Controlled Hydrogen Fleet and Infrastructure Analysis

2011 DOE Annual Merit Review and Peer Evaluation Meeting

Keith Wipke, Sam Sprik, Jennifer Kurtz, Todd Ramsden, Chris Ainscough, Genevieve Saur

May 13, 2011
Washington, DC

NREL/PR-5600-50780

This presentation does not contain any proprietary, confidential, or otherwise restricted information
Fuel Cell Electric Vehicle Learning Demo
Project Objectives, Relevance, and Targets

• Objectives
  – Validate H₂ FC Vehicles and Infrastructure in Real-World Setting
  – Identify Current Status and Evolution of the Technology

• Relevance
  – Objectively Assess Progress Toward Targets and Market Needs
  – Provide Feedback to H₂ Research and Development
  – Publish Results for Key Stakeholder Use and Investment Decisions

**Key Targets**

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>2009*</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cell Stack Durability</td>
<td>2000 hours</td>
<td>5000 hours</td>
</tr>
<tr>
<td>Vehicle Range</td>
<td>250+ miles</td>
<td>300+ miles</td>
</tr>
<tr>
<td>Hydrogen Cost at Station</td>
<td>$3/gge</td>
<td>$2-4/gge**</td>
</tr>
</tbody>
</table>

*Project extended 2 years through 2011; **For 2020; Previously $2-3/gge for 2015

Details of each of these 3 results in technical backup slides

Burbank, CA station. Photo: NREL
Project Overview

Timeline
- Project start: FY03
- Project end: early FY12
- ~90% of Task III complete (see timeline slide)

Tech. Val. Barriers
A. Vehicles – lack of controlled & on-road H₂ vehicle and FC system data
B. Storage – technology does not yet provide necessary 300+ mile range
C. Hydrogen Refueling Infrastructure – cost and availability
D. Maintenance and Training Facilities – lack of facilities and trained personnel
E. Codes and Standards – lack of adoption/validation
H. Hydrogen Production from Renewables – need for cost, durability, efficiency data for vehicular application
I. H₂ and Electricity Co-Production – cost and durability

Budget
- NREL funding prior to FY10: $4867K
- NREL FY10 funding: $650K
- NREL FY11 funding: $650K

Partners
- See partner slide
Approach and Accomplishments:
Project Timeline and Major Milestones

<table>
<thead>
<tr>
<th>Task I</th>
<th>Task II</th>
<th>Task III</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 FY03</td>
<td>2 FY04</td>
<td>3 FY05</td>
</tr>
<tr>
<td>4 FY06</td>
<td>5 FY07</td>
<td>6 FY08</td>
</tr>
<tr>
<td>7 FY09</td>
<td>8 FY10</td>
<td>9 FY11</td>
</tr>
<tr>
<td>10 FY12</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

**Task I – Project Preparation [100% Complete]**

**Task II – Project Launch [100% Complete]**

**Task III – Data Analysis and Feedback to R&D activities (partial list) [90% Complete]**

- 8 Publication of first “composite data products”
- 9 Evaluate FC stack time to 10% voltage degradation relative to 1000-hour target
- 10 Decision for purchase of additional vehicles based on performance, durability, cost
- 11 Preliminary evaluation of dominant real-world factors influencing FC degradation
- 12 Introduction of 2nd generation FC systems into vehicles begins
- 13 FCVs demonstrate 250-mile range without impacting passenger cargo compartment
- 14 Validate FCVs with 2,000 hour durability and $3.00/gge (based on volume production)
- 15 Data analysis continues with data from 2 of the 4 OEM/Energy teams plus CHIP stations
- 16 Conclusion of data submission to NREL on pre-commercial FCEVs (Sept. 2011)
- 17 DOE Milestone: Validate 40 adv. technology FCEVs with up to 600 hours operation
- 18 Final data analysis and report on Learning Demonstration

2 teams concluded their projects
Project Approach

• Provide facility and staff for securing and analyzing industry sensitive data
  – NREL Hydrogen Secure Data Center (HSDC)

• Perform analysis using detailed data in HSDC to:
  – Evaluate current status and progress toward targets
  – Feed back current technical challenges and opportunities into DOE H₂ R&D program
  – Provide analytical results to originating companies on their own data (detailed data products)
  – Collaborate with industry partners on new and more detailed analyses

• Publish/present progress of project to public and stakeholders (composite data products)
Project Approach (cont.)
Supporting Both DOE/Public as Well as Fuel Cell Developers

Bundled data (operation & maintenance/safety) delivered to NREL quarterly

Internal analysis completed quarterly

Detailed Data Products (DDPs)
- Individual data analyses
- Identify individual contribution to CDPs
- Shared every six months only with the partner who supplied the data

Composite Data Products (CDPs)
- Aggregated data across multiple systems, sites, and teams
- Publish analysis results every six months without revealing proprietary data

1) Data exchange may happen more frequently based on data, analysis, & collaboration
2) Results published via NREL Tech Val website, conferences, and reports (http://www.nrel.gov/hydrogen/proj_learning_demo.html)
Industry Partners: Two Teams Concluded Their Projects in 2009, Three are Continuing through 2011

Ford/BP and Chevron/Hyundai-Kia Concluded in 2009

Daimler, GM, and Air Products Continue to Demonstrate Vehicles/Stations within Project through 2011
Vehicle Status: All Project Vehicles on Road Use 700 bar Storage

Vehicle Deployment by On-Board Hydrogen Storage Type

(1) Retired vehicles have left DOE fleet and are no longer providing data to NREL
(2) Two project teams concluded in Fall/Winter 2009

Total of ~40 project vehicles expected on road in 2011, for total of ~170 deployed
Status: Out of 24 Project Stations, 15 Are Still Operational* (3/5 outside of DOE project)

* CDP station status is as of 12/31/10

Legend:
- Online
- Future**
- Current Project
- Continuing Outside
- CEC
- CARB
- Other

** Funded by state of CA or others, outside of this project
Station Status: The Project Stations Still in Operation
Use Delivered H₂ (80%) or Electrolysis (20%)

### Learning Demonstration Hydrogen Stations By Type

<table>
<thead>
<tr>
<th>Station Type</th>
<th># of Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivered Compressed H₂</td>
<td>11</td>
</tr>
<tr>
<td>Natural Gas On-Site Reforming</td>
<td>4</td>
</tr>
<tr>
<td>On-Site Electrolysis</td>
<td>2</td>
</tr>
<tr>
<td>Delivered Liquid H₂</td>
<td>2</td>
</tr>
</tbody>
</table>

- Total of 140,000 kg H₂ produced or dispensed from the 24 stations
- *Some project teams concluded Fall/Winter 2009. Markers show the cumulative stations operated during the 2005-2009 period*
Accomplishment: 23 Quarters (~6 years) of Data Analyzed to Date, Two New Sets of Composite Data Products Published

Through March 2011: 460,000 individual vehicle trips 107 GB of on-road data

Size of Data (MB)

0 10000 20000 30000 40000 50000 60000 70000 80000 90000 100000

Cumulative On-Road Data Received for Fuel Cell Vehicle Learning Demonstration

# Trips

0 100000 200000 300000 400000 500000

CDP = Composite Data Products Published

CDP = Composite Data Products Published

2004 Review

2005 Review

2006 Review

2007 Review

2008 Review

2009 Review

2010 Review

2011 Review
Accomplishment: Continued Publication of Two Sets of CDPs, Despite Fewer Teams

80 Spring 2010 Results

- Most comprehensive set we ever published
- Includes durability, range, fuel economy
- Covers data from all 4 Learning Demo teams + CHIP project over 5-year period
- Majority of these will now stay static, serving as a historical record of Gen 1 & Gen 2 comparisons.
  (subset of results presented at 2010 AMR)

23 Spring 2011 Results

- 5 new CDPs, and updated 18 previously published CDPs with data from last 12 months
- Results on most recent durability, range, fuel economy, not yet possible to publish until more data accumulated (end of 2011)
- Covers data from 2 Learning Demo OEMs + CHIP project
- Emphasized changes observed in last 12 months through use of gray (old) and colors (new)
Accomplishment: Monitored Fueling Rate Trends as Stations Move to 700 bar as Standard

Histogram of Fueling Rates
Vehicle and Infrastructure

- 25,464 fills
  - Average = 0.77 kg/min
  - 23% >1 kg/min
- 2,766 fills
  - Average = 0.63 kg/min
  - 2% >1 kg/min

Result of average H₂ per fill increased 23%, but average fueling time also increased 35%

New state-of-the-art 700 bar stations not included in this data set; just coming online now
Accomplishment: Leveraging Effort to Other FC Applications; Cross-Application CDPs Initiated

Fueling rates vary by application, driven by constraints on nominal pressure, volume, tank materials.
Accomplishment: Quantified Continued Improvement in Real-World Driving Range Between 3 Sets of Vehicles

Distance Driven Between Refuelings: All OEMs

Gen1
Refuelings $^1$ = 18941
Median distance between refuelings = 56 Miles

Gen2
Refuelings $^1$ = 6870
Median distance between refuelings = 81 Miles

Gen1 to Gen 2
+45% improvement

Refuelings after 2009Q4 $^1$ = 4196
Median distance between refuelings = 94 Miles

+68% improvement in real-world driving range with latest adv. tech. vehicles

1. Some refueling events are not detected/reported due to data noise or incompleteness.
2. Distance driven between refuelings is indicative of driver behavior and does not represent the full range of the vehicle.

Note: Actual range possible >200 miles
Accomplishment: Based on Limited Number of Fuelings in Last 12 Months, Higher Level of Tank at Refueling Observed

1. Some refueling events not recorded/detected due to data noise or incompleteness.
2. The outer arc is set at 20% total refuelings.
3. If tank level at fill was not available, a complete fill up was assumed.
Accomplishment: Driving Behavior (Timing) in Last 12 Months Much More Similar to National Average

Driving by Time of Day

% of driving trips b/t 6 AM & 6 PM: 85.3%
% of NHTS trips b/t 6 AM & 6 PM: 81.5%
% of driving trips b/t 6 AM & 6 PM: 78.2%

1. Driving trips between 6 AM & 6 PM
2. The outer arc is set at 12% total Driving.
3. Some events not recorded/detected due to data noise or incompleteness.

Driving time of day is similar to national average, except for 5-6PM

2001 NHTS Data Includes Car, Truck, Van, & SUV day trips
ASCII.csv Source: http://nhts.ornl.gov/download.shtml#2001

Fall 2010
Accomplishment: More Weekend Driving Observed in Last 12 Months – Still Less than National Average

![Driving by Day of Week](image_url)

- **2001 NHTS Data Includes Car, Truck, Van, & SUV day trips**
- **ASCII.csv Source:** [http://nhts.ornl.gov/download.shtml#2001](http://nhts.ornl.gov/download.shtml#2001)
Accomplishment: Compared Recent Driving Speeds to First 5 Years and National Avg.

Recent driving is at higher speeds than first 5 years, and close to national average.

1) Excludes trips <= 1 mile (40.9%)
2) Excludes trips <= 1 mile (21.0%)

Through 2009Q4
After 2009Q4
NHTS Data
NHTS Avg Speed

Average trip speed of 23.2 mph
Average trip speed of 25.9 mph

179,424 trips
18,188 trips

2001 NHTS data includes Car, Truck, Van & SUV day trips

Created: Mar-21-11 4:12 PM
Accomplishment: Factors Affecting Fuel Economy Were Quantified, Showing Large Spread in Data

Fuel economy relatively insensitive to average trip length, except for very short trips

Factor of 2X observed for fuel economy as a function of average trip speed

Effect of Average Trip Length on Fuel Economy

Effect of Average Trip Speed on Fuel Economy

(1) Data after 2009Q4. The data has been normalized to the max of the median curve for each fleet. Data binned every 5 miles for calculating median and percentiles.
Accomplishment: Created New Infrastructure CDP to Give Insight Into Specific Fueling Usage Patterns

Several stations seeing major increase in utilization

Some stations still significantly under utilized
Highlights of Interactions and Collaborations in the Last Year

Auto/Energy Industry Partners
- Detailed discussion of NREL results and methodology
- Discussion of voltage degradation calculations; discussions of how to do new/previous CDPs with fewer teams
- Project partners review all results prior to publication

FreedomCAR and Fuel Technical Teams
- H₂ Storage (4/11) Tech Team Briefing

FCHEA Technical Working Groups
- Transportation Working Group
- Joint H₂ Quality Task Force

California Organizations
- CaFCP and CHBC: NREL actively participating as member
- CARB and CEC: New stations to provide future data to NREL

Early FC Market Evaluations: DOD (DLA) and ARRA
- Leveraging experience to evaluate FC forklifts and backup power
Future Work

Remainder of FY11:
- Create new and updated composite data products (CDPs) based on data through June 2011 (potentially Sept 2011)
- Begin receiving performance data from new/restarted stations
  - Burbank reformer, Torrance pipeline, Fountain Valley tri-generation
- Support DOE milestone (Sept. 2011) to document operation of advance technology vehicles for up to 600 hours
- Support OEMs, energy companies, and state organizations in coordinating early infrastructure plans

FY12:
- Publish Fall 2011 composite data products as the last anticipated results from the project
- Submit final summary report for the project
- Present final results at conferences and meetings
- Continue to leverage analysis capability to other validations
- Identify and exploit new opportunities to document FC & H₂ progress publicly
Technical Summary

- Project has completed ~6 years of validation
- **Vehicle operation**: 131,000 hours, >3 million miles, 460,000 trips
- **H₂ station operation**: 140,000 kg produced or dispensed, 28,000 fuelings
- **Safety**: No vehicle safety reports since last AMR; no infrastructure incidents & major reduction in safety reports
- **DOE Key Technical Targets Met:**
  - FC Durability >2,000 hours and Range >250 miles
- **New CA fueling stations planned for inclusion in future NREL infrastructure analysis as they come online and provide data**
Wrap-up

• Relevance
  – Provided DOE and taxpayers strong return on investment made in large hardware demonstration/validation projects
  – Many system-level DOE program targets validated by this project

• Approach
  – Collaborative relationship to analysis with industry partners; HSDC capability

• Technical Accomplishments and Progress
  – 85 total CDP analysis results available; publication at conferences every 6 months
  – Project has achieved its key technical targets (refer to technical backup slides and 87 page Progress Report)

• Collaborations
  – Worked closely with industry partners to validate methodology and ensure relevance of results

• Future Work
  – Document final project results (report and presentation)
  – Seek new opportunities to objectively evaluate status of H₂ & FC technology
Questions and Discussion; Contact Info. and Web Resources

Project Contact: Keith Wipke, National Renewable Energy Lab
303.275.4451 keith.wipke@nrel.gov

All public Learning Demo, FC Bus, and Early Market papers and presentations are available online at http://www.nrel.gov/hydrogen/proj_tech_validation.html

NREL’s Renewable H₂ Station, storing over 250 kg H₂ and dispensing at 350 bar
TECHNICAL BACKUP SLIDES
**Project Achieved Both Technical Goals; Outside Analysis Used for Cost Evaluation (2010 AMR)**

<table>
<thead>
<tr>
<th><strong>Vehicle Performance Metrics</strong></th>
<th>Gen 1 Vehicle</th>
<th>Gen 2 Vehicle</th>
<th>2009 Target</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Cell Stack Durability</strong></td>
<td></td>
<td></td>
<td>2000 hours</td>
</tr>
<tr>
<td>Max Team Projected Hours to 10% Voltage Degradation</td>
<td>1807 hours</td>
<td>2521 hours</td>
<td>✔️</td>
</tr>
<tr>
<td>Average Fuel Cell Durability Projection</td>
<td>821 hours</td>
<td>1062 hours</td>
<td>✔️</td>
</tr>
<tr>
<td>Max Hours of Operation by a Single FC Stack to Date</td>
<td>2375 hours</td>
<td>1261 hours</td>
<td>✔️</td>
</tr>
<tr>
<td><strong>Driving Range</strong></td>
<td>103-190 miles</td>
<td>196-254 miles</td>
<td>250 miles</td>
</tr>
<tr>
<td><strong>Fuel Economy (Window Sticker)</strong></td>
<td>42 – 57 mi/kg</td>
<td>43 – 58 mi/kg</td>
<td>no target</td>
</tr>
<tr>
<td><strong>Fuel Cell Efficiency at ¼ Power</strong></td>
<td>51 - 58%</td>
<td>53 - 59%</td>
<td>60%</td>
</tr>
<tr>
<td><strong>Fuel Cell Efficiency at Full Power</strong></td>
<td>30 - 54%</td>
<td>42 - 53%</td>
<td>50%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Infrastructure Performance Metrics</strong></th>
<th>2009 Target</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H₂ Cost at Station (early market)</strong></td>
<td></td>
</tr>
<tr>
<td>On-site natural gas reformation</td>
<td>$7.70 - $10.30</td>
</tr>
<tr>
<td>On-site Electrolysis</td>
<td>$10.00 - $12.90</td>
</tr>
<tr>
<td><strong>Average H₂ Fueling Rate</strong></td>
<td>0.77 kg/min</td>
</tr>
<tr>
<td></td>
<td>1.0 kg/min</td>
</tr>
</tbody>
</table>

Outside of this project, DOE independent panels concluded at 500 replicate stations/year:
- Distributed natural gas reformation at 1500 kg/day: $2.75-$3.50/kg (2006)
- Distributed electrolysis at 1500kg/day: $4.90-$5.70 (2009)
1) FC Durability Target of 2000 Hours Met By Gen 2 Projections (2010 AMR)

**Durability is defined by DOE as projected hours to 10% voltage degradation**

---

(1) Range bars created using one data point for each OEM. Some stacks have accumulated hours beyond 10% voltage degradation.

(2) Range (highest and lowest) of the maximum operating hours accumulated to-date of any OEM's individual stack in "real-world" operation.

(3) Range (highest and lowest) of the average operating hours accumulated to-date of all stacks in each OEM's fleet.

(4) Projection using on-road data -- degradation calculated at high stack current. This criterion is used for assessing progress against DOE targets, may differ from OEM's end-of-life criterion, and does not address "catastrophic" failure modes, such as membrane failure.

(5) Using one nominal projection per OEM: "Max Projection" = highest nominal projection, "Avg Projection" = average nominal projection.

The shaded projection bars represents an engineering judgment of the uncertainty on the "Avg Projection" due to data and methodology limitations. Projections will change as additional data are accumulated.

(6) Projection method was modified beginning with 2009 Q2 data, includes an upper projection limit based on demonstrated op hours.
2) Vehicle Range Achieved 2009 Target of 250 Miles with Gen 2 Adjusted Fuel Economy (2010 AMR)

(1) Range is based on fuel economy and usable hydrogen on-board the vehicle. One data point for each make/model.
(2) Fuel economy from unadjusted combined City/Hwy per DRAFT SAE J2572.
(3) Fuel economy from EPA Adjusted combined City/Hwy (0.78 x Hwy, 0.9 x City).
(4) Excludes trips < 1 mile. One data point for on-road fleet average of each make/model.
(5) Fuel economy calculated from on-road fuel cell stack current or mass flow readings.
3) Projected Early Market H₂ Production Cost from Learning Demo Energy Partners’ Inputs (2010 AMR)

### Projected Early Market 1500 kg/day Hydrogen Cost¹ *

<table>
<thead>
<tr>
<th>Natural Gas Reforming²</th>
<th>Electrolysis²</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/kg</td>
<td></td>
</tr>
</tbody>
</table>

#### Key H₂ Cost Elements and Ranges

<table>
<thead>
<tr>
<th>Input Parameter</th>
<th>Minimum (P10)</th>
<th>Maximum (P90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility Direct Capital Cost</td>
<td>$10M</td>
<td>$25M</td>
</tr>
<tr>
<td>Facility Capacity Utilization</td>
<td>85%</td>
<td>95%</td>
</tr>
<tr>
<td>Annual Maintenance &amp; Repairs</td>
<td>$150K</td>
<td>$600K</td>
</tr>
<tr>
<td>Annual Other O&amp;M</td>
<td>$100K</td>
<td>$200K</td>
</tr>
<tr>
<td>Annual Facility Land Rent</td>
<td>$50K</td>
<td>$200K</td>
</tr>
<tr>
<td>Natural Gas Prod. Efficiency (LHV)</td>
<td>65%</td>
<td>75%</td>
</tr>
<tr>
<td>Electrolysis Prod. Efficiency (LHV)</td>
<td>35%</td>
<td>62%</td>
</tr>
</tbody>
</table>

---

(1) Reported hydrogen costs are based on estimates of key cost elements from Learning Demonstration energy company partners and represent the cost of producing hydrogen on-site at the fueling station, using either natural gas reformation or water electrolysis, dispensed to the vehicle. Costs reflect an assessment of hydrogen production technologies, not an assessment of hydrogen market demand.

(2) Hydrogen production costs for 1500 kg/day stations developed using DOE’s H₂A Production model, version 2.1. Cost modeling represents the lifetime cost of producing hydrogen at fueling stations installed during an early market rollout of hydrogen infrastructure and are not reflective of the costs that might be seen in a fully mature market for hydrogen installations. Modeling uses default H₂A Production model inputs supplemented with feedback from Learning Demonstration energy company partners, based on their experience operating on-site hydrogen production stations. H₂A-based Monte Carlo simulations (2,000 trials) were completed for both natural gas reforming and electrolysis stations using default H₂A values and 10th percentile to 90th percentile estimated ranges for key cost parameters as shown in the table. Capacity utilization range is based on the capabilities of the production technologies and could be significantly lower if there is inadequate demand for hydrogen.

(3) DOE has a hydrogen cost goal of $2-$3/kg for future (2015) 1500 kg/day hydrogen production stations installed at a rate of 500 stations per year.

---

This project provides an excellent learning opportunity, but stations are not meant to emulate high volume replicate stations of the future. Permitting was in transition.

---

Outside of this project, DOE independent panels concluded at 500 replicate stations/year:

- Distributed natural gas reforming at 1500 kg/day: $2.75-$3.50/kg (2006)
- Distributed electrolysis at 1500 kg/day: $4.90-$5.70 (2009)
REVIEWER-ONLY SLIDES
Responses to Previous Year (FY10) Reviewers’ Comments

*Three Related comments about promotion of results more broadly:*

Q: “Need better marketing and promotion of the program and results to the media, both public and government”

Q: “There should be an expanded presentation of results from primarily fuel cell events to broader auto events, government conferences, etc.”

Q: “Need to promote findings and activities more. If the public and/or government knew of the scope of this project and results and data found, it would greatly help industry fight critics and skeptics who write off FCVs. A website is not enough because most people would not know to look there.”

Response:

A: Our role in this project is to objectively evaluate the performance and progress of FCEVs and H2 stations and make the information publicly available. We do this at least 3 times a year at FCHEA, FC Seminar, and AMR, but also periodically at EVS, JHFC, and CARB meetings. *We would be interested to hear specific ideas or venues that we could use to further broadcast the results.*

Q: “A final project report dissemination plan should be developed. The plan should include a presentation at the IPHE and IEA.”

A: If invited and supported by DOE we would be pleased to present at IPHE and IEA.

Q: “Battery analysis could be improved. The life-cycle cost analysis should be looked at and analyzed.”

A: Our battery analysis intentionally limited, as evaluation of battery performance is not one of the objectives of this project. We are now collaborating with NREL’s transportation center on analyzing battery degradation analogous to our FC evaluation.
Publications and Presentations
(Since FY10 AMR, Key Text in Bold)

1. Wipke, K., presentation of Learning Demonstration results to FreedomCAR and Fuels Hydrogen Storage Tech Team, April 2011. (presentation)


Critical Assumptions and Issues

• **Issue:** After the Learning Demonstration Concludes, there Will Be a Gap in Public Knowledge on Actual FCEV and H₂ Station Performance and Status
  
  – *See next slide for graphical representation*
  – Many critical questions will remain unanswered before vehicles enter the market in ~2015
  – Information flow on technology progress and benefits must be continuous to build market confidence
  – Decision makers (private & public) may withhold investment without a credible objective source to provide actual technology progress and benefits

• **Proposed solution:**
  – We will work with our industry partners to find a way to continue to provide objective information to decision makers in the future
Issue (cont.) -- Learning Demo Feeds Pipeline of Objective Info for Decision Makers; Potential Data Gap Approaching

New questions will arise:
• Is the technology ready?
• Does it meet targets?
• How does it compare to BEVs, PHEVs, alt. fuels?
• Should investment be made in fueling stations?
• Should vehicle purchase incentives be provided?

OBJECTIVE CREDIBLE EVALUATIONS LEAD TO INFORMED DECISIONS

POTENTIAL DELAYS OF INVESTMENT BY DECISION-MAKERS DUE TO UNCERTAINTY