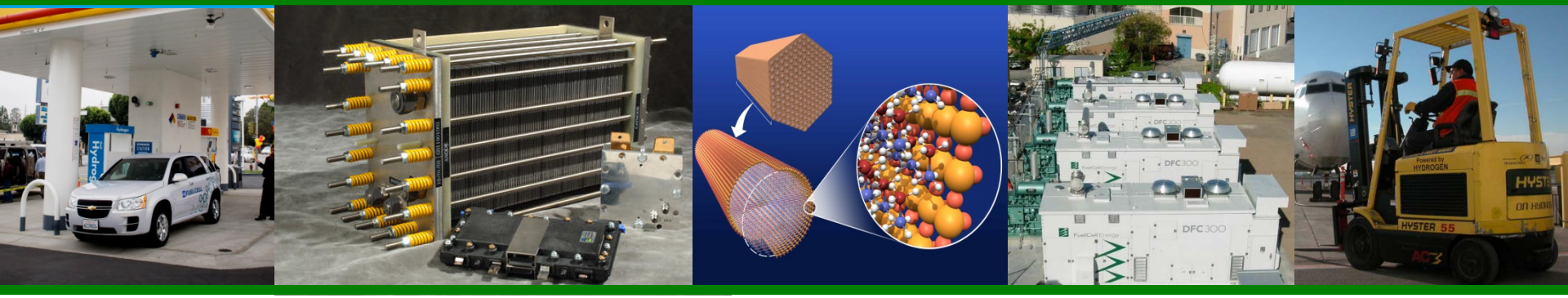
U.S. DEPARTMENT OF ENERGY



Manufacturing R&D Program Area
- Plenary Presentation -

Nancy L. Garland, Ph.D.

Fuel Cell Technologies Office

2016 Annual Merit Review and Peer Evaluation Meeting

June 6, 2016

Goals and Objectives

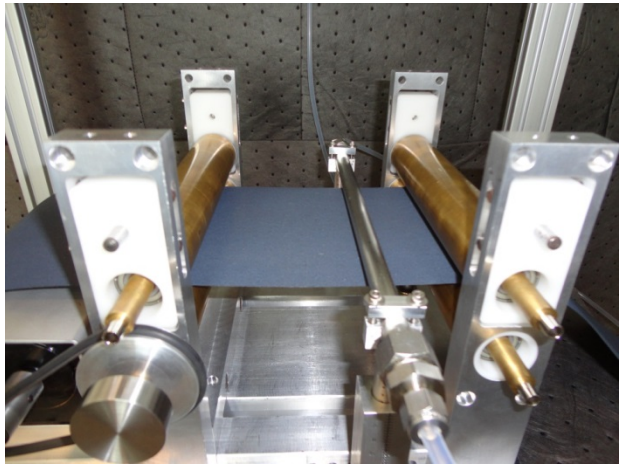
Goals:

- Reduce the cost of manufacturing hydrogen production, delivery, storage, and fuel cell component systems through research, development, and demonstration.
- Identify areas where the United States might have viable manufacturing opportunities

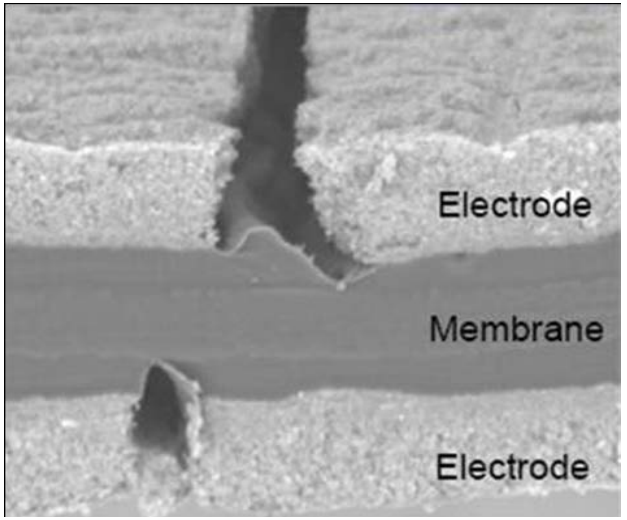
Objectives

- 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[1] to $20/kW by 2020.
- Develop processes to manufacture compressed hydrogen pressure vessels for onboard storage at a cost of $10/kWh by 2020, with an ultimate target of $8/kWh.
- Support efforts to reduce the cost of manufacturing components and systems to produce hydrogen at <$4/gge (2007 dollars) (untaxed, delivered, and dispensed) in 2020.

[1]http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/mass_production_cost_estimation_report.pdf



QC Diagnostics at NREL



Defect in Membrane Electrode Assembly

Manufacturing Challenges & Strategy

Barriers

- Key opportunities in the hydrogen and fuel cell supply chain (where the U.S. can increase manufacturing competitiveness) have not been identified.
- Existing steel pipeline used to carry natural gas is costly to convert to hydrogen delivery due to high labor costs associated with joining steel pipes.
- Levels of Quality Control (QC) in production facilities are low.
- The supply chain for hydrogen and fuel cells is not mature.

Strategy

- Identify cost drivers of manufacturing processes
- 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
- Conduct outreach to facilitate the development of the domestic supply chain of hydrogen- and fuel cell-related components in the U.S

R&D Focus

- Explore in-line defect diagnostics for QC of MEAs and MEA components
- Develop processes that reduce steps and scrap in the production of MEAs
- Conduct an extensive global manufacturing competitiveness analysis for hydrogen- and fuel cell-related technologies

Key Areas

Hydrogen Delivery

- Develop an innovative reinforced thermoplastic coupler that exceeds service requirements for hydrogen delivery

Supply Chain

- Expand the domestic supply chain of components and systems necessary for the manufacture of products and scale-up of the supply chain

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

Budget: Manufacturing R&D

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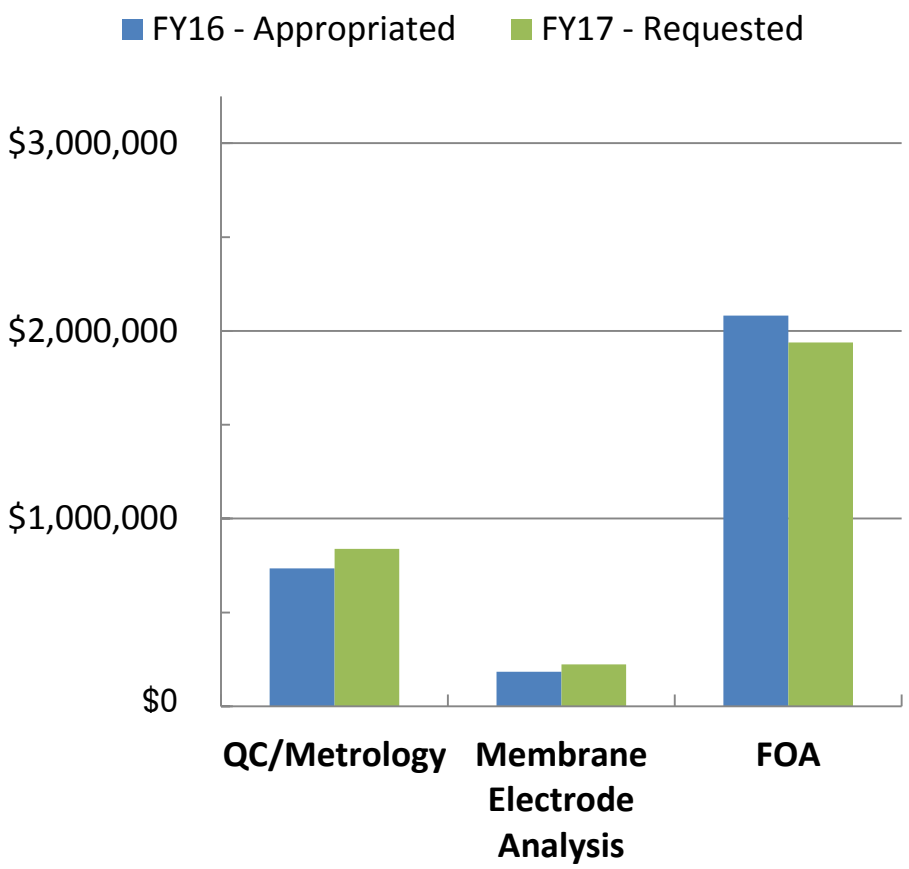
FY 2016 Appropriation = $3M

FY 2017 Request = $3M



EMPHASIS

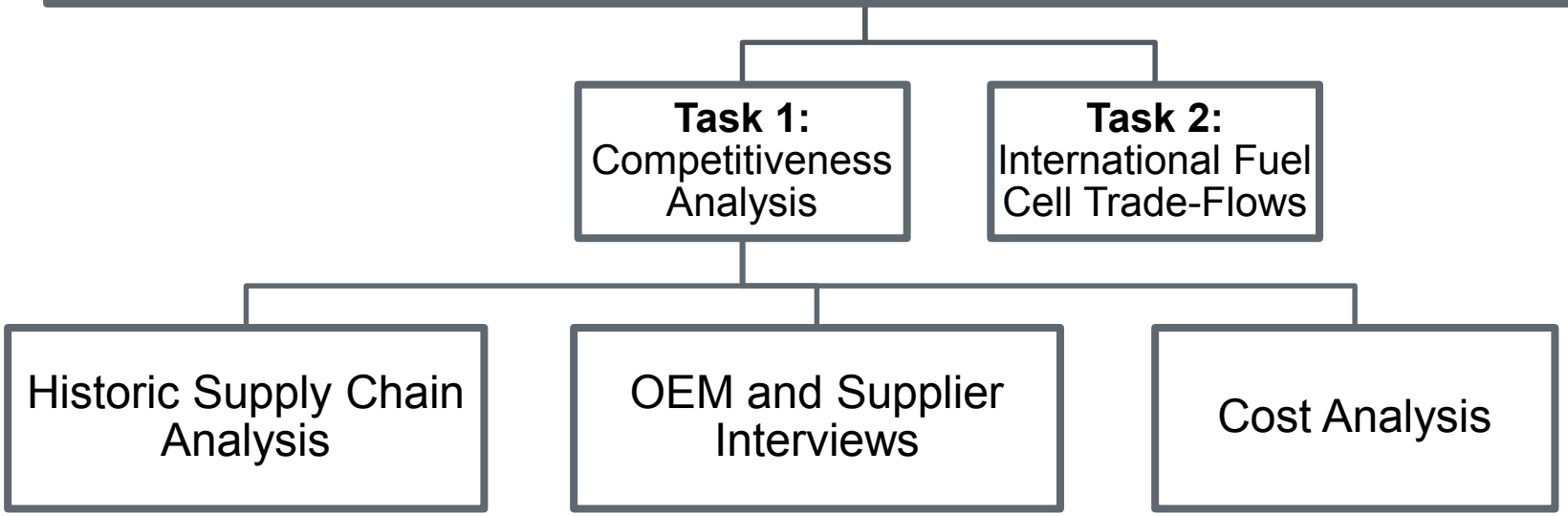
- Quality control critical to enabling low-cost manufacturing with reduced waste; correlate defect morphology with loss in performance (NREL, LBNL)
- New project from FY15 FOA: Fiber reinforced composite pipeline coupler (Automated Dynamics)
- SBIR Phase 1: Cross-polarized detection of membrane pinholes (Mainstream)
- 2016 FOA topic: Develop low-cost manufacturing processes and components for hydrogen fueling stations. Demonstrate the components in hydrogen service.
- Future focus could include improved manufacturing processes to reduce cost and increase the reliability & efficiency of:
  - Compressors
  - Hoses
  - Seals
- Leveraging cross-cutting manufacturing opportunities across EERE

GLWN - Global Manufacturing Competitiveness

U.S. DEPARTMENT OF ENERGY

Clean Energy Supply Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells

U.S Department of Energy Project DE-EE-0006935



Project Objective:

- **Study the state of hydrogen and fuel cell manufacturing**
- **Characterize the factors that impact the global competitiveness of fuel cell- and hydrogen-related manufacturing**

#MN014
Wed. 5:15
Del. A

Questionnaire for OEMs and suppliers

Bipolar Plate - Technology and Manufacturing Readiness

NOTE: Preliminary data only. Interviews are still in process.

	BPP Technology and Manufacturing Readiness			
	OEM's		Tier 1's	
	Technology	Manufacturing	Technology	Manufacturing
1. Is current component design ready for launch at 1,000 vehicles/yr?	YES	YES	YES	YES
2. Is current technology & manufacturing development ready for production >1,000 vehicles/yr. to at least 100,000 vehicles/yr.?	YES	**YES** for some, others more process development for 100k vehicles/yr	YES	**NO** -Added presses or new roll equipment needed
3. Are components available from credible suppliers that meet OEM cost / performance targets at 100,000 vehicles/yr.?	**Yes** for most	**NO** - need investment for 100k/yr	**Yes -** Current design is credible for 100k/yr	**NO** - Will need more presses or in-line process for 100k/yr
4. What are the R&D shortfalls in technology or manufacturing for 100,000 vehicles/yr. and what timing to achieve?	Defined tolerances. Timing is 3-4 yrs	Stamping or roll-to-roll continuous production	Eliminate plate ctgs, improve electrical conductivity, sealing solutions	High volume production of plates. "In-line process"
5. How many more vehicle powertrain demonstrations will be required before OEMs are ready to commit funds to produce 100,000 vehicles /yr?	At least two sets. One at 1000 and one at 10,000, before 100k.	No project unless neutral business case with variable cost. R&D funding of supply chain	OEM call	Run @ Rate demonstrations to step volume

Current capability up to 10K/yr. vehicles, further substantial investment needed for 100K/yr.

GLWN – Shipment data (E4tech)

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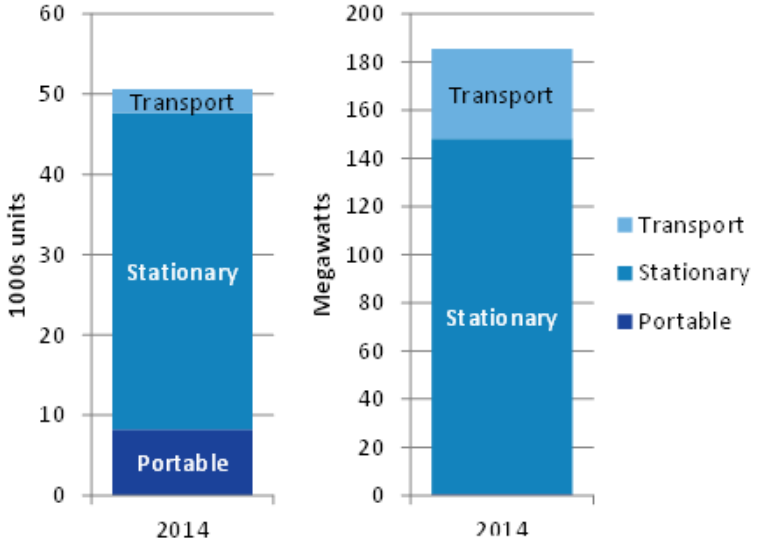
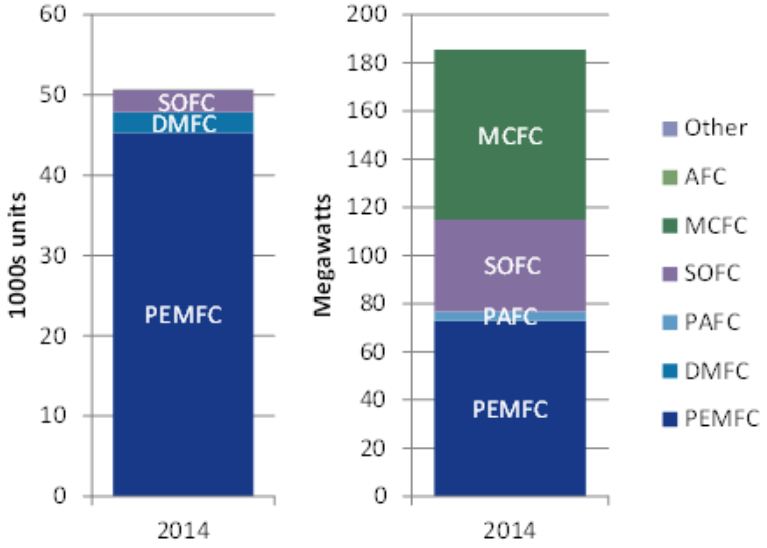
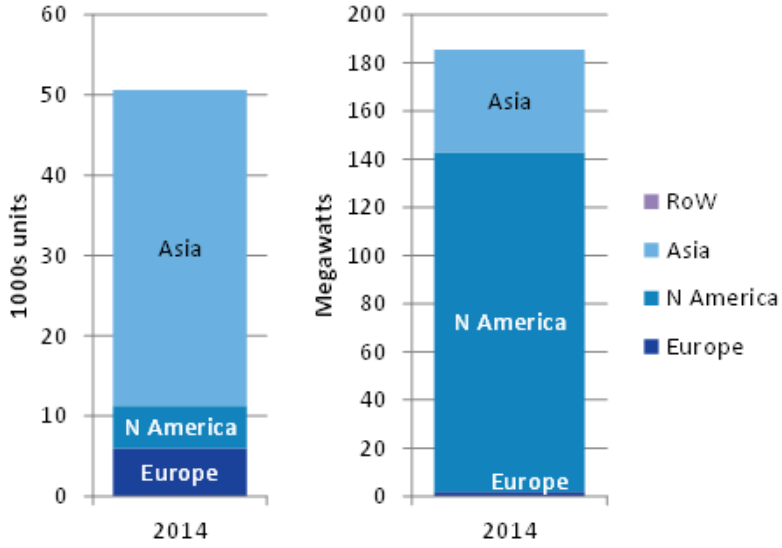
- E4tech gathered and delivered FC system shipment data for 2014
- Finalization of FC shipment data for 2015 is ongoing
- Gathering of shipment data for key components is ongoing (MEA, GDL, Bipolar plates, BOP)







OFCC – Supply Chain Analysis

U.S. DEPARTMENT OF ENERGY

Objectives

1. Increase **communication** between OEMs and hydrogen and fuel cell component suppliers.
2. Support establishment of a **web-accessible database** with Virginia Clean Cities.
3. **Standardize** component and subsystem component specifications.
4. Develop strategies to lower cost, increase performance, and increase durability of components.

OFCC
OHIO FUEL CELL COALITION

Accomplishments:

- **An integrated network** of regional Technical Exchange Centers:
  - East Coast (CCAT)
  - Midwest (OFCC)
  - Central States at NREL's National Fuel Cell Technology Evaluation Center
  - West Coast (UC Irvine)
- **The Technical Exchange Centers**:
  - Collect and catalog non-proprietary product information from regional suppliers and OEMs
  - Maintain a supplier contact list to introduce OEMs to suppliers
  - Hold annual supply chain exchanges

Held 2 annual supply chain exchanges this FY
Provided product info and contact list to VCC

#MN012
Wed. 4:15
Del. A

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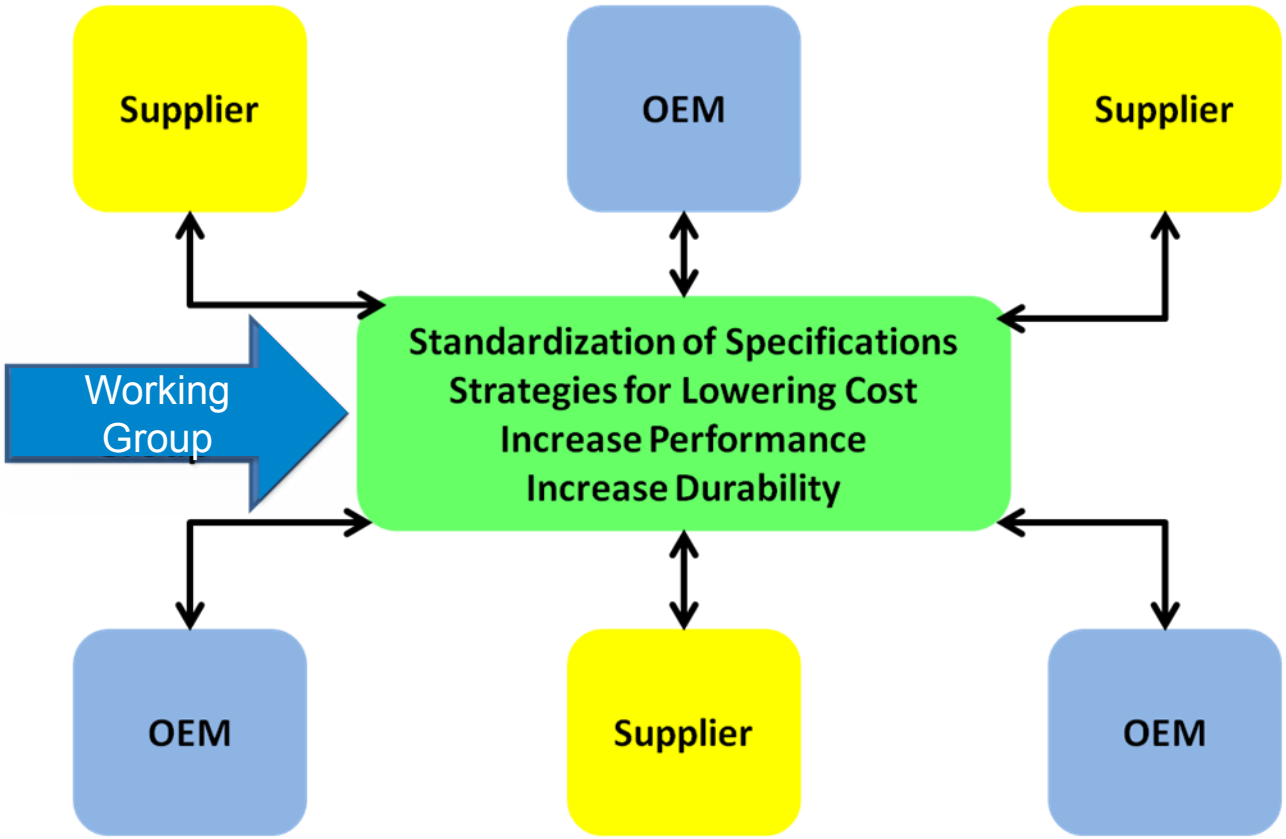
Approach

- Analyze needs of OEMs
  - Multiple suppliers
- Standardization of component specifications
- Mitigate the gap
  - OEM needs and supplier components



Status:
Working groups are identifying pathways to standardization of components and subsystems – in progress

Virginia Clean Cities

U.S. DEPARTMENT OF ENERGY

Project Objectives

1. Expand the domestic supply chain of fuel cell & hydrogen components and systems.
2. Build and populate a comprehensive communications database.
3. Drive U.S. companies to the website via an aggressive outreach campaign.

Virginia Clean Cities

Progress

- Name of website chosen: www.HFCnexus.com
- Server space acquired from James Madison University; web portal created
- Website design, graphics and user interface in development
- Data entry of 220 hydrogen and fuel cell companies into website so far
- Developing the Matchmaker Interface

#MN013 Wed. 4:45 PM
RM Del. A

NREL – Quality Control Diagnostics

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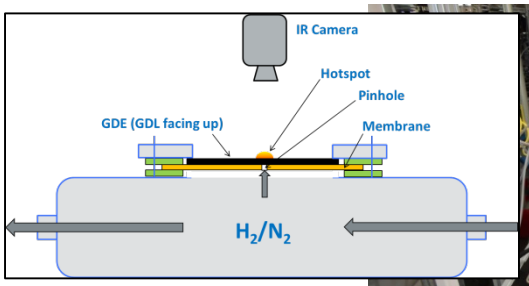
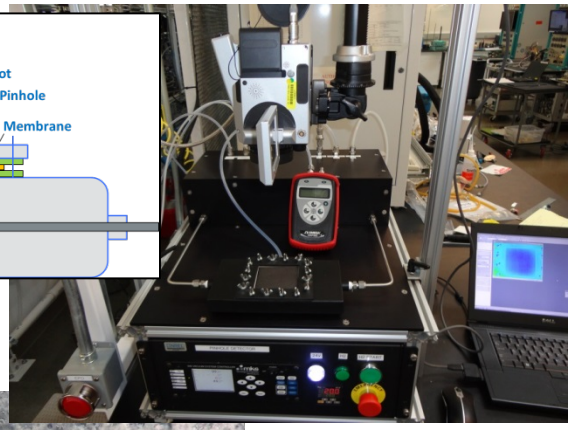
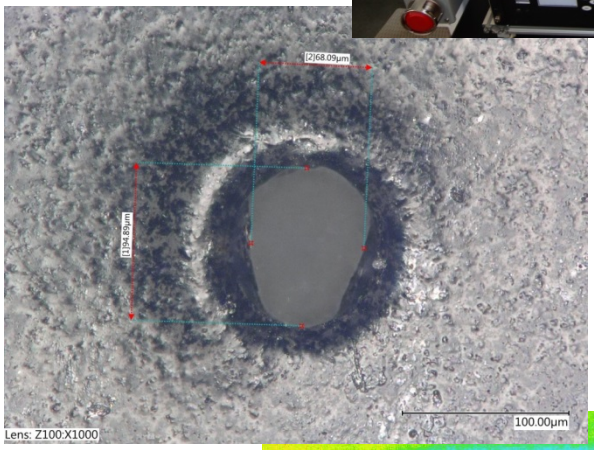
- Through-plane reactive excitation used to detect:
  - Failure of membrane integrity in CCMs, half-cells, or full MEAs
  - Location & severity of failure
- Successfully detected defects
  - <150 µm, < 5 s exposure time
  - Samples from GM and NREL
  - Parameters: reactive gas exposure time, H_2 concentration, flow rate for potential in-line implementation

#MN001
Wed. 3:15
Del. A



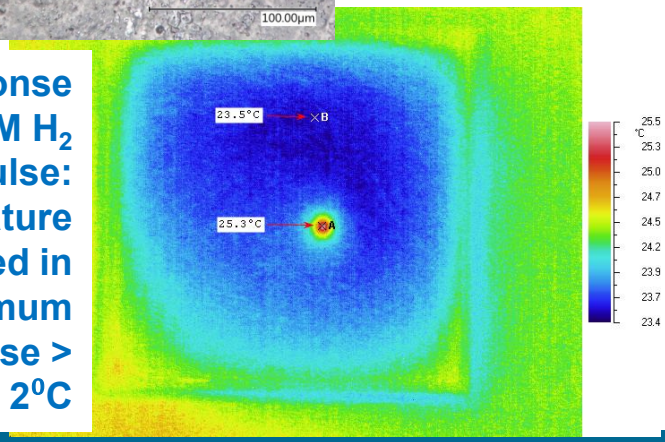


Pinhole detection apparatus



90 µm diameter pinhole in 18 µm thick membrane, tested with GDE (0.2 mg/cm² Pt)

Thermal response with 0.5 LPM H_2 flow, 5 s pulse: 1^0C temperature rise achieved in 2 s; Maximum temperature rise > 2^0C



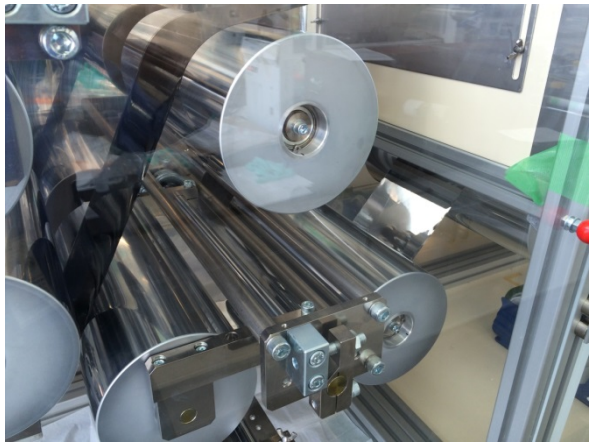
NREL – Tech-to-Market

U.S. DEPARTMENT OF ENERGY

"Manufacturing QC - Auto OEM Road Show"

- Ensure information about QC development capabilities is understood by auto OEMs
- **Impact**:
  - Fine-tune existing QC techniques per OEM requirements
  - Technology transfer
  - New joint projects
- **Accomplishments:**
  - CRADA worked with GM
  - NDAs setup with AFCC & Ballard; visit to Burnaby
  - Hosted and held discussions with Toyota Mirai staff

- **MEA scale-up**
- Emerging core competency
- Synergistic with NREL's MEA Integration and Manufacturing core competencies
- Process-material-performance studies
- Currently have R2R membrane, electrode coating capability
- Exploring MEA fabrication

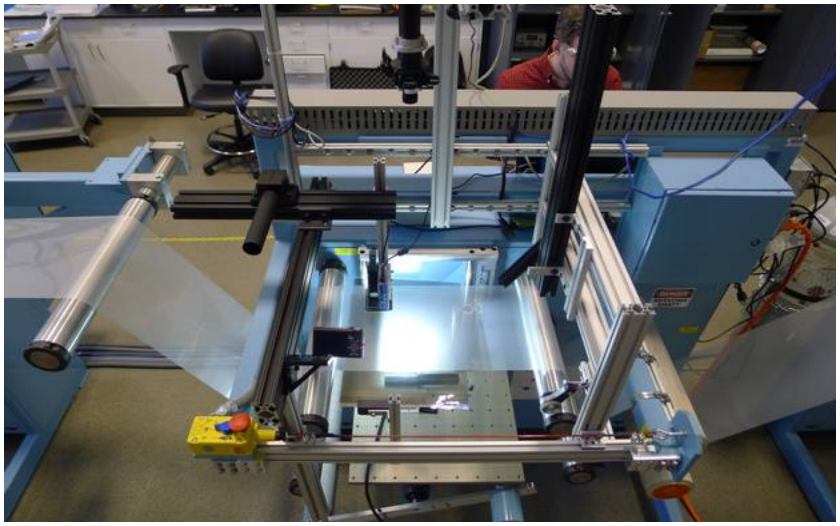


Collaborated with Mainstream on QC device development

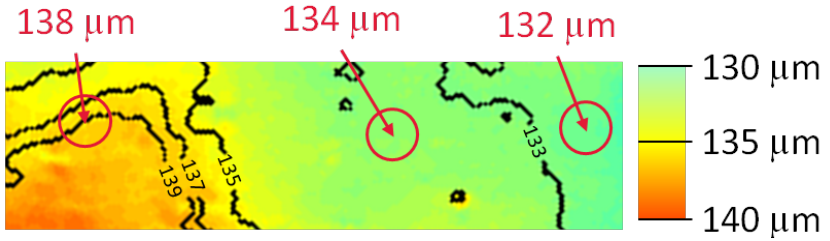
Mainstream - Accomplishments

U.S. DEPARTMENT OF ENERGY

- SBIR TTO project awarded to Mainstream to design commercializable device based on NREL's optical inspection patents
- Mainstream demonstrated prototype device at NREL
  - Used web-line and roller systems
  - Used rolls of membrane materials from commercial and industry partners
- Accomplishments:
  - 4 µm defects at 100 ft/min
  - 0.5 µm thickness resolution
  - 5σ false-positive and negative rate
  - Fully packaged prototype (TRL 7)



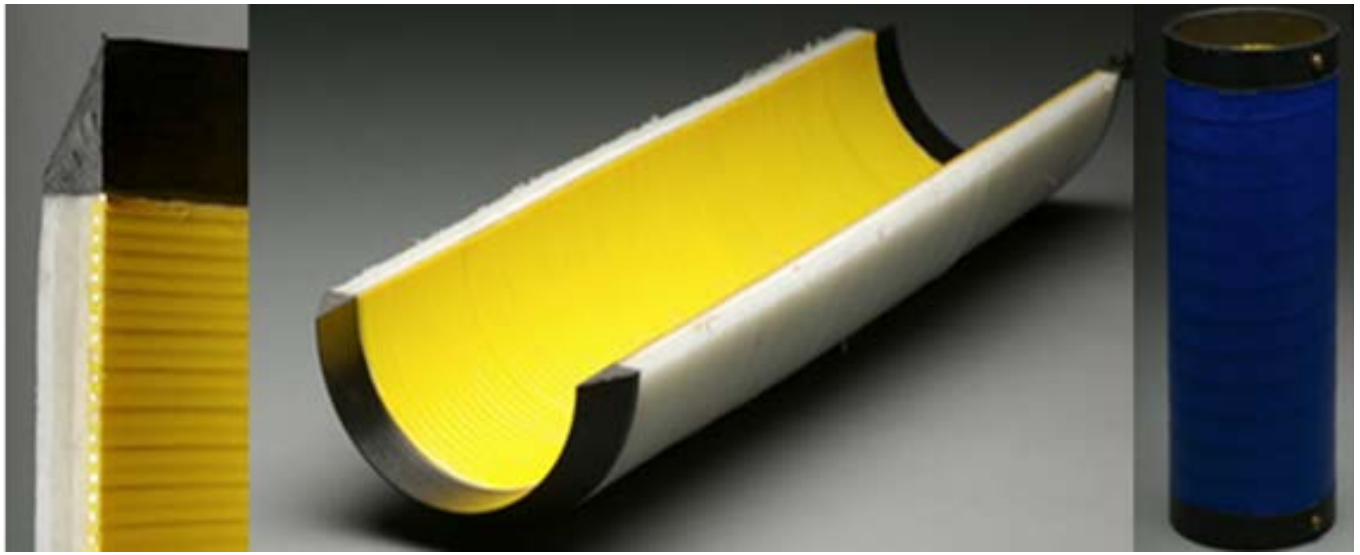
Mainstream's Phase I prototype on the NREL web line with optical system, encoder, printer, and data analyzer



Thickness map of a deformed Nafion®-115 sample (Mainstream result)

#MN016
Wed. 12:30
Exhibit Halls

Automated Dynamics – Hydrogen pipeline coupler



Objectives:

1. Develop an electrofusion coupler, a high-pressure pipe joint, to join fiber-reinforced composite pipe.
2. Manufacture prototype couplers for initial mechanical testing (TRL 3 to TRL 5)
3. Hold discussions with potential partners in Year 1; finalize relationships for commercialization by the end of Year 2; engage the partners as advisors for the commercialization of the coupler in Year 3.

Accomplishment: Completed the coupler's technical specification

#MN015
Wed. 12:30
Exhibit Halls

Cross-cutting Manufacturing Activities

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Small Business Vouchers Pilot
U.S. DEPARTMENT OF ENERGY

Round 1 awards within FCTO

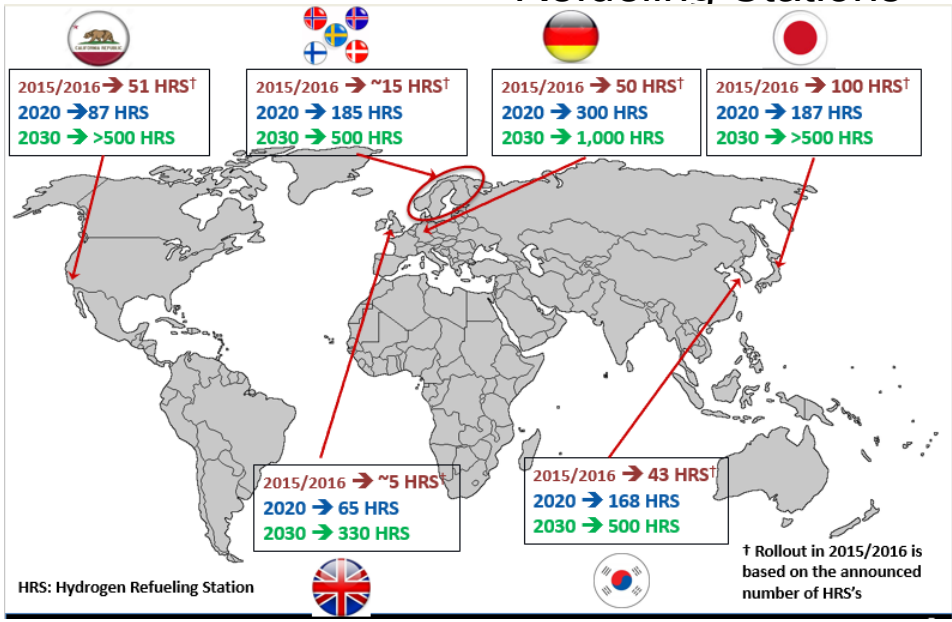
- Altergy Systems - SNL
- Amsen Technologies – LANL
- Element One – NREL
- KWJ Engineering – LANL/NREL
- Midwest Energy Group - NREL
- Sustainable Innovations – LANL
- Treadstone Technologies – ORNL/LANL

Proposals for round 2 are currently under review

#MN017
Wed. 5:45
Del. A

CEMAC Clean Energy Manufacturing Analysis Center

CEMAC provides objective analysis and up-to-date data on global clean energy manufacturing. In concert with GLWN, CEMAC is carrying out Manufacturing Competitiveness Analysis for Hydrogen Refueling Stations



International HRS Rollouts

Collaboration

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REGIONAL ACTIVITIES

- Connecticut Center for Advanced Technology
- Northeast Electrochemical Energy Storage Cluster
- Ohio Fuel Cell Coalition
- UCI
- Colorado Hydrogen Coalition

DOE – EERE

- Manufacturing R&D
- CEMI Days (3M, UTRC)
- Industry Day ORNL
- Advanced Manufacturing Office
- AMO-funded 5-lab cooperation in lithium ion batteries – extend to fuel cells?

INDUSTRY

- Mainstream
- Automated Dynamics
- Council on Competitiveness

INTERNATIONAL

- Potential collaboration between NREL QC and CEA. NREL visited CEA May 9-13, 2016

National Collaborations (inter- and intra-agency efforts)

NIST Advanced Manufacturing National Program Office (AMNPO)

16

Recent and upcoming activities

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SBIR:

- Phase II TTO to develop optical reflectance devices for defect detection; proposals under review

- **Supply Chain Exchange and Partnership Development Forum, 10/15 – Springfield, MA**
  Host: CCAT at the Business of Energy Storage Conference
  - Attendance: 127 including 20 OEMs, 48 Suppliers, 7 Utilities/Integrators
  - Connections: 170 meetings between OEMs, suppliers, and business partners

- **Supply Chain Exchange and Partnership Development Workshop, 5/16 – Long Beach, CA**
  - **Host: NFCRC** at the Advanced Clean Energy Expo

- **Supply Chain Exchange and Partnership Development Regional Forum – Fall 2016 – North Canton, Ohio**
  - **Host: OFCC** with Stark Area Regional Transit Authority, Stark State College, and LG Fuel Cell Systems

FY 2016	FY 2017	FY 2018
1Q FY16: FOA topic for new R&D projects on manufacturing hydrogen delivery components. 3Q FY16: Demonstrate processes for direct coating of electrodes on membranes or gas diffusion media.	1Q FY17: FOA topic for new R&D projects on manufacturing hydrogen and fuel cell components. 4Q FY17: Develop processes and methods to decrease the amount of time and equipment intensity currently required for stack testing	1Q FY18: FOA topic for new R&D projects on manufacturing hydrogen and fuel cell components 4Q FY18: Demonstrate methods to inspect full MEAs and cells prior to assembly into stacks

Contacts

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