Ford Plug-In Project: Bringing PHEVs to Market

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Overview

Timeline

- Start: October, 2008
- Finish: December, 2012
- 65% Complete (vehicle build – 100%)

Budget

- Total Project Funding
  - DOE: $ 10,000,000
  - Ford: $ 10,027,792
- Funding recv'd in FY08 – FY10 = $7,547,748
- Funding for FY11 = pending approval

Partners

- Electric Power Research Institute
- Southern California Edison
- Detroit Edison
- NY Power Authority
- Consolidated Energy
- NY State Energy Research & Development Authority
- Progress Energy
- Southern Company
- National Grid
- American Electric Power
- Pepco Holdings Inc.
- Hydro-Quebec

Barriers

- Battery Cost
- Battery Charge Time
- Extreme Temperature Operation
- Lack of Uniform Codes & Standards

Objectives

- Identify a sustainable pathway toward accelerated and successful mass production of PHEV's.
- Launch a 21-vehicle demonstration fleet
  - Provide real-world usage data
  - Provide laboratory data
- Support a customer-valued PHEV production program
  - Propulsion system design
  - Vehicle controls
  - Two-way Communication
    - Vehicle to Meter
    - Meter to Vehicle

Approach

- Phase I
  - Validate battery/control enhancements
  - Demonstrate the technology on a new, more fuel efficient engine
- Phase II
  - Progress the battery/control system closer to production intent.
  - Demonstrate two-way communication
  - All Phase II vehicles will be flex-fuel capable
- Phase III
  - Continues with fleet demonstration, data analysis, and reporting
  - Demonstrates V2G and G2V communications
- Phase IV
  - Continues vehicle demonstrations from Phase III, to accumulate mileage/time in service and document effects

Technical Accomplishments

2010 Completed Milestones …

V2G/G2V Demonstration	- Complete field demonstration of smart meter communication with remaining utility partners
Battery Software Improvements	- Improve vehicle robustness at colder temperatures - Improve battery charge and cell balance algorithms
Vehicle Software improvements	- Cabin heating software implementation on remaining vehicles
Vehicle & Design Build Updates	- Remaining NA fleet vehicles deployed (18 vehicles) - 2 vehicles targeted for data collection in EU and China - Completed 230/50 HZ charging, 57 mph all electric mode calibration and electric AC upgrades to EU and China vehicles
Vehicle Service	- Bi-weekly Customer Action team meetings to support and service in-field vehicles; Begin partners report out of vehicle performance and experiences in field
Data Acquisition, analysis, and reporting	- Support DOE sponsored fuel economy testing - Continue data acquisition, analysis and reports
Testing	- Implemented vehicle data collection and reporting system

Technical Accomplishments

2011 Milestones …

Vehicle Controls & Development	- Complete design and development required for J1772 connector upgrade
Vehicle & Design Build Updates	- Implement roll-out plan for fleet updates to revised connector port – including new cords - Target 100% completion of upgrades by mid-2011
Vehicle Service	- Continue bi-weekly Customer Action Team meetings to support and service in-field vehicles; Continue partners report out of vehicle performance and experiences in field
Data Acquisition, analysis, and reporting	- Continue data acquisition, analysis and reports
Testing	- Support INL data and report review process for publication

Technical Accomplishments

PHEV – J1772 Upgrades …

Upgrade Assumptions

- Allows vehicle charging using level II (240V) EVSE
- Allows level I (120V) charging –*per project requirements*
- Charge rate will not change. Charger output limited to 1.4kW

Upgrade Components

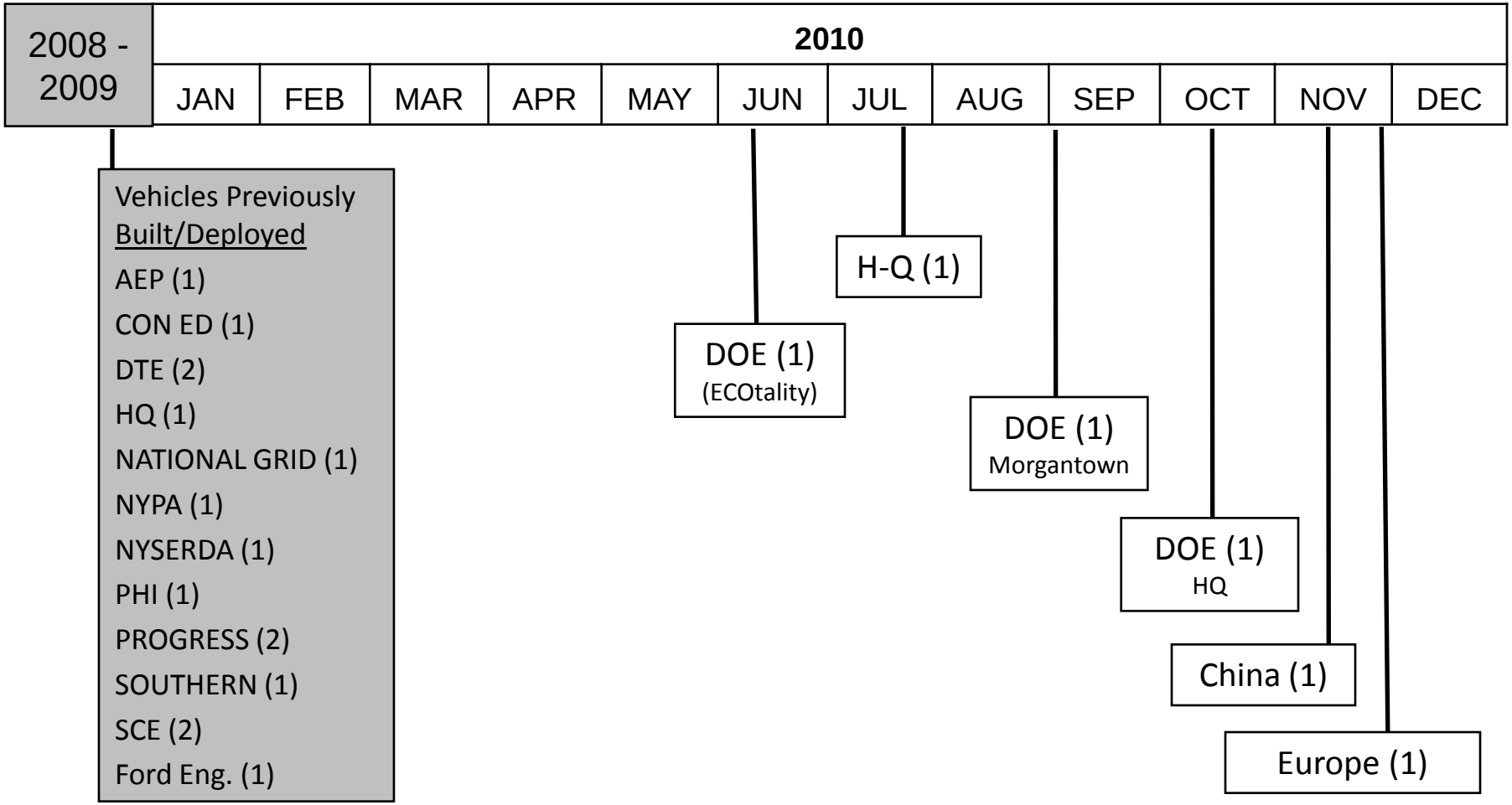
- J1772 Charge Port Assembly

- J1772 Level I (120V) Charge Cord

- Charger Assembly (including low voltage charger cooling fans)

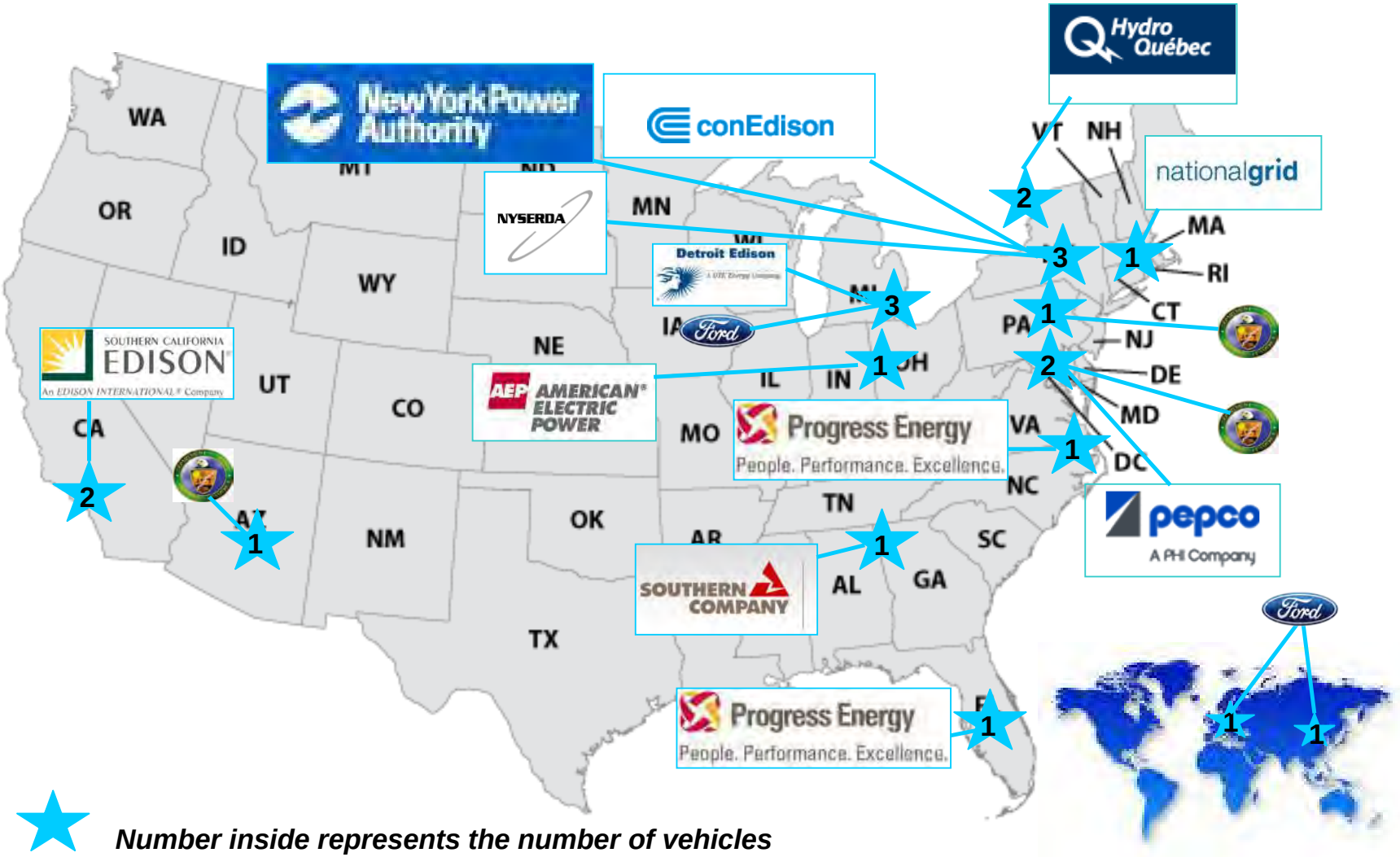
Technical Progress

Vehicle Delivery Timeline …



Technical Progress

Vehicle Locations …



★ ***Number inside represents the number of vehicles***

Technical Progress

Fleet Mileage …

	Customer	Vehicle Miles (2/22/11)
#01	SCE I	22,683
#02	H-Q I	22,152
#03	PHI	24,927
#04	AEP	21,304
#05	Ford Engineering	7,477
#06	DTE II	33,479
#07	NYSERDA	34,839
#08	NYPA	18,101
#09	ConED	17,245
#10	Southern	49,996
#11	Progress I	25,101
#12	National Grid	28,194
#13	DTE II	23,386
#14	SCE II	11,462
#15	DOE I (ECOtality)	7,525
#16	Progress II	13,766
#17	DOE II	5,712
#18	DOE III	10,492
#19	China	3,040
#20	H-Q II	11,105
#21	FoE	5,526
Total Miles		**397,512**

Total Fleet Miles
397,512
as of 2/22/2011

Collaborations

Public Education & Events …

Partners	Major Event
Ford Motor Company	• Display, Ride and Drive at National Earth Day Celebration in Washington DC • Display, Ride and Drive at Ohio's Moving Ahead Conference, OSU Columbus, OH • Display and media Ride and Drive at Texas Electrification Forum in Austin, TX • Ride and Drive for NHTSA event in Dearborn, MI • Ride and Drive at EEI Show in Hollywood, FL • Ride and Drive for Reuters reporters in Dearborn • Display for Electric Vehicle Tour across North America • Display for Senator Carl Levin in Dearborn, MI • Ride and Drive for Young Presidents Organization at Ford Test Track • Display for Live Green Fair in Ferndale, MI • Display for National AFV Day Odyssey at Lansing Community College in Lansing, MI • Ride and Drive at Green Festival in Washington, DC • Display for Michigan Public Service Commission in Lansing, Mi • Display for German American Council meeting at Ford in Dearborn MI
Hydro-Quebec	• EPRI Power Quality Conference in Quebec City on June 14 • Ride and Drive Event with Reporters and Scientists at the International Conference on Lithium Batteries in Montreal in June • Media Article: http://auto.sympatico.ca/tournant-ecolo/3548/hydro-quebec-prete-pour-larrivee-de-la-voiture-electrique • Static Display at World Energy Conference in Montreal,

Collaborations

Public Education & Events …

Partners	Major Event
SCE	• SCE Earth Day Event on April 30
Southern Company	• Earth Day Event at Vulcan Park with Alabama Power on April 25 • Alabama Power Junior High School Education event for girls interested in math and engineering on April 28 • State of Alabama Event at the State Capitol Building on June 10 • Static Display at McWane Science Center Event for Alabama Power • Static Display at Green Building Focus Conference
Detroit Edison	• Static Display at DOW Solar Discovery Center in Midland, Mi • Static Display at Leadership Meeting in Traverse City, Mi • Static Display at K of C fundraiser for Brighton Hospice and VA Hospital • Static Display at North American International Auto Show in Detroit, MI
AEP	• Moving Ahead 2010 Conference, Columbus, Ohio • Ride and Drive event with David Sandalow, Assistant Secretary for Policy and International Affairs, DOE • Static Display and Ride and Drive event with American Association of Blacks in Energy (AABE) Conference, Columbus, Ohio
NYSERDA	• Dept.of Environmental Conservation State Commissioner tour of NY State Earth events: http://adirondackcouncil.org/DEC_chief_marks_environmental_success_stories.pdf

Collaborations

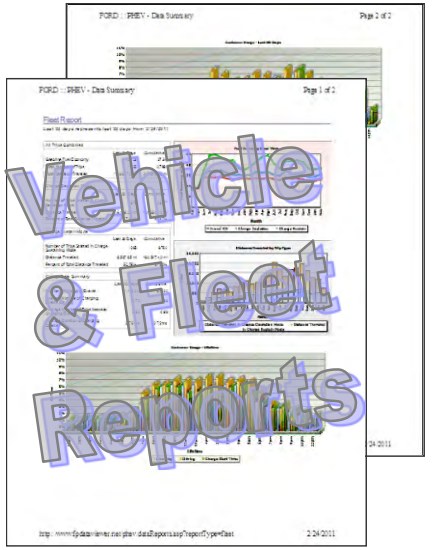
Public Education & Events …

Partners	Major Event
Pepco	• Earth Day event on the National Mall
Progress Energy	• PHEV Escape used at UCF Dedication of New Thermal Energy Storage System • Ride and Drive at North Carolina Homebuilders Association 21st Century Building Expo & Conference in Charlotte, NC • Ride and Drive and Southern Environmental Expo in Asheville, NC • Static Display for University of Central Florida Green Expo in Orlando, FL • Static Display for Charger Station Unveiling event in Raleigh, NC
National Grid	• Static Displays at Boston Greenfest and Carbon Day in Boston MA • Static Display for Massachusetts Clean Cities EV Symposium in Lowell, MA • Static Display for Massachusetts Energy Summit in Worcester, MA • Static Display for Ocean State Clean Cities Coalition Take Charge Electric Vehicle Conference at University of Rhode Island • Static Display for Advanced Energy Research and Technology center (AERTC) Conference in New York City • Static Display for National Grid Go Green Events in Melrose, Athol & Hanover MA
New York Power Authority	• Static Display for NYPA/Ford Electric Vehicle Workshop in White Plains Office • Static Display at 142nd Street Block Association in Bronx, NY • Static Display at Mt. Sinai Medical School Event in Bronx, NY • Static Display at NYPA/New Your City & Lower Hudson Valley Clean event • Static Display at communities Plug-in Electric Vehicle workshop in White Plains

Collaborations

Vehicle and Fleet Reports …

- Project partners have access to the data that is being collected via the onboard data acquisition system (DAP)
- Near real time data availability – depending on access to wireless
- Partners have access to Reports of:
  - –individual fleet vehicle performance in the field, as well as
  - –the entire fleet performance (all vehicles)
- Reports can be filtered to select desired time ranges (from / to specific dates)
- Report Parameters



All Trips Combined	Charge Depletion Mode	Charge Sustaining Mode	Charge Data
✓ Gasoline Fuel Economy ✓ Total Number of Trips ✓ Total Distance Traveled	✓ Number of Trips Started in Charge Depletion Mode ✓ Distance Traveled ✓ Percent of Total Distance Traveled	✓ Number of Trips Started in Charge Sustaining Mode ✓ Distance Traveled ✓ Percent of Total Distance Traveled	✓ Number of Charging Events ✓ Average Number of Charging Events per Day ✓ Average Number of Trips between Charging Events ✓ Average Duration of Charging Events

Technical Progress

Charging Events …

- Fleet charging profile indicates majority of charging taking place during the day
- Further analysis of data revealed that less than 20% of the PHEV in the fleet began with the HV battery SOC greater than 90%
- Discussions with partners have resulted in some variations in this profile

Collaborations

INL Reporting ….

- INL has been directed by DOE to identify data collection parameters and reporting methods with Ford
  - INL brings consistent data quality, analysis and dissemination methodology
  - INL provides third party neutrality to DOE
- Ford and INL have had ongoing demonstration data collection discussions
  - INL has access to Ford PHEV Engineering data and reports
  - Ford created software to provide data in INL preferred format
  - Ford has provided INL all data descriptions and vehicle specific software algorithms
  - Ford/INL have complete data correlation analysis
- INL will produce fleet summary reports based on vehicle data received from Ford
  - 3-page monthly summary report format
  - Results of all fleet vehicles aggregated
  - Published to AVTA website

At time of this report filing, INL report under review prior to publication

Technical Accomplishments

Technical Accomplishments for Phase III …

- Battery Controls and Development
  - Performed HV Battery software adjustments to improve charge, cell balance and robust vehicle operation at colder temperatures
- Interface & Communications
  - Continuing field demonstration of Smart Meter communication at utility partner locations and document lessons learned
  - Field demonstration has identified areas of improvement
- Vehicle & Controls Development/Updates
  - Vehicle Upgrades to support J1772 Connector
    - Modified Charge Port Assembly
    - New J1772 Level 1 (120V) Charge Cord
    - Updated Charger Assembly including New Cooling Fans

Technical Accomplishments

Technical Accomplishments for Phase III (continued) …

- Vehicle & Controls Development/Updates (continued)
  - Vehicle Modifications for EU and China Demonstration
    - Modified to electric A/C (air conditioner capable of running during engine-off operation)
    - Mechanical and electrical upgrades for charge operation at 230/50 HZ
    - Increase electric mode speed to 57 mph
    - Data Acquisition System updates
    - Other – Radio and GPS systems
- Testing, Data Acquisition, Analysis & Reporting
  - Testing conducted by SCE to validate data acquisition reporting algorithms has been completed. Algorithm modifications based on this testing have been implemented
  - Continued field testing; Collection of field data, analysis and reporting

Future Work

Planned work for Phase IV …

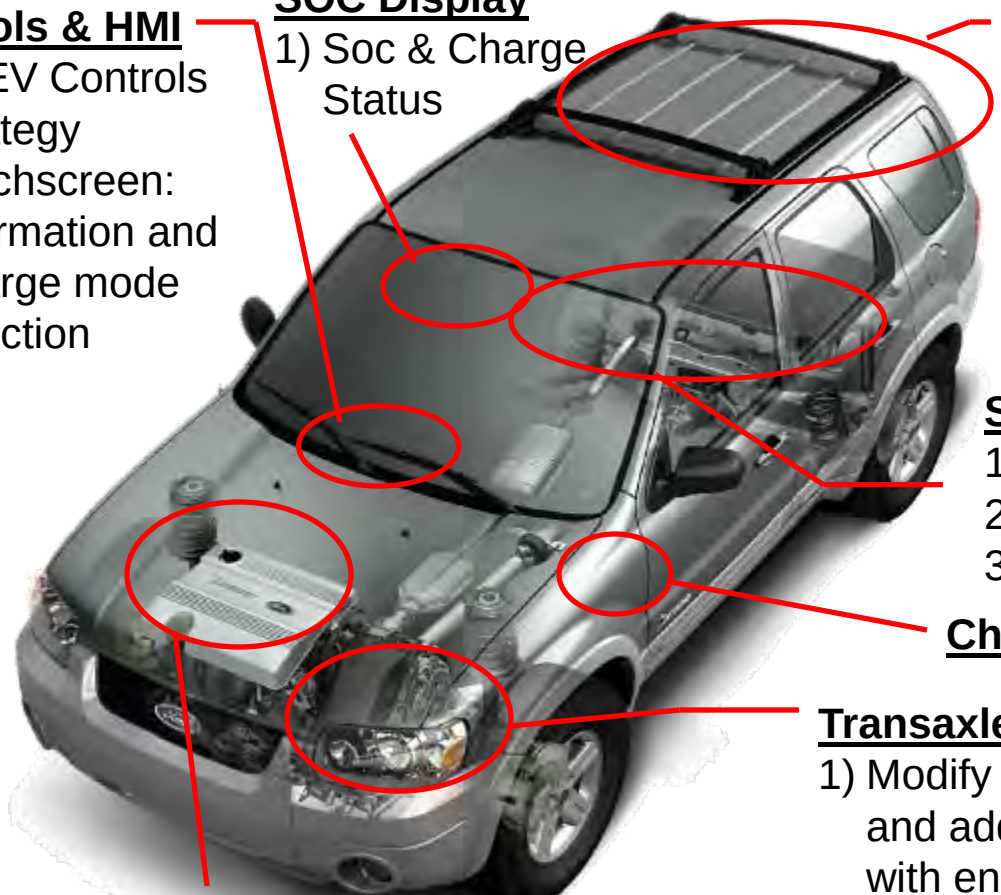
- Continued Demonstration of PHEV fleet in NA; Additional demonstration in EU and China
- Continued V2G/G2V Communication Demonstration
  - Improve systems reliability in the presence of secondary system noise
  - Implement dynamic keying
- Vehicle Upgrades
  - Roll out vehicle modifications to support J1772 connector and Level 2 charging
- Vehicle Service
  - Continue with bi-weekly Customer Action Team meetings
  - On going service and support of field vehicles
- Data Acquisition, Analysis, and Reporting
  - Continue with vehicle data collection
  - Continue with vehicle data analysis and reports to DOE and partners

Summary

- DOE-sponsored program supports the announcement of a 2012 mass production PHEV program in North America and 2013 mass production PHEV program in Europe
- Engineering development continues to drive production vehicle designs
- DOE-sponsored program has enabled nation wide outreach effort – educational, community and industry/utility events
- Strong interest from public
- Fleet customers are very satisfied with battery charging and driving experience

Technical Back-Up Slides

PHEV - Features and Specifications



Controls & HMI
1) PHEV Controls Strategy
2) Touchscreen: Information and Charge mode selection

SOC Display
1) Soc & Charge Status

Rear Cargo Area
1) Replace production high voltage battery with a ~11.5 kWh Li-Ion battery from JCS
2) Add 1.4 kW, 120V battery charger
3) Add Data Acquisition Module
4) Add ZigBee module (Bi-directional communication)

Structure and Suspension
1) Rear Suspension modifications
2) Structural enhancements
3) Exhaust System

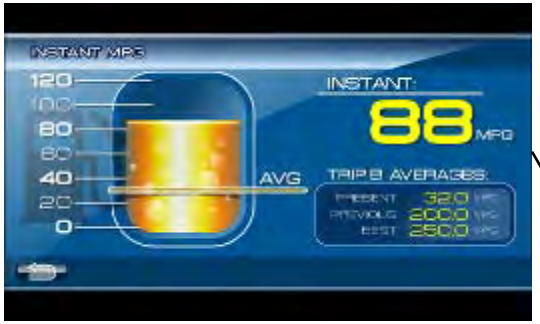
Charge Plug J1772 modifications

Transaxle Modifications
1) Modify transaxle oil lubrication/cooling circuit and add external electric oil pump for oil flow with engine off
2) Add oil to air heat exchanger to increase continuous operating capability of electric machines

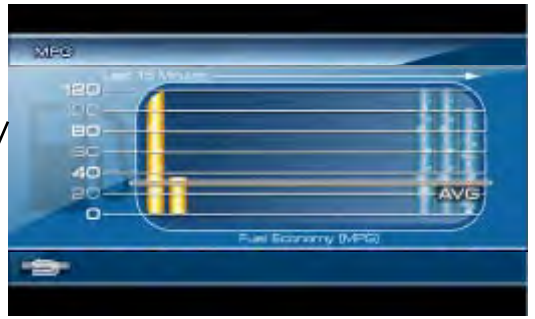
Engine & Fuel System
1) Flex Fuel (E-85) hardware and software

Human Machine Interface (NAV System)

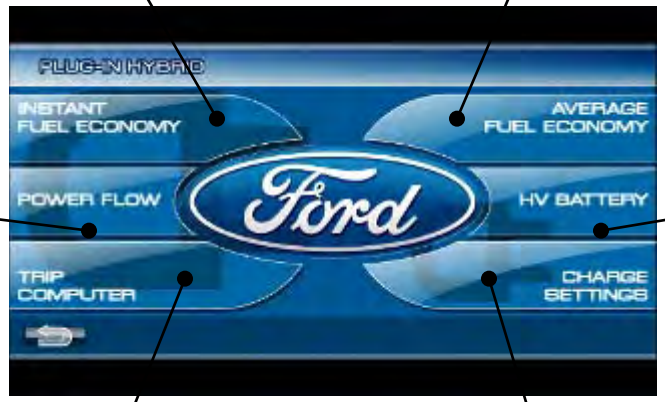
Instant Fuel Economy



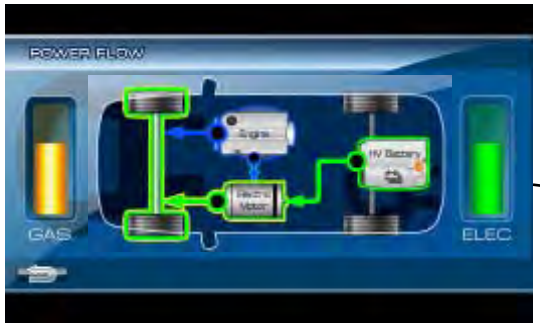
Average Fuel Economy



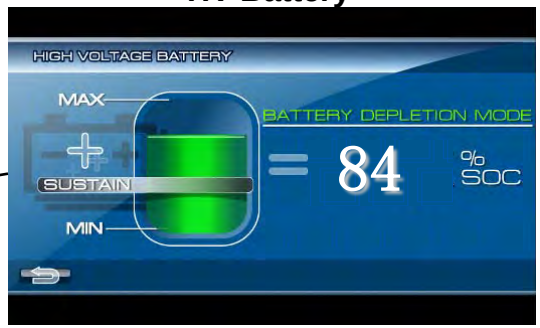
Main Menu



Powerflow



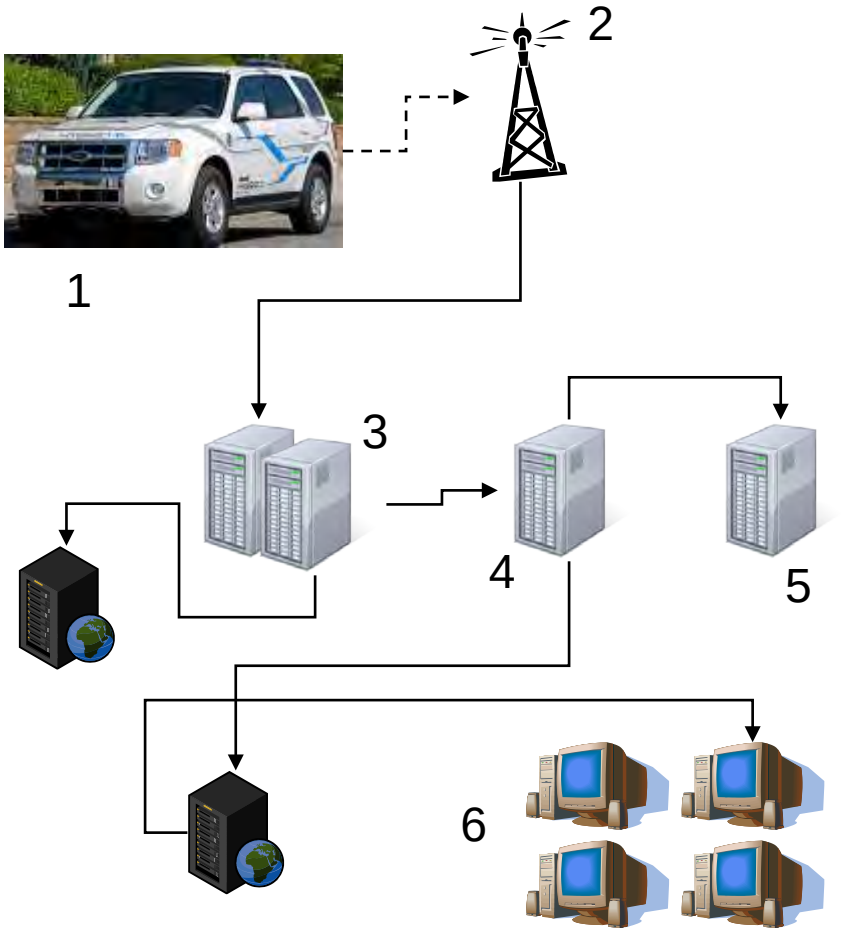
HV Battery



Trip Calculator

Charge Settings

Vehicle Data Collection and Reporting



1. Data collected on vehicle.
2. Data received by broadband wireless network
3. Data archived in collection server
4. Data relayed to website server
5. Website server backed-up nightly
6. Data available to authorized users through web

Technical Accomplishments for Phase I

- Vehicle & Design Build Updates
  - High Voltage (HV) Battery optimization
    - Improved power and State of Charge (SOC)
  - Implemented AC current and charger temperature controls
  - Low temperature robustness transaxle improvements
- Battery Controls and Development
  - LOS / Quit On Road Strategy completed and validated
  - Initial evaluations of vehicle battery management systems communications are completed
- Vehicle Controls & Development
  - Software modifications to allow Silent Key Start
  - Implemented a new charge port design
  - Engine and control system modifications have been made to allow for E-85 operation (08MY engine)
  - E-85 strategy and calibration under development for Phase II vehicles (09MY engine)
  - Sourced broadband on-vehicle data acquisition and transfer supplier
  - Sourced on-vehicle data organization and web-based access supplier
- Testing
  - FE testing completed at Argon National Labs
  - Pre-delivery NVH and Performance evaluations completed

Technical Accomplishments for Phase II

- Vehicle & Design Build Updates
  - Provide Technology retrofits to vehicles 01-04 (upgrade structure and charge port, implement flex fuel E85 capability, improve trans cooling, and install data acquisition and Ford Works hardware)
  - Vehicle build 12-21 (complete vehicle build and battery integration, develop new model-year engine and fuel system hardware for flex fuel E-85, develop and implemented V2G/G2V communication hardware)
- Battery Controls and Development
  - LOS / Quit On Road Strategy completed and validated for JC-S supplied battery system
  - Developed and implemented V2G/G2V communication software
  - Completed software modifications for NAV system
- Vehicle Controls & Development
  - Software modifications to allow Silent Key Start on 2009MY vehicles
  - Completed E-85 strategy & calibration development for 2.5L engine in 2009MY vehicles
  - Implemented on-board data acquisition system on the vehicles
  - Implemented on-vehicle data organization, analysis and web-based access
- Testing
  - Completed baseline FE testing of Phase I vehicle Argonne National Labs
  - Pre-delivery NVH and Performance evaluations completed
  - Continued collecting field data, analysis and reporting