less by 2017.*
- Other specific objectives are in the Fuel Cell MYRD&D Plan.

*Objective under revision.





Challenges & Strategy

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Comprehensive strategy to address barriers to manufacturing

Barriers

- Lack of High-Volume Membrane Electrode Assembly (MEA) Manufacturing Processes
- High Cost of Processing High-Temperature Fuel Cell Materials
- Low Levels of Quality Control (QC)
- Lack of Standardized Balance-of-Plant Components
- High-cost Carbon Fiber for Hydrogen Storage Tanks
- Lack of Reliable Hydrogen Compressors

Strategy

- Identify cost drivers of manufacturing processes
- Modify processes to eliminate process steps
- Reduce cost by implementing process control tools
- Increase automation
- Improve yields and reduce scrap
- Scale-up laboratory fabrication methods to low-cost, high-volume production
- Develop QC diagnostics and validate in-line
- Quantify the effect of defects on performance and durability

R&D Focus

- In-line defect diagnostics for QC of MEAs and MEA components
- Developing processes that reduce steps and scrap in the production of MEAs
- Developing new methods to manufacture Type IV pres-sure vessels for hydrogen storage

Key Areas

Pressure Vessels

- Improve designs

Membrane electrode assemblies

- Reduce the use of intermediate backer materials
- Reduce the number and cost of coating passes
- Minimize solvent use
- Develop diagnostics for in-line QC for MEAs and components
- Investigate the effects of MEA component manufacturing defects on MEA performance and durability

Manufacturing MYRD&D available at:
http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/index.html

EERE/Clean Energy Manufacturing Initiative (CEMI) QC/Metrology Workshop

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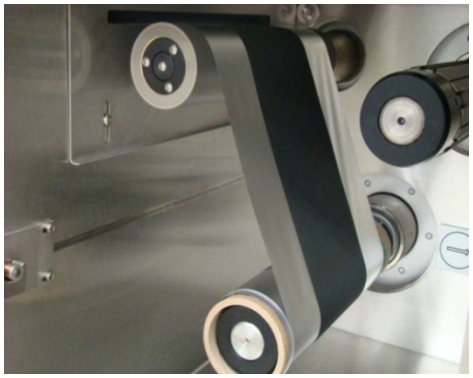
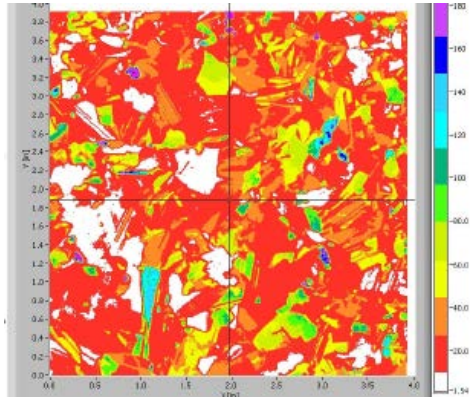
- The purpose of the workshop was to:
  - Note gaps in which current inspection & metrology (I&M) techniques are inadequate or missing altogether
  - Discuss similarities in materials I&M needs that cross-cut technologies
  - Identify opportunities for collaboration
- Co-sponsored by FCTO, AMO, SETO, VTO, and BTO
- Identified 3 key technical areas for action:
  - Cross-cutting I&M development needs, e.g., thickness, defects, surface structure, delamination, sensitivity of sensors, and data collection and analysis
  - Correlation of defects to performance and lifetime
  - Cost-benefit analyses as a function of materials, processes, yields, and volumes
- Identified 2 key programmatic areas to assist collaborative efforts:
  - Improve methods of communications and interactions with and technology transfer to industry
  - Facilitate more detailed technical exchange between researchers, developers, and vendors across different technologies to better identify and leverage synergies

http://energy.gov/sites/prod/files/2014/05/f15/eere_qc_workshop_final_report.pdf

Examples of non-uniformities



Battery electrode processing



Optical reflectance measurement of silicon wafer grain boundaries

Budget

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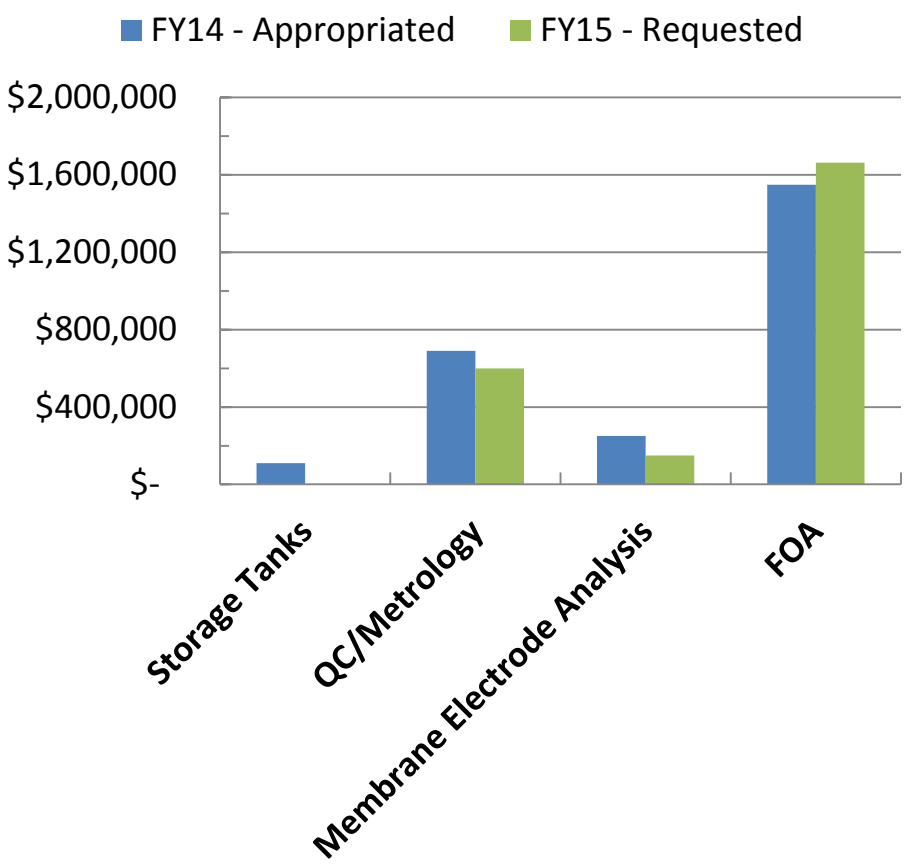
FY 2015 Request = $3M

FY 2014 Appropriation = $3M



EMPHASIS

- Quality control critical to enabling low-cost manufacturing with reduced waste (NREL, LBNL, EERE-CEMI QC/QA Workshop)
- Direct coating of membrane electrode assemblies
- 2014 FOA topics include supply chain development and global manufacturing competitiveness analysis
- Leveraging efforts across EERE where cross-cutting manufacturing challenges exist (AMO, SETO, BTO, VTO)

Accomplishments: NREL In-line Defect Diagnostics

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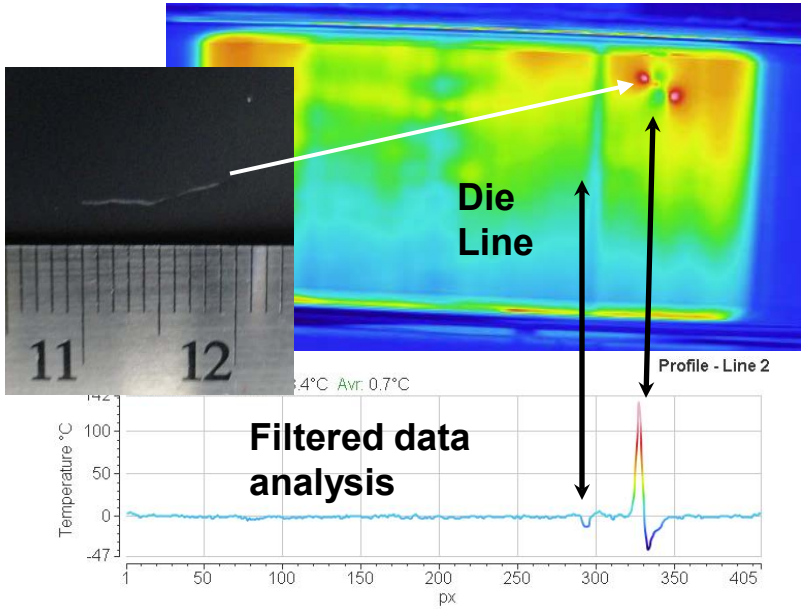
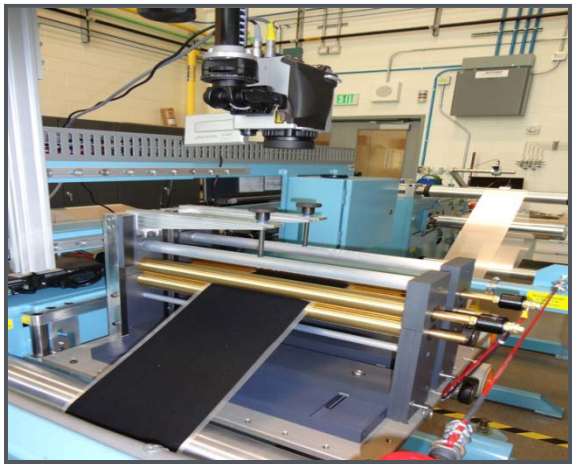
MN001

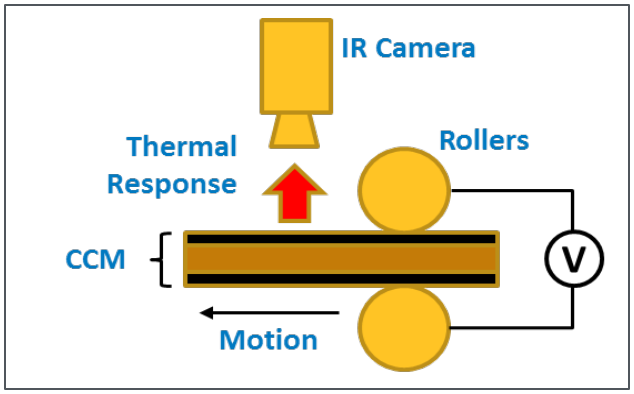
- Fabricated and commissioned new roller system on NREL webline
- **Tech-to-Market – implemented IR/DC on industrial coating line at Ion Power**; successfully detected defects at speed at the drying oven exit

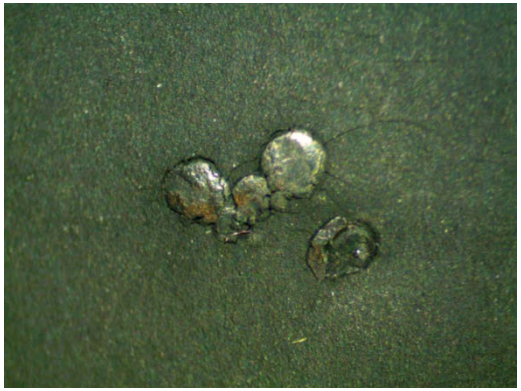




Agglomerates in catalyst layer

Demonstrated through-plane IR/DC on 2-sided CCM sheet





Accomplishments: Low-cost MEA manufacturing R&D at Gore

MN004

Approach:

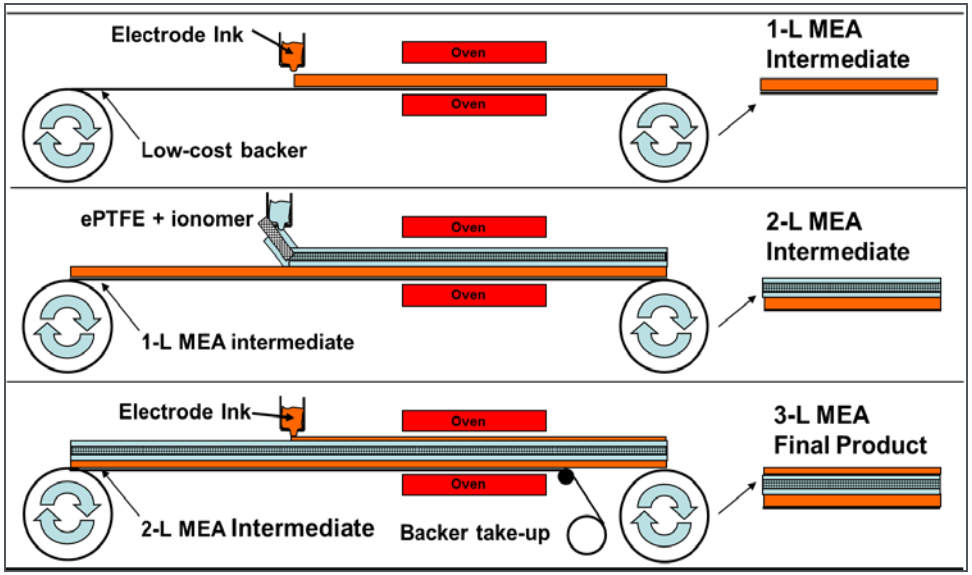
New 3-Layer (3-L) MEA Process with mechanical modeling of reinforced 3-L MEA (University of Delaware) and 5-L Heat & Water Management Modeling (University of Tennessee, Knoxville - UTK)

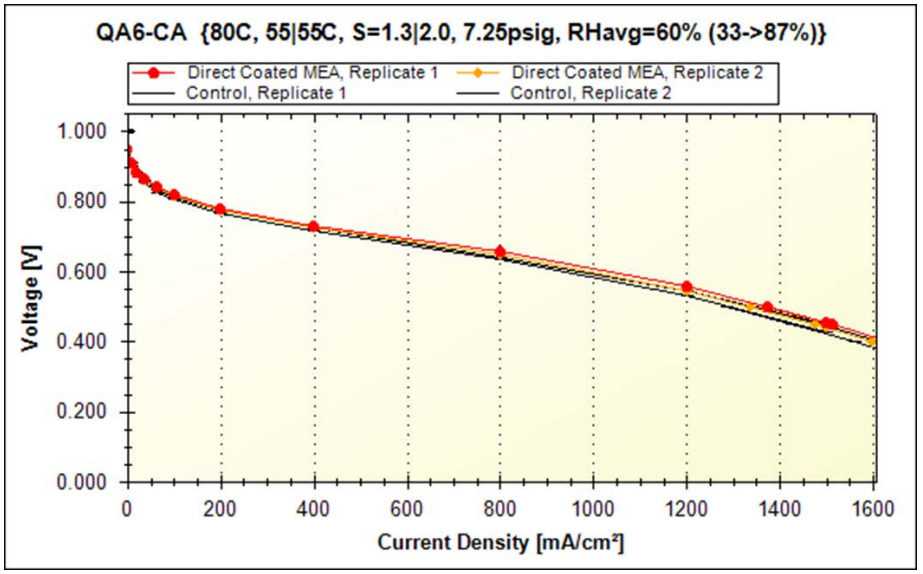
Accomplishments:

- Direct-coated the membrane layer on top of the cathode layer using a modified backer
- Gore has coated over 100 m of intermediate MEA material by a roll-to-roll process
- Optimization of direct-coated 3-L MEA is in progress

Next steps:

- A fuel cell stack will be built and tested at UTK using Gore's new 3-L MEA manufacturing process.
- The MEAs will be scalable to potential fuel cell industry volumes in 2015 (estimate 100,000 m^2 / year) and will meet or exceed Gore's current power density and durability.





Accomplishments: Quantum Pressure Vessels

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Objective: To manufacture low-cost, Type IV H_2 storage pressure vessels, using a hybrid process with advanced fiber placement (AFP) & commercial filament winding (FW)

MN008

FY14 Accomplishments

- Improved fiber placement
  - Within 2° of the angle specified
  - Within 0.05” of polar openings
- Improved end cap process

Vessels 15 & 16 CT scan showed no voids

- Vessel 15 achieved 103% of required burst pressure in mid cylinder, confirmed the in-house software is sufficient for hybrid design
- Vessel 16 achieved target cycle test count of 15,000

Future Work

- Replace AFP end caps with localized FW process
- Incorporate polar boss feature into foam tool to minimize gap between AFP end cap and liner

Cost model shows 20% cost savings over baseline 129L tanks

DOE's Clean Energy Manufacturing Initiative

U.S. DEPARTMENT OF ENERGY

Goals of CEMI:

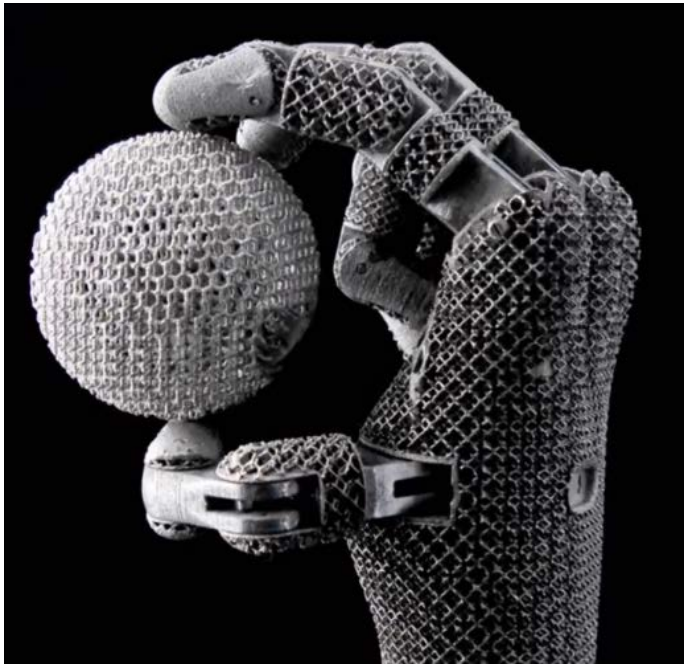
1. Increase U.S. competiveness in the production of clean energy products
2. Increase U.S. manufacturing competitiveness across the board by increasing energy productivity

Recent Activities:

- Joint EERE-CEMI QC/Metrology Workshop with FCTO, SETO, BTO, AMO, and VTO (Golden, CO)
- Regional Summits (Toledo, OH; San Francisco, CA)
- Dialogues with the Council on Competitiveness to develop Public-Private Partnership (Washington, D.C.; Schenectady, NY; Toledo, OH; San Francisco, CA; Berkeley, CA)
- Global manufacturing competitiveness analysis—Solar PV and Wind

Feedback from Regional Summit:

Challenges include: lack of ability to access government lab resources, low volume, volatile demand, and sluggish supply chain engagement



FCTO Funding Opportunity Announcement

U.S. DEPARTMENT OF ENERGY

EERE/FCTO released a Funding Opportunity Announcement on "Clean Energy Supply Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cell Technologies" on May 20, 2014. DOE Funding is up to $2M.
https://eere-exchange.energy.gov/#FoaId428150a1-c915-45c7-895d-994aab16e205

Topics Include:

- **Outreach to develop strategies and new approaches to facilitate development and expansion of the domestic supply chain of hydrogen and fuel cell related components in the U.S.**
  - Identify gaps in the supply chain and strategies to mitigate the gaps for hydrogen and fuel cell components and systems
  - Develop supply chain enhancement strategies (e.g., online supply chain exchanges, supply chain outreach 'speed dating' events)
- **Global manufacturing competitive analysis for hydrogen and fuel cell-related technologies**
  - Carry out comprehensive analysis of the factors affecting U.S. manufacturing competitiveness for hydrogen and fuel cell components and systems
  - Provide manufacturing-related market analyses related to the global fuel cell industry trends, including the number of units and size (MW) of fuel cells shipped and binned by country and type of application

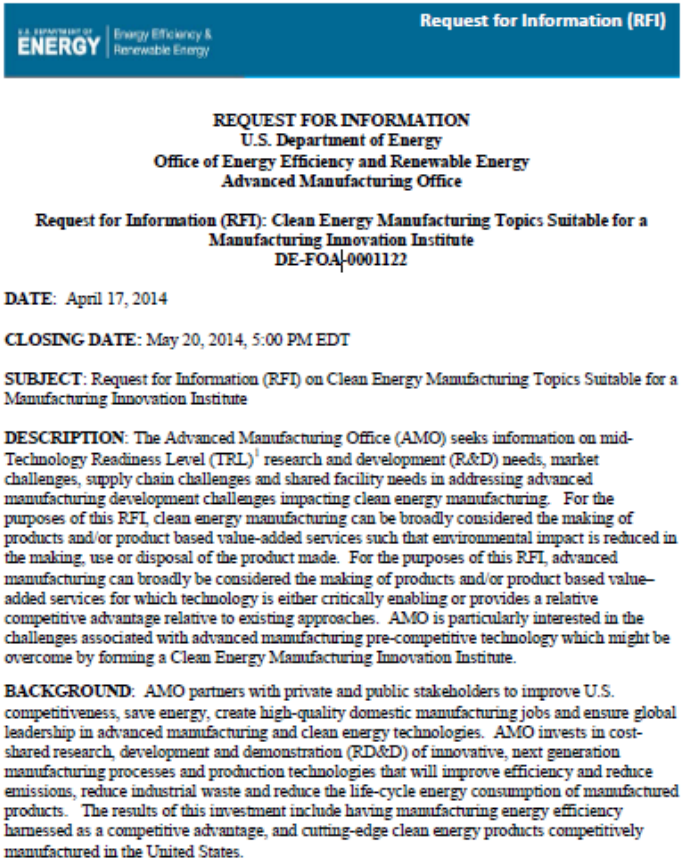
Letters of Intent Due: 5/30/2014
Applications Due: 6/30/2014

AMO's Request for Information (RFI)

U.S. DEPARTMENT OF ENERGY

The Advanced Manufacturing Office (AMO) released an RFI on April 17, 2014
https://eere-exchange.energy.gov/#FoaId9f021b00-a457-42a8-97a4-51e2143e9bec

- AMO sought information on mid-Technology Readiness Level research and development needs, market challenges, supply chain challenges, and shared facility needs in advanced manufacturing development of clean energy technologies.
- AMO solicited feedback on general issues and topics critical to the establishment of potential Clean Energy Manufacturing Innovation Institutes.
- AMO sought to understand cross-cutting as well as specific manufacturing challenges in the formation of a Manufacturing Innovation Institute, consistent with the mission of DOE, EERE, and AMO.



ENERGY | Energy Efficiency & Renewable Energy — Request for Information (RFI)

REQUEST FOR INFORMATION
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Advanced Manufacturing Office

Request for Information (RFI): Clean Energy Manufacturing Topics Suitable for a Manufacturing Innovation Institute
DE-FOA-0001122

DATE: April 17, 2014

CLOSING DATE: May 20, 2014, 5:00 PM EDT

SUBJECT: Request for Information (RFI) on Clean Energy Manufacturing Topics Suitable for a Manufacturing Innovation Institute

DESCRIPTION: The Advanced Manufacturing Office (AMO) seeks information on mid-Technology Readiness Level (TRL)[1] research and development (R&D) needs, market challenges, supply chain challenges and shared facility needs in addressing advanced manufacturing development challenges impacting clean energy manufacturing. For the purposes of this RFI, clean energy manufacturing can be broadly considered the making of products and/or product based value-added services such that environmental impact is reduced in the making, use or disposal of the product made. For the purposes of this RFI, advanced manufacturing can broadly be considered the making of products and/or product based value–added services for which technology is either critically enabling or provides a relative competitive advantage relative to existing approaches. AMO is particularly interested in the challenges associated with advanced manufacturing pre-competitive technology which might be overcome by forming a Clean Energy Manufacturing Innovation Institute.

BACKGROUND: AMO partners with private and public stakeholders to improve U.S. competitiveness, save energy, create high-quality domestic manufacturing jobs and ensure global leadership in advanced manufacturing and clean energy technologies. AMO invests in cost-shared research, development and demonstration (RD&D) of innovative, next generation manufacturing processes and production technologies that will improve efficiency and reduce emissions, reduce industrial waste and reduce the life-cycle energy consumption of manufactured products. The results of this investment include having manufacturing energy efficiency harnessed as a competitive advantage, and cutting-edge clean energy products competitively manufactured in the United States.

Closed May 20, 2014

Collaboration

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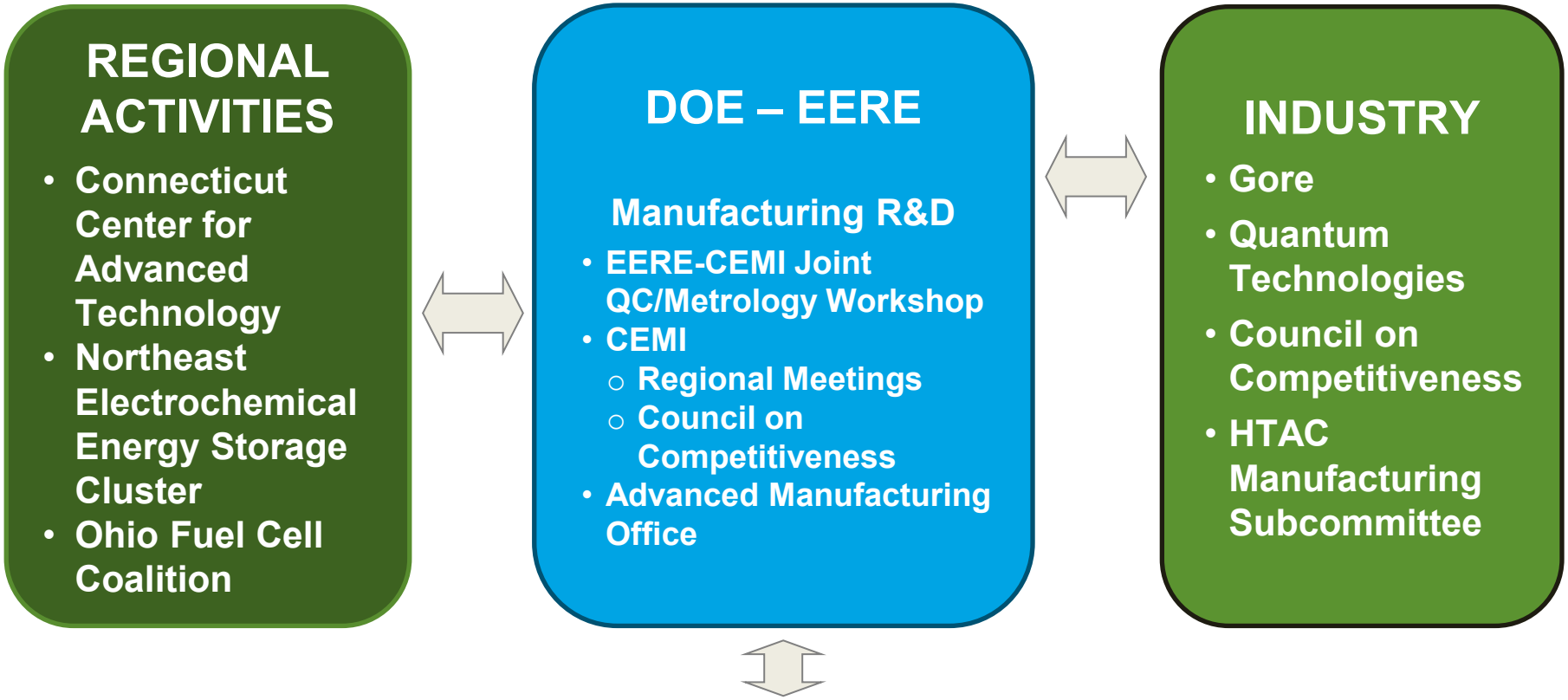

National Collaborations (inter- and intra-agency efforts)

NIST Advanced Manufacturing National Program Office (AMNPO)

Recent and Upcoming Activities

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Quality Control

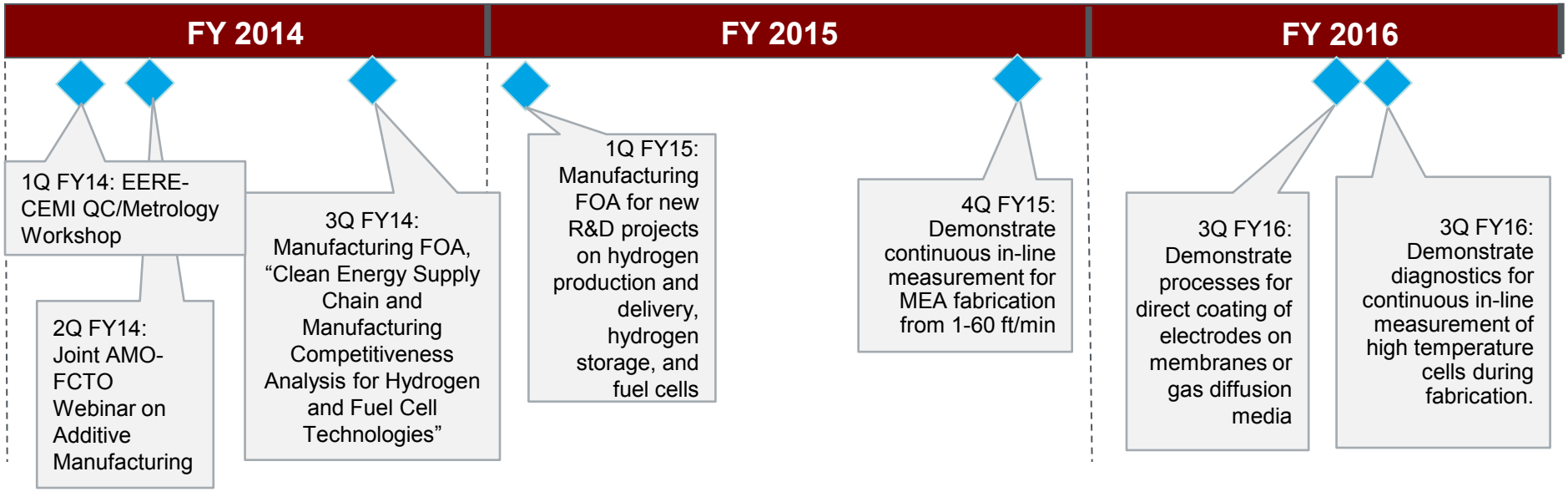
- Projects underway to demonstrate in-line QC for MEAs and components
- Workshop held to identify cross-cutting QC needs across multiple EERE technology offices

Low-cost MEA Manufacturing

- Demonstrate low-cost MEA manufacturing with improved performance

Manufacturing Competitiveness

- Funding Opportunity for:
  - Global competitiveness analysis
  - Domestic supply chain development



Contacts

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http://energy.gov/eere/fuelcells/fuel-cell-technologies-office