



**Clean Energy
Supply Chain
and Manufacturing
Competitiveness
Analysis
for Hydrogen
and Fuel Cell
Technologies**

US DOE Office of EERE
Fuel Cell Technologies Office
AMR, Washington, D.C., June 6, 2017

Project ID: MN012

Principal Investigator: Pat Valente, OFCC
pat.valente@fuelcellcorridor.com



TIMELINE

- Start Date: Sept. 2015
- End Date: Aug. 2018
- Currently in Budget Year 2

BUDGET

- Start Date: Sept. 2015
- End Date: Aug. 2018
- Total Project Budget \$583,243
- Total Federal Share \$583,243
- Total Federal Funds spent: \$199,191.08 as of 3/31/17

BARRIERS

- Lack of standardization and cost of manufacturing
- Lack of national accessible database
- Lack of communication nationally between OEMs and suppliers

PARTNERS/COLLABORATORS

- Pat Valente, Ohio Fuel Cell Coalition (OFCC - project lead)
- Douglas Wheeler, DJW Technology (DJWT)
- Michael Ulsh, National Renewable Energy Lab (NREL)
- Jack Brouwer, National Fuel Cell Research Center (NFCRC) at UC Irvine
- Joel Reinbold, Connecticut Center for Advanced Technology (CCAT)

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- **DOE Hydrogen and Fuel Cells Program
Manufacturing Challenges Addressed:**

- **Cost of Manufacturing** - The route to reducing manufacturing costs includes the development of a robust domestic supply chain.
 - Identify critical opportunities in the hydrogen and fuel cell supply chain between Original Equipment Manufacturers (OEMs) and Component Suppliers via Supply Chain Exchanges/Workshops/database research.
 - Present needs, capabilities and value proposition. Providing this outreach works toward filling supply chain gaps and promote competitive pricing.
 - Advance supply chain with respect to multiple applications – including stationary, transportation, commercial, utility, and infrastructure.
 - The information gained from database research and Exchange events will be utilized in the national Hydrogen and Fuel Cell Nexus, which promotes business-to-business interaction and an expanded domestic supply chain. (Project MN-013)

➤ **Durability, Reliability, and Performance**

- The formation of supplier working group(s) to openly exchange and analyze specific needs of the OEMs with multiple suppliers.
 - Standardization of components work to address these issues, as well as promote competition and improve components reliability and efficiency.

➤ **Broad range of environmental benefits**

- Includes sustainability, clean energy and use of renewable power, reduced greenhouse gas emissions, improved air quality and energy conversion.

➤ **Barriers Relevance**

- Over 400 personal interactions facilitated through events to improve national communication between OEMs and component suppliers.
- Considering the seven critical components reviewed in GLWN's project (MN-014), opportunities for standardized components have been identified.
- Over 600 database contacts/information to national database.

Task #	Milestone and/or Deliverable	Description	Verification	Est. Quarter Completion	Planned Completion	Actual Completion
1.1	M1	Technical Exchange Centers Start-up and update of existing databases; JMU compatibility; Hold Supply Chain Exchange	2 Centers started, 2 converted; JMU compatibility verified, one supply chain event held in CT 10/2015	1	Mar-16	Sep-16
1.2	M2/D1	Creation of OEM needs brochure identifying components to be produced by suppliers	OEM needs to be determined with working group, but facing barriers of proprietary information and participation concerns	2	Sep-17	
1.3/1.4	none	OFCC and subcontractors to hold Supply Chain Exchanges	Supply Chain Exchanges held in CA 5/2016 and OH 9/2016	4	Sep-16	Sep-16
2.1	none	Identification of working group participants	In progress but proceeding slower than expected due to OEM response times and concerns	4	Sep-17	
2.2	M3	Identification of components and subsystems for standardization	In collaboration with MN014, GLWN, seven components are under consideration for standardization	4	Sep-17	
Go/ No Go	none	Facilitate 200+ supplier and OEM interactions; 50 new contacts for national database	213 interaction facilitated; 476 contacts to national database	4	Sep-16	Sep-16
3.1	M4	Promote data exchange between OEMs and suppliers/provide progress report; hold Supply Chain Exchanges	Supply Chain Exchange in OH 3/2017; one to be held in CO 8/2017; progress report to be submitted	8	Sep-17	

Future

In progress

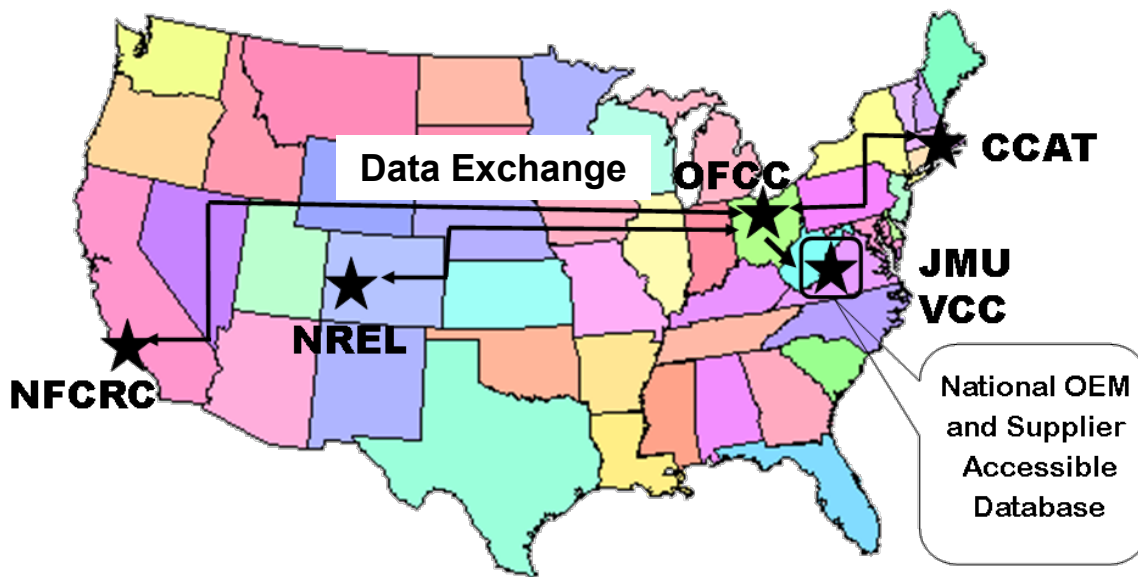
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3.2	M5	National Supply Chain Exchange at FCS & EE	No national event in 2016; 2017 just announced for 11/2017	6	Nov-17	
4.1	none	Working Group to identify components for standardization	In conjunction with GLWN (MN-014) suggested components identified	6	Dec-17	
4.2	M6/D2	Implement working group strategy for standardization; report on gaps, strategies, cost reduction	Team will work with suppliers/OEMs to identify topics and strategies for cost, performance, and durability improvements.	8	Dec-17	
Go/No Go	none	Facilitate 250+ supplier and OEM interactions; 50 new contacts for national database	To date - facilitated 247 interactions (one more event scheduled); 50 contacts to national DB	8	Sep-17	
5.1	none	Establish national database	Working with MN-013 JMU/VCC and info transfer ongoing	12	Mar-18	
5.2	M7	Hold one national and several regional Supply Chain Exchanges and collect data and provide summary	Team will continue to plan and host events for interaction at both regional and national level	12	Aug-18	
6.1	M8/D3	Working group recommendations for specs and production processes for initial standardized component; report on such to DOE	Team will work with working group for recommendations and prepare report	12	Aug-18	
7	D4	Reports, AMR presentation and project results to DOE	Reports, other deliverables, and final report will be prepared	12	Aug-18	

Future In progress

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Operation of 4 Regional Technical Exchange Centers to transition to National Website Database



Due to the concentration and location of manufacturing facilities and number of states involved, four regional centers allow more thorough research, advanced interactions between OEMs and suppliers, and ability to build a quality supply chain database.

- **May 5, 2016 – Long Beach, CA - Supply Chain Exchange and Partnership Development Forum**
 - Collaborator – National Fuel Cell Research Center (NFCRC) at UC, Irvine, the Governor's Office of Business and Economic Development (Go-Biz), and the California Hydrogen and Business Council (CHBC)
 - Attendance: 45; S.C. Exchange participants: 7 integrators, 11 Suppliers
 - Connections: 77 meetings between integrators & suppliers
 - Reach: Representing British Columbia and Ontario, Canada, CT, WA, CA, UT, TX, and OR
- **September 27, 2016 – North Canton, OH - Supply Chain Exchange and U.S. Dept. of Energy Hydrogen & Fuel Cell Supply Chain Development Stakeholder Session**
 - Collaborator – Ohio Fuel Cell Coalition (OFCC), U.S. DOE/EERE/FCTO
 - Attendance: 125; S.C. Exchange participants: 10 integrators, 18 Suppliers
 - Connections: 157 meetings between integrators & suppliers
 - Reach: 15 states represented including MA, NY, NJ, TN, PA, TX, CT, MI, MD, & Canada
 - Unveiling of Stark Area Regional Transit Authority's \$1.6 million hydrogen refueling station
 - Symposium survey results : excellent/good 100%; information: excellent/good 98%
 - Supply Chain Exchange Survey: 80% very satisfied; information: excellent/good 90%

- **November 17-18, 2016 – Hartford, CT - H2FC Forum w/Technology Showcase and RFI**
 - Collaborator – Connecticut Center for Advanced Technology (CCAT),
 - Attendance: 125
 - RFI for component standardization: Hydrogen and Fuel Cell Manufacturing Identifying Specific Components for Manufacturing Standardization
 - Survey results – event and content: excellent/good 90%; supply chain development: very useful/useful 60%
- **March 31, 2017 – Elyria, OH - Supply Chain Exchange and BOP Workshop**
 - Collaborator – Ohio Fuel Cell Coalition (OFCC), U.S. DOE/EERE/FCTO
 - Attendance: 128; S.C. Exchange participants 6 integrators, 17 Suppliers (50% new)
 - Connections: 90 meetings between integrators and suppliers
 - Reach: 14 states represented including BC, Ontario Canada, MI, FL, WI, CO, PA, IL, OR, TN, CT
 - Event survey results – content: excellent/good 94%; usefulness: excellent/good 92%
 - S.C. Exchange survey – Satisfaction: very satisfied/satisfied 100%; usefulness: excellent/good 100%; new connections made: 100%

SAMPLE MATCHMAKING SCHEDULE

Integrators	Integrator 1	Integrator 2	Integrator 3	Integrator 4	Integrator 5	Integrator 6
2:30 PM	Introduction					
2:40 PM	Supplier 1	Supplier 6	Supplier 10	Supplier 4	Supplier 5	Supplier 7
2:50 PM	Supplier 2	Supplier 13	Supplier 14	Supplier 3	Supplier 9	Supplier 4
3:00 PM	Supplier 3	Supplier 5	Supplier 12	Supplier 11	Supplier 10	Supplier 9
3:10 PM	Supplier 4	Supplier 3	Supplier 1	Supplier 12	Supplier 14	Supplier 10
3:20 PM	Supplier 5	Supplier 4	Supplier 2	Supplier 1	Supplier 13	Supplier 11
3:30 PM	Supplier 6	Supplier 15	Supplier 3	Supplier 13	Supplier 1	Supplier 12
3:40 PM	Supplier 7	Supplier 8	Supplier 13	Supplier 5	Supplier 2	Supplier 1
3:50 PM	Supplier 8	Supplier 16	Supplier 15	Supplier 14	Supplier 3	Supplier 2
4:00 PM	Supplier 9	Supplier 17	Supplier 6	Supplier 15	Supplier 11	Supplier 3
4:10 PM	Supplier 10	Supplier 9	Supplier 7	Supplier 6	Supplier 15	Supplier 16
4:20 PM	Supplier 11	Supplier 14	Supplier 8	Supplier 7	Supplier 6	Supplier 15
4:30 PM	Supplier 12	Supplier 11	Supplier 9	Supplier 16	Supplier 8	Supplier 5
4:40 PM	Supplier 13	Supplier 2	Supplier 16	Supplier 8	Supplier 12	Supplier 6
4:50 PM	Supplier 14	Supplier 1	Supplier 5	Supplier 10	Supplier 4	Supplier 8
5:00 PM						

Events Relevance: DOE Manufacturing R & D activities for supply chain development.

- Initiate and promote communication between OEM's and integrators
 - In advance of events, suppliers and OEMs completed grids indicating needs and capabilities, for more effective matchmaking.
 - Different event focus has different participants = more information and contacts
- Secure information in needs assessment, specification analysis, and standardization (Tasks 2, 4, 6)
- Events in-progress align with project objectives for Tasks 1 & 3, Start-up/Operation of Regional Technical Exchange Centers

Database Progress

- Continue to evaluate and research relevant companies for database info and events
- Initiated start of Mountain Region Database with over 50 entries
- Contribute information gained thus far, over 400 contact entries, from research and events to JMU for inclusion in the Hydrogen and Fuel Cell Nexus (MN-013)
- Finalized database fields (including hydrogen refueling components), and continuity with JMU; coordinated contacting organizations to prevent duplication

Standardization (tasks 2, 4, 6)

- Companies identified as potential contributors to standardization
 - Focus on PEM Fuel Cell Systems
 - Automotive – Motive – Stationary Power
 - Initial emphasis on North American Companies

Location	OEMs Contacted	OEMs to Contact	Suppliers Contacted	Suppliers to Contact
North America	5	5	13	12
Europe		2	3	6
Asia		3		6

Collaboration with GLWN (MN-014) in contacting automotive OEMs regarding standardization of fuel cell components.

Standardization (tasks 2, 4, 6)

- Continue collaboration with GLWN (MN-014) in contacting automotive OEMs regarding standardization of fuel cell components.
 - Responses indicate some OEM's (but not all) are willing to work with other OEMs on standardization of some components; e.g., hydrogen sensors and many of the balance-of-plant components.
 - Components specific to the fuel cell stack design would be difficult to standardize as most contain proprietary technology and the concept of a standard fuel cell stack did not appear to be feasible.
- The following standardized components are suggested:
 - High pressure valves for the hydrogen storage system.
 - Filters to remove gas impurities.
 - Temperature and voltage/current sensors.
 - Compressor/Expander
 - Membrane Humidifier and Demister
 - Coolant subsystem and associated components
 - Flow controls- including ejectors and pumps

Reviewer's Comment from 2016	2017 Response/Action to comment
<p>Why four technical exchange centers and how do they contribute in developing communication between OEMs and Suppliers and address key barriers?</p>	<p>This project was divided into regions to effectively research and interact with potential participants for the National database. Some regions have multiple OEMs and a dense supplier/manufacturing sector, while other regions are spread out with minimal known relevant participants. Our designated regions help us to more effectively concentrate and evaluate an area, prevent duplication of efforts, and allowed us to include more states in the project.</p>
<p>There is no apparent effort to match specific, quality companies with potential buyers of the hardware.</p>	<p>Before companies participate in a Supply Chain Exchange event, they must complete an OEM needs or suppliers capabilities grid (see next slide). These grids are reviewed and the matchmaking is set-up based on the needs of the OEMs, so they are meeting with relevant suppliers.</p>
<p>Need status of the working group, its members, and pathways to standardization.</p>	<p>Consideration and acceptance to participate in the working group has not been as forthcoming as we had hoped. It has required multiple individual interactions and additional information, which has slowed the process. We continue to work on obtaining group members. We are working with the DOE on the information gained from the live RFI held in Nov. 2016, to assist in developing a plan for the standardization effort.</p>

Hydrogen FC Components	Company			
	Check (x) Appropriate Boxes			
Products				
Systems				
Complete Systems				
Stacks				
Humidifier(s)				
Selective (Polymer) Membrane Separation (gas cleanup)				
Gas Diffusion Layers				
Micro Porous Layer				
Bipolar Plates				
Carbon/graphite				
Metallic				
Manifolds				
End Plates				
Compressive load (Belleville washers)				
IGBT (inverter components)				
DC-AC Inverter				
DC-DC converter				
DC bus controller				
Electronics				
Controllers				
Automation of system integration				
Switches				
Analytical instruments				
Electric switchgear for interconnection with grid				
Breakers				
Surge and short circuit protection				
Synchronize with grid waveform				
"Lock-out" switches				
HT Pressurization Machinery				
Natural gas				
Air				
HT/HP Containment Vessels				
Low Chrome				
Si Treating				
Insulators - High temp insulators				

Solid Oxide FC Components	Check (x) Appropriate Boxes			
Products				
Systems				
Complete Systems				
Stacks				
IGBT (inverter components)				
DC-AC Inverter				
DC-DC converter				
DC bus controller				
Electronics				
Controllers				
Automation of system integration				
Switches				
Analytical instruments				
Electric switchgear for interconnection with grid				
Breakers				
Surge and short circuit protection				
Synchronize with grid waveform				
"Lock-out" switches				
HT Pressurization Machinery				
Natural gas				
Air				
HT/HP Containment Vessels				
Low Chrome				
Si Treating				
Insulators - High temp insulators				

Collaborators (w/project budget)	Relevance of Collaborators
Patrick Valente, Ohio Fuel Cell Coalition Prime (\$153,222)	Responsible for all programmatic and technical decisions for the project.
Joel Reinbold, Connecticut Center for Advanced Technology (CCAT); subcontractor (\$130,000)	Establish and coordinate the East Coast Technical Exchange Center; assist with supply chain mapping and standardization.
Douglas Wheeler, DJW Technology (DJWT); subcontractor (\$120,021)	Establish and coordinate the West Coast Technical Exchange Center at NFCRC; set –up working group; consulting.
Jack Brouwer, National Fuel Cell Research Center (NFCRC) at UC Irvine; subcontractor (\$50,000)	Establish and coordinate the West Coast Technical Exchange Center.
Michael Ulsh, National Renewable Energy Lab (NREL – Federal Lab); subcontractor (\$130,000)	Technical support and establish and coordinate Central Plain/Mountain Region States Technical Exchange Center; establish working groups.

Additional Collaborations	JMU/VCC MN-013 and GLWN MN-014
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- Lack of national accessible database
- Lack of communication nationally between OEMs and suppliers
 - Supply chain event issues: with limited OEMs nationwide, frequency of exchanges/events create challenges; need to provide new and different suppliers to meet them.
- Lack of robust supply chain for fuel cell and hydrogen industry
 - High manufacturing cost of component and fuel cell systems
- Lack of component and system standardization
 - Working group and standardization barriers: release of proprietary information; hesitancy to participate
 - Fuel cell stack, carbon fiber composite, and fabricators of hydrogen storage tanks too proprietary to focus on standardization
- Improve reliability and durability of the materials and components for these systems.
- Integration of hydrogen fueling station components and their supply chain

- **FY 2017:**

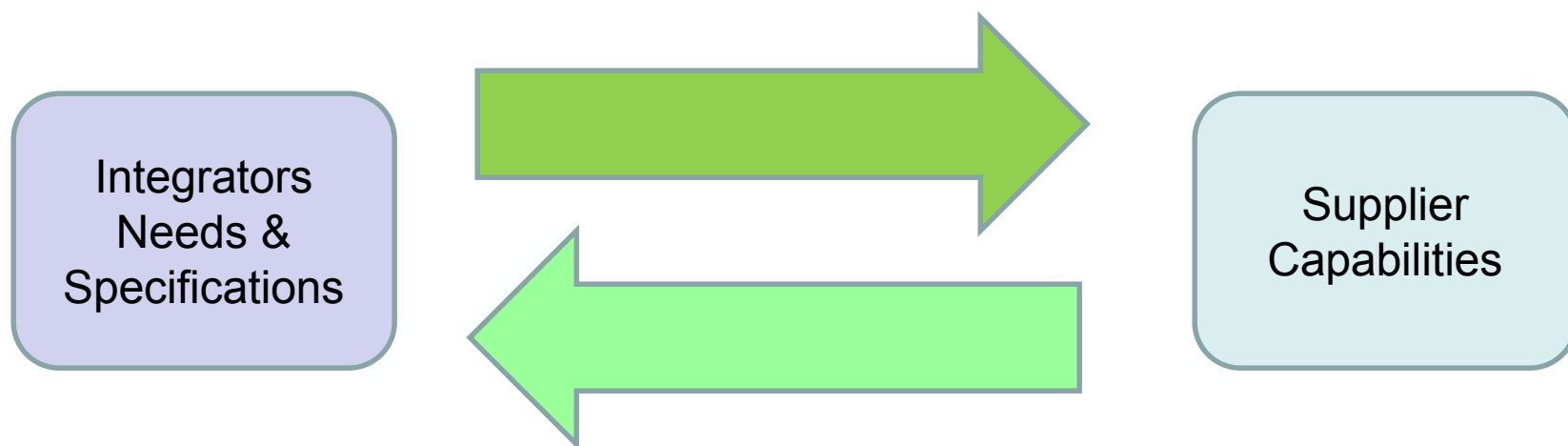
- Facilitate supplier and OEM interaction through two scheduled events (to date):
 - *August 17, 2017 – Parker, CO* - Workshop and Supply Chain Exchange Event
Collaborator – National Renewable Energy Laboratory (NREL)
 - *November 7-9, 2017 – Long Beach, CA* - National Fuel Cell Seminar and Supply Chain Exchange Event - Collaborator – Ohio Fuel Cell Coalition (OFCC) and Subcontractors
- Continue evaluation of organizations/companies for potential event participation and inclusion in the H & FC Nexus
- Finalize Working Group participants, define strategy for standardization, finalize component(s) to standardize (in collaboration with MN-014)
- Create OEM needs brochure from information gained through Working Group and OEM interviews; discuss w/suppliers
- Creation of an easily accessible, stand-alone, informational marketing piece to further explain this project and Hydrogen & Fuel Cell Nexus

- **FY 2018:**

- National and regional supply chain events will be held in year 3 for OEM/supplier interaction, needs and gaps assessment
- Utilize Working Group recommendations for component standardization, cost evaluation
- Work with JMU/VCC (MN-013) on H & FC Nexus, provide contacts/information, promote more user participation

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Project focus is two way technology transfer between
Integrators and Suppliers



The Integrated Regional Technical Exchange Centers project is to facilitate the development of a robust supply chain for fuel cell and hydrogen systems that will accelerate mass production, reduce costs, and improve performance and durability of these systems by:

- Regional Technical Exchange Centers and nationwide supply chain exchanges provide increased communications between OEMs and suppliers, identification of needs and gaps in supply chain, contact and component information for web and public accessible national database.
- Working groups (supplier, OEMs and standardization) provide strategy for component standardization, recommendation for specifications and production processes leading to competitive cost reduction, more durable and better performing parts.
- Identification of critical opportunities in the hydrogen and fuel cell supply chain where the U.S. can achieve or maintain a competitive advantage.