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U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competitiveness Analysis

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GLWN

Westside Industrial Retention & Expansion Network

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Project ID: MN014

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Overview

Timeline

- Project Start Date: 06/01/15
- Project End Date: 05/31/19

Budget

Total Project Budget: $777,379
- Total Recipient Share: $163,365
- Total Partner Share: $122,983

Total DOE Funds Spent*: $ 286,348

** as of 3/31/16*

Total DOE Funds Received to Date: $361,250

Partners

- GLWN – Project Lead
- Strategic Analysis, Inc.
- DJW Technologies
- E4tech

Barriers Addressed

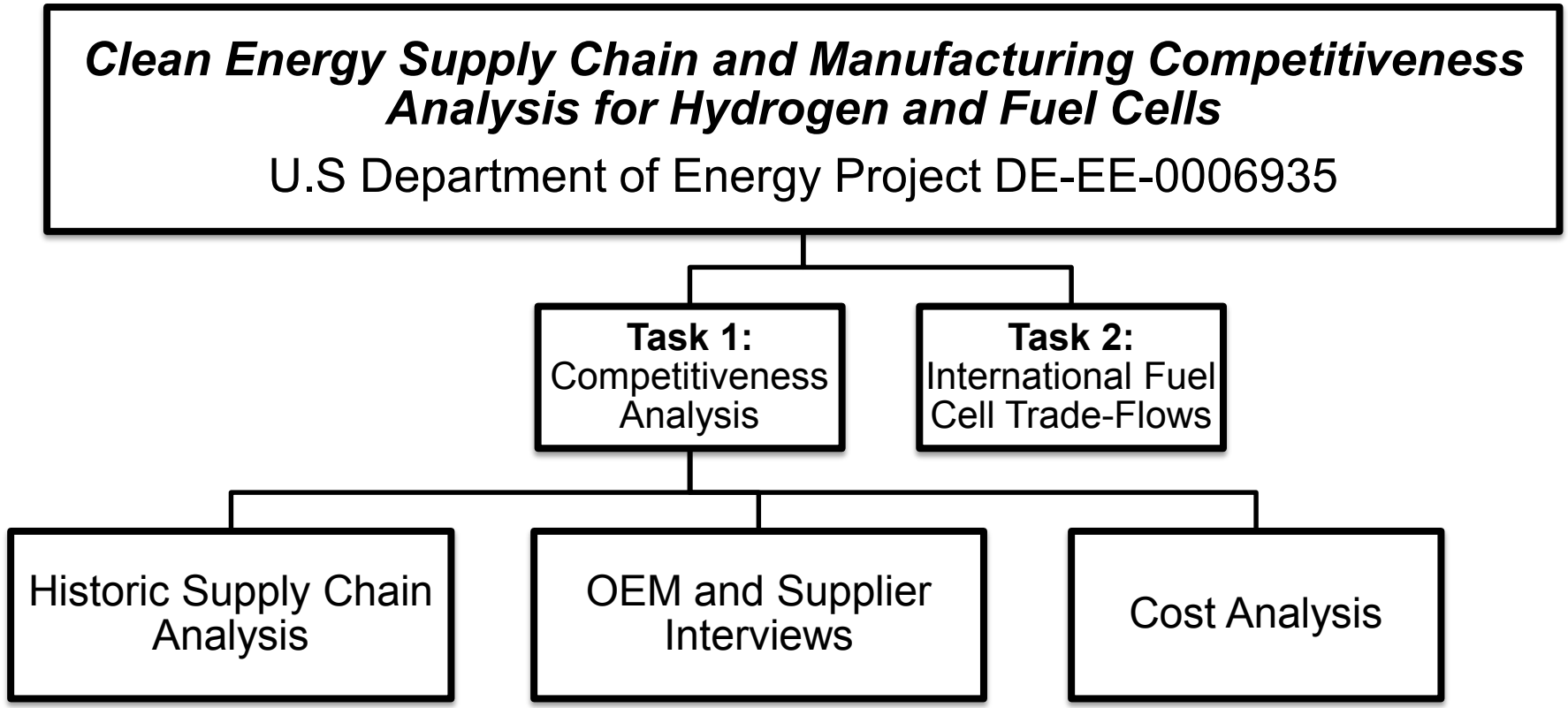
Note: Barriers currently under reevaluation

- A. Lack of high volume MEA processes (includes catalyst, membrane, GDL)
- B. Lack of high speed bipolar plate manufacturing processes
- K. Lack of low cost fabrication techniques for storage tanks
- I. Lack of Standardized Balance-of-Plant Components

Relevance

- Project falls under the Clean Energy Manufacturing Initiative (CEMI) mission to increase domestic
  - Manufacture of clean energy products
  - Increased energy productivity
- Competitiveness is largely driven by cost, thus we examine
  - Current and projected cost
  - Supply chain evolution
  - Global trade flows
- Outcome of this project will
  - Aid DOE/CEMI in identifying strategic investments
  - Lay out prospective future supply chain
  - Identify technology areas for R&D investment

Approach



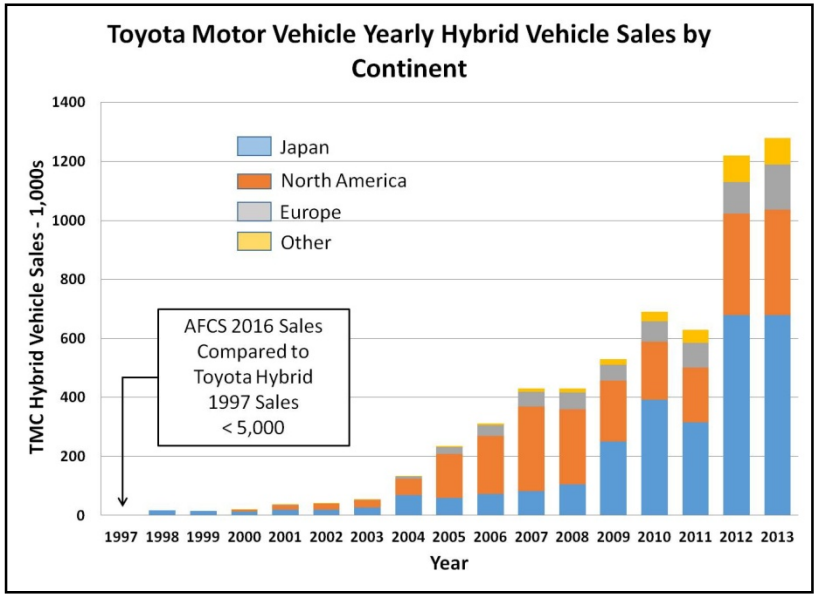
Project Summary: To study the state of hydrogen and fuel cell manufacturing, and to characterize the factors that impact the global competitiveness of fuel cell and hydrogen related manufacturing

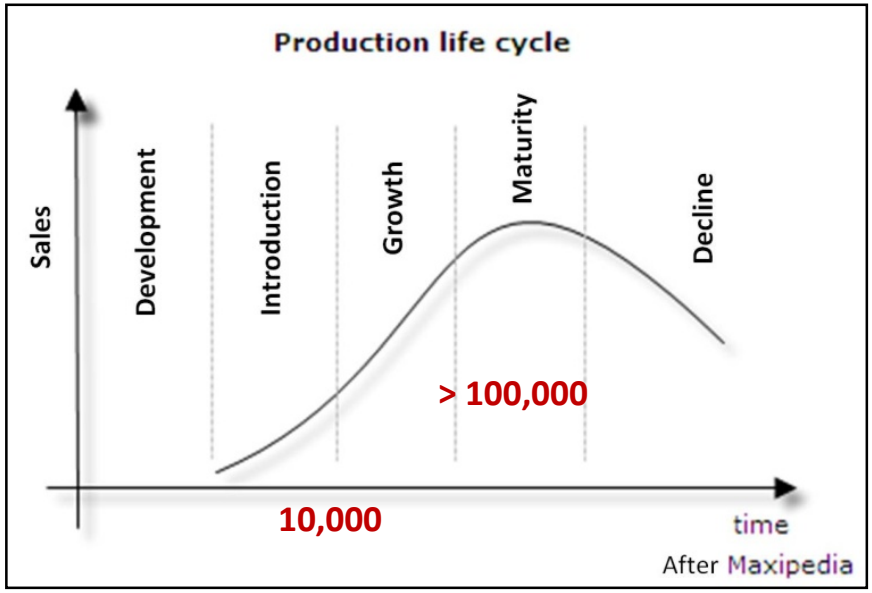
Accomplishments and Progress

- **Automotive Fuel Cell System Supply Chain Evolution mapped**
- **Developed detailed Questionnaire with current DOE cost target and process assumptions baseline shared**
- **Questionnaire interviews and plant visits to date**
  - Conducted 6 OEM interviews with 2 more OEMs planned
  - Conducted 8 Tier 1 interviews with 14 more planned
  - Conducted 1 OEM and 5 Tier 1 plant visits with 10 more planned
- **Generic drawings and specifications developed for 5 key components. Request for Quotes sent to 15 global suppliers.**

Accomplishments and Progress (cont.)

Automotive Fuel Cell System Supply Chain Evolution Status





Comparison of Toyota Hybrid Vehicle Sales and Fuel Cell Vehicle Sales

- **Fuel cell vehicles are in the Development/Introduction stage of the Production life Cycle**
- **Transition from Development/Introduction stage to Growth/Maturity stage assumed at 10,000 units per year; Growth/Maturity stage at >= 100,000 units/year**

The fuel cell supply chain is in the Development/Introduction stage

Accomplishments and Progress (cont.)

Development/Introduction Stage: Fuel Cell Stack - 2016

Suppliers to Fuel Cell Stack

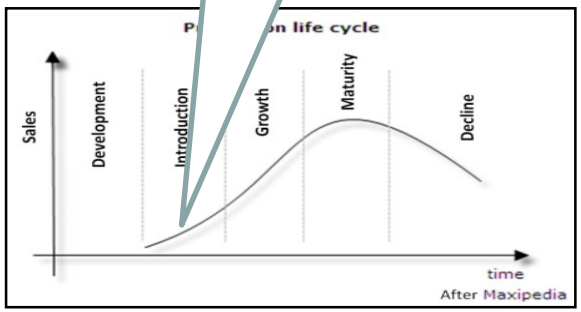
Tier 2

- Membrane
- Catalyst
- GDL
- Bipolar Plates

OEM Builds Fuel Cell Stack

CCM & GDL Assembled → OEM Builds Individual Cells → OEM Builds Fuel Cell Stacks

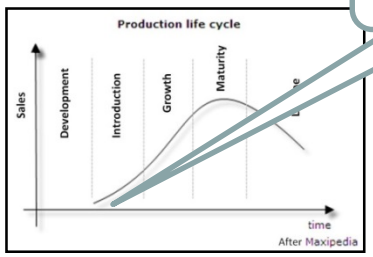
Development & Introduction



OEM assembles all components, builds individual cells and fuel cell stack

Accomplishments and Progress (cont.)

Development/Introduction Stage: OEM builds AFCS - 2016



Development & Introduction

Compressor-Expander Module [CEM]

Suppliers CEM & CEM-BOP

Tier 2

CEM

CEM-BOP

Tier 1

CEM & CEM-BOP Assembled

OEM

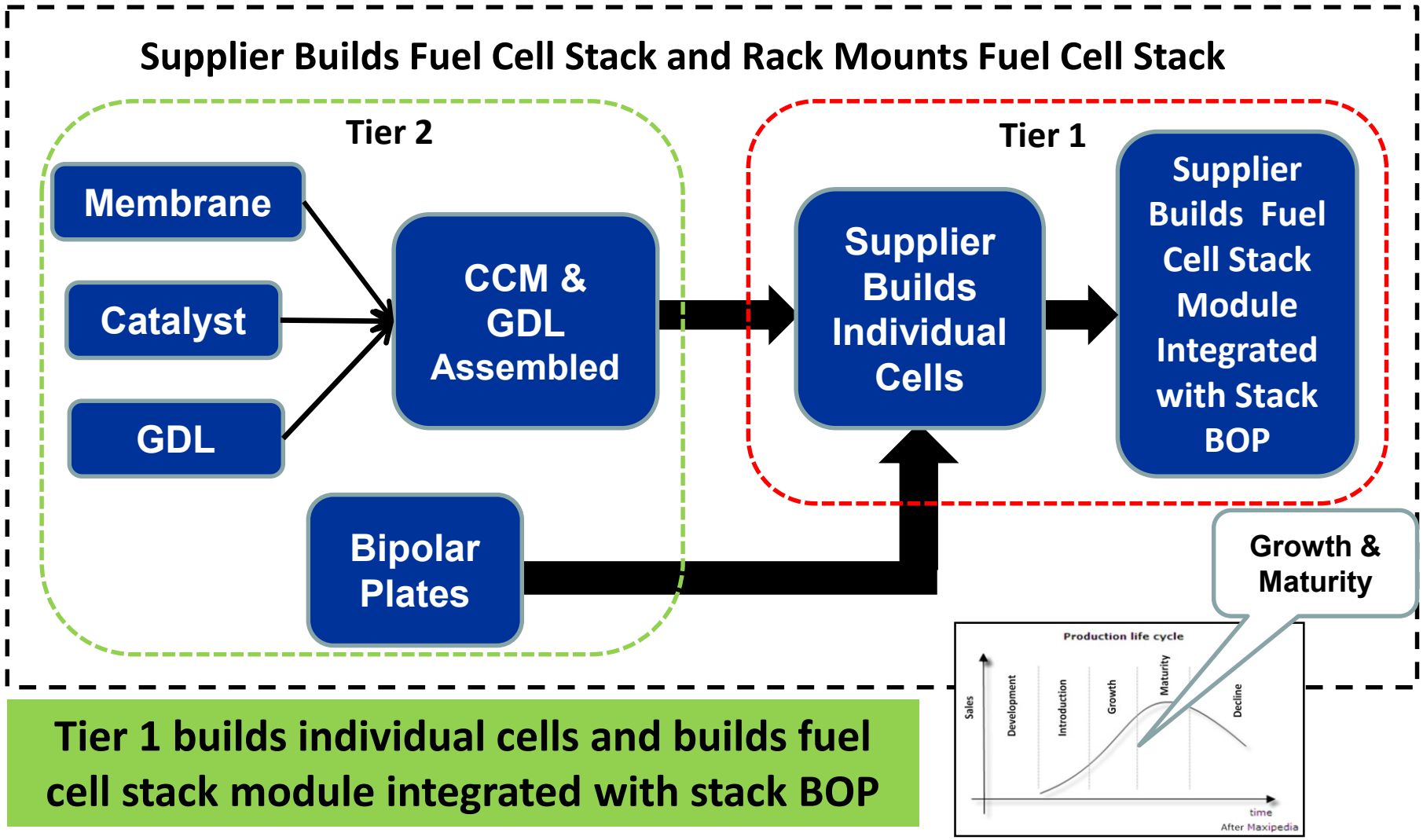
OEM Assembles BOP

OEM Built Fuel Cell Stacks

OEM builds fuel cell system for vehicle

Accomplishments and Progress (cont.)

Projected Growth/Maturity Stages: Tier 1 Builds Fuel Cell Stack



Tier 1 builds individual cells and builds fuel cell stack module integrated with stack BOP

Accomplishments and Progress (cont.)

Projected Growth/Maturity Stages: AFCS – Assembly by OEM

Suppliers

Tier 1

Supplier Builds Rack Mounted Fuel Cell Stacks

Tier 2

CEM

Assembles BOP

CEM - BOP

Tier 1

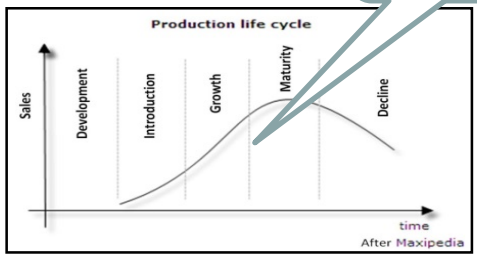
Module Integrated with CEM-BOP

Tier 1s build fuel cell stack & CEM-BOP modules

OEM

OEM inserts both modules into vehicle

Growth & Maturity



Accomplishments and Progress (cont.)

Prelim. Result: Large Data Spread in OEM Stack Cost Projections

- Cost projections are useful proxies in identifying technology and production status and shortfalls that will be important for future competitiveness
- Data reconciliation in progress
  - Trend in cost differs between OEMs and Suppliers
  - Degree of vertical vs. horizontal integration may partially explain differences
  - Greater uncertainty due to limited high volume fuel cell manufacturing
- DOE Baseline Costs are generally:
  - Low cost relative to OEM projections for low volume
  - Similar cost to OEM projections at high volume

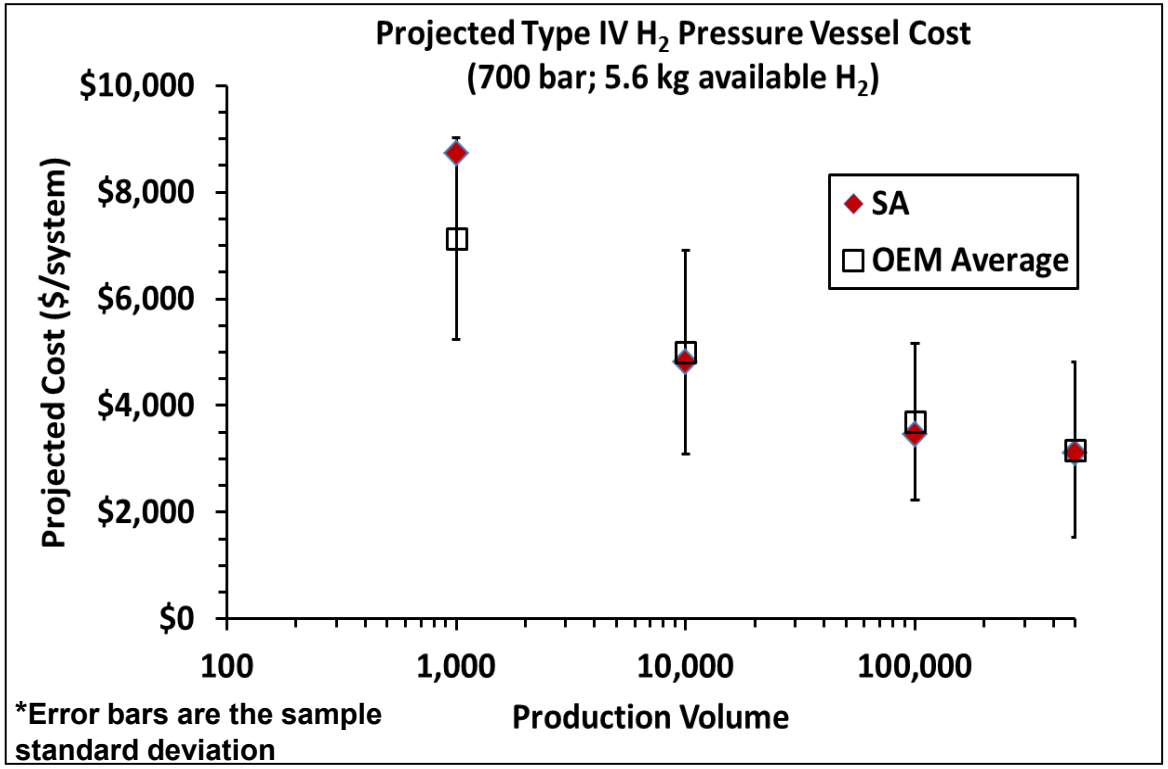
Ratio Between Highest and Lowest OEM Estimates

	Annual System Production Rate			
	1,000	10,000	100,000	500,000
Catalyst Ink & Application	9x	5x	3x	1.5x
Bipolar Plates	14x	18x	10x	1x
Membranes	2x	2x	2x	2x
GDLs	1.4x	4x	3x	1.3x

Accomplishments and Progress (cont.)

Prelim. Result: General Agreement in Storage Cost Projections

- Storage systems OEM data spread is narrower than fuel cell systems
- General OEM agreement with DOE Baseline Storage System Cost Projections
  - Consistent with Type 4 vessels being a more mature technology
  - Good agreement between OEM average and DOE Baseline



Accomplishments and Progress (cont.)

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.

Accomplishments and Progress (cont.)

MEA - Technology and Manufacturing Readiness

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

	MEA 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,** with some technology and quality	**No -** need investment for 100k/yr and reliability improvements	**YES**	**NO -** need new wider (~1m) equipment
3. Are components available from credible suppliers that meet OEM cost / performance targets at 100,000 vehicles/yr.?	**NO** - Difficult to get what is needed now. More devel. needed	**NO** - need investment for 100k/yr	**YES**	**YES,** with new equipment
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	Defined tolerances. Timing is 3-4 yrs	Current is acceptable	High volume roll to roll processing
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. More to 100k.	Need to demonstrate low risk	OEM call	Run @ Rate demonstrations to step volume

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

Accomplishments and Progress (cont.)

CEM - Technology and Manufacturing Readiness

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

	CEM 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**-Technology is ready.	**NO**-Automated production line needed for > 50k.	**YES**-Technology is ready.	**NO**-Automated production line needed for > 50k.
3. Are components available from credible suppliers that meet OEM cost / performance targets at 100,000 vehicles/yr.?	**YES**	**NO -** Suppliers should invest in automated production line for > 50k	**YES**	**NO -** Suppliers should invest in automated production line for > 50k
4. What are the R&D shortfalls in technology or manufacturing for 100,000 vehicles/yr. and what timing to achieve?	Quality control for next gen air foil bearing	High Volume capability	Qlty from comp. to comp. Qlty control for next gen air foil bearing	High volume capability
5. How many more vehicle powertrain demonstrations will be required before OEMs are ready to commit funds to produce 100,000 vehicles /yr?	**YES -** we will need more demonstrations	Run @Rate Demonstration	OEM call	Run @ Rate Demonstrations to step volume

Current capability at 50K/yr. vehicles, further substantial investment needed for 100K/yr.

Accomplishments and Progress (cont.)

Pressure Vessel - Technology and Manufacturing Readiness

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

	PRESSURE VESSEL MFG AND TECHNOLOGY 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.?	**NO** - Further tech development for volume production & winding.	**NO** – Currently need many lines for winding at 100k.	**NO** - Further tech development for volume production & winding.	**NO** – need more stations for winding at 100k.
3. Are components available from credible suppliers that meet OEM cost / performance targets at 100,000 vehicles/yr.?	NO - carbon fiber suppliers limited. Need DFMA	**NO** - Winding process needs multiple lines	**NO -** need design options to lower cost	**NO -** need manufacturing options to reduce cost
4. What are the R&D shortfalls in technology or manufacturing for 100,000 vehicles/yr. and what timing to achieve?	Design alternatives to CF winding	Need manufacturing alternatives to winding	Lower CF strength/ higher quality resin. Reduce total system weight	Need manufacturing alternatives to winding
5. How many more vehicle powertrain demonstrations will be required before OEMs are ready to commit funds to produce 100,000 vehicles /yr?	**YES -** we will need more demonstrations with design changes	Run @ Rate Demonstrations	OEM call	Run @ Rate Demonstrations to step volume

Current capability at 50K/yr. vehicles, further substantial investment needed for 100K/yr.

Accomplishments and Progress (cont.)

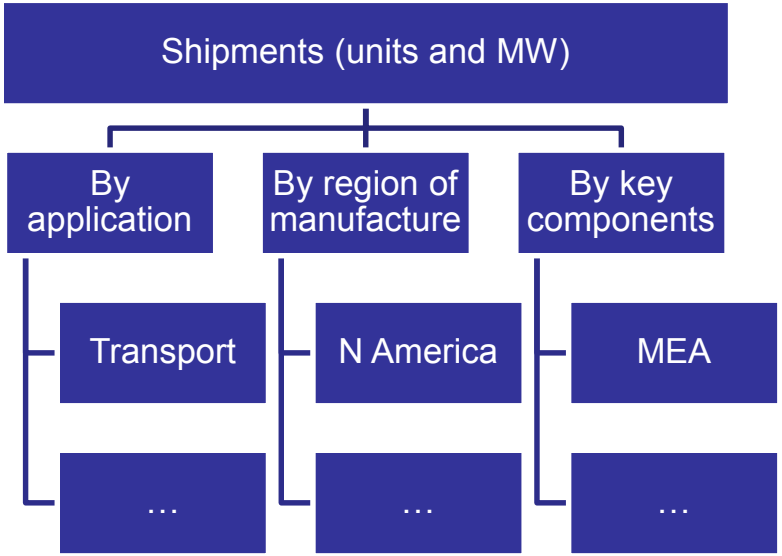
Task 2 -Trade flows and suppliers

- **Scope**
  - This analysis will focus on the **most relevant players** in PEM FC and hydrogen storage technology, and from there will identify relevant countries to include on a global map
- **Approach**
  - Fuel cell components
    - **Use technology list from Task 1**
    - **Filter list using criteria of 'relevance'**
  - Hydrogen storage technology
    - **Build list of players**
    - **Filter list using criteria of 'relevance'**
  - Identify and map supplier **relationships**
  - Gather data on governmental funding, capital available & technology focus
- **Status**
  - Some progress has been made in advance of formal kick-off, taking advantage of other Tasks
  - Initial company list built
  - Supplementing list in course of OEM interviews
  - Next step is prioritization of supplier list and planning of further interviews

Accomplishments and Progress (cont.)

Task 3 - Shipment data for relevant technology

- **Gather and aggregate shipment data** for PEM fuel cells with defined scope and level of detail
  - Annual basis (calendar year)
  - Global reach
  - Break down global data into subsets
    - Systems by application
    - Systems by Region of manufacture
    - U.S. system production split
    - Key PEM components



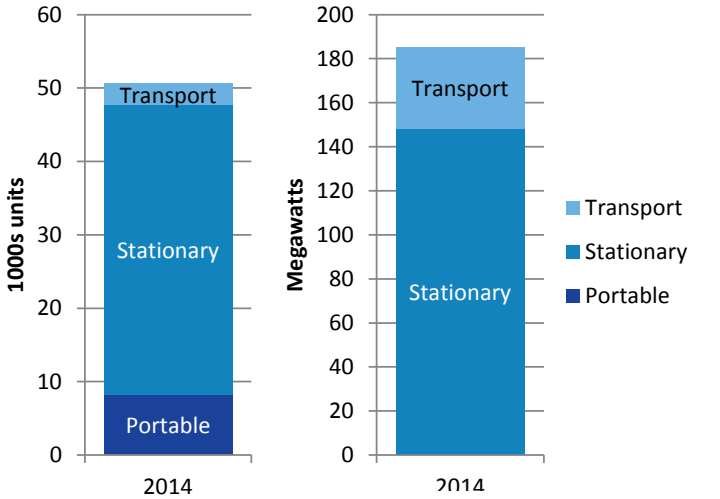
Above: Non-exhaustive, illustrative breakdown

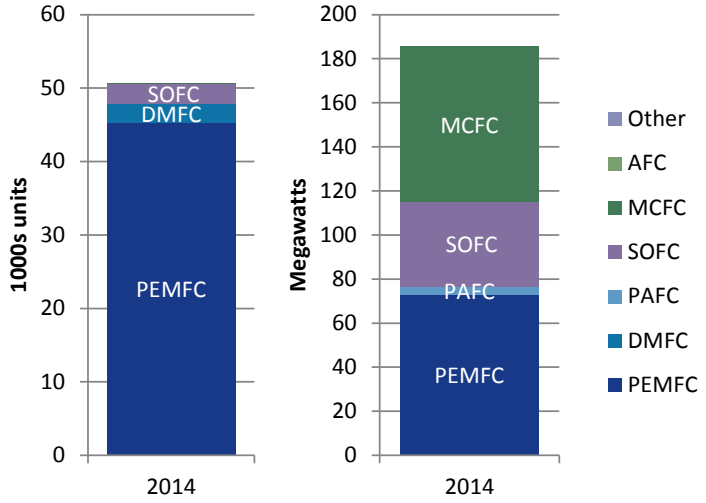
- **Approach**
  - Start with original data previously gathered by E4tech (in an aggregated form only)
  - Collect additional data directly from fuel cell manufacturers where they are willing to share it (use DOE introduction letter)
  - Fill gaps in original data with
    - interviews with industry experts
    - careful review of publicly available sources

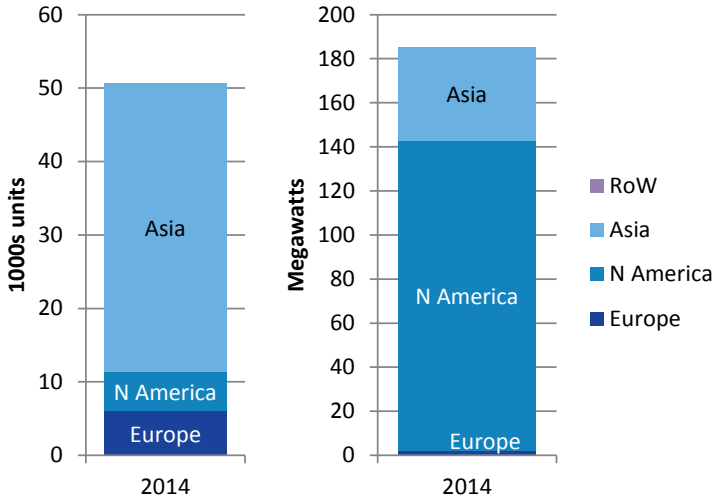
Accomplishments and Progress (cont.)

Task 3 - Shipment data for PEM technology

- **Gathered and delivered FC system shipment data for 2014 (see overview charts)**
- **Finalization of FC shipment data for 2015 ongoing**
- **Gathering of shipment data for key components ongoing** (MEA, GDL, Bipolar plates, BOP)







Response to Previous Years Reviewers' Comments

This project was presented but was not reviewed in June 2015

Collaborations

- **Strategic Analysis Inc.** – Subcontractor
  - DFMA cost analysis responsible, part of interview process
- **E4tech** – Subcontractor
  - Annual Data collection, part of the interview process, and plant visits Europe, Asia
- **DJW Technology** – Subcontractor
  - Supply Chain Evolution Summary, part of the interview process
- **Brent Fourman** – Subcontractor
  - Drawing Designer
- **Bowen Liu** – Subcontractor
  - Supporting China/Asian CBA, VSM, and plant visits
- **DOE Fuel Cell Technologies Office, Office of Energy Efficiency and Renewable Energy** – Dr. Nancy Garland, Jesse Adams
- **NREL** – data collaboration
- **Automotive OEM's (8) and Tier 1 suppliers (22)** – interview participants

Remaining Challenges and Barriers

- Overall OEMs and Tier 1s are providing general process steps, headcount, and cost direction compared to the current DOE database (SA studies)
- Supplier responses to RFQ's of generic drawings with Cost Breakdown Analysis and process flows for value stream mapping are in process.
  - Challenge gathering desired level of detail.
  - Challenge ensuring (often confidential) supply data and supplier links are gathered

Proposed Future Work

- **Remainder of FY2016**
  - Reconcile gaps between OEMs and Tier 1's cost estimates
  - Complete OEM and Tier 1 interviews and data summary
  - Complete Cost Breakdown Analysis and Value Stream Mapping
  - Complete Supply Chain Mapping and Trade Flows
  - Gather data for Total Systems and MW shipped broken out by application and Location of manufacture - for 2015 data
- **FY2017**
  - Identify 3 manufacturing opportunities, 3 tipping points, 3 high value opportunities, and **3 strengths for U.S. manufacturers**
  - Complete assessment of trade flows, supply and demand, global suppliers, government funding, capital available, country's development technology **and US manufacturing advantage**
  - Work w/ NREL to Complete Draft Competitive Analysis Manuscript
  - Complete Competitive Analysis report which will include the **3 highest opportunities for U.S. manufacturers**

Technology Transfer Activities

This project has no technology transfer tasks.

Project Summary

- Questionnaire Developed sharing the current DOE database of Key Component Process Flows and Costing
  - OEMs and Tier 1's providing data correlation to DOE database
  - One OEM quote " *It is very helpful that in the past DOE put out very ambitious technology development targets, no comparable targets elsewhere globally. It is good guidance for fuel cell development technology globally*."
  - Automotive Fuel Cell System Supply Chain Evolution mapped
- Generic drawings & specifications of 5 key components have been developed and are out for quote in 3 regions: U.S., Europe, Asia
- Global Plant visits in process to identify process flows for Value Stream Mapping and best practices
- 2014 Shipment data by application and region completed
- Month 18 report will be finalized – currently in Month 10

Questions?

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