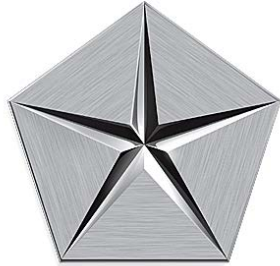


Advancing Transportation Through Vehicle Electrification - PHEV



CHRYSLER



Abdullah A. Bazzi

Chrysler Group LLC

May 17, 2012

Project ID # ARRAVT067

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Timeline

- Project Start: September, 2009
- Project Complete: June, 2014
- 60% Complete (Project Deliverable Perspective)

Budget

- Total Project Funding
 - DOE: \$48,000,000
 - Chrysler \$49,408,996
- Funding received FY10 : \$ 9.79M
- Funding received FY11 : \$17.77M
- Funding received FY12 : \$ 4.89M
- Chrysler/Partner Share⁽¹⁾: \$33.97M

(1) As of March 31, 2012

Barriers

1. Battery performance across extreme ambient conditions
2. Thermal Management Integration
3. Charging System Integration
4. Understanding customer acceptance and usage patterns for PHEV technology

Development Partners & Key Suppliers

• Behr America • Electrovaya • Hitachi • Delphi • TDI • Continental • CASCO Products • EPRI • Michigan State University • University of Michigan • Sacramento Municipal Utility District (SMUD) • NextEnergy • UC Davis

Demonstration Partners

• Sacramento Municipal Utility District (SMUD), Sacramento, CA • City of Yuma, AZ • DTE, Detroit, MI • Duke Energy, NC • MBTA, MA • National Grid, NY, MA, RI • Tri-State, CO • CenterPoint, Houston, TX • New York Police Department, New York • Nevada Energy, Las Vegas & Reno, NV • City of Auburn Hills, MI • Central Hudson, NY • EPRI (NC, CA) • Argonne National Labs / INL • City and County of San Francisco, CA • DOD (LA Air Force Base and Fort Carson, CO)

- Demonstrate 140 pickup trucks in diverse geographies and climates, spanning across the United States, and a range of drive cycles and consumer usage patterns applicable to the entire NAFTA region
- Verify plug-in charging mode performance based on charger and battery model
- Verify AC power generation mode
- Prove product viability in “real-world” conditions
- Develop bi-directional (communication and power) charger interface
- Support the creation of “Green” Technology jobs and advance the state of PHEV technology for future production integration
- Develop an understanding of Customer Acceptance & Usage patterns for PHEV technology
- Quantify the benefits to customers and to the nation

RAM 1500 PHEV Program Results – Relevance



Federal Test Procedures Results

Objective	Target	Status	Procedure	R/G/Y																																				
RANGE	Equivalent All Electric Range (EAER) of 20 miles	20+ miles EAER achieved	California Exhaust Emission Standards And Test Procedures, as amended December 2, 2009	GREEN																																				
EMISSIONS	ATPZEV Compliance	<table border="1"> <thead> <tr> <th>Test</th> <th>Test Mode</th> <th>Standard</th> <th>Results</th> </tr> </thead> <tbody> <tr> <td>FTP City</td> <td>CD & CS</td> <td>SULEV</td> <td>Passed ✓</td> </tr> <tr> <td>US06</td> <td>CS</td> <td>SULEV</td> <td>Passed ✓</td> </tr> <tr> <td>SC03</td> <td>CS</td> <td>SULEV</td> <td>Passed ✓</td> </tr> <tr> <td>Highway</td> <td>CS</td> <td>SULEV</td> <td>Passed ✓</td> </tr> <tr> <td>50 F City</td> <td>CS</td> <td>SULEV</td> <td>Passed ✓</td> </tr> <tr> <td>20 F Cold</td> <td>CS</td> <td>SULEV</td> <td>Passed ✓</td> </tr> <tr> <td>Evaporative</td> <td>CS</td> <td>PZEV</td> <td>Passed ✓</td> </tr> <tr> <td>Purge Volume</td> <td>CS</td> <td>PZEV</td> <td>Passed ✓</td> </tr> </tbody> </table>	Test	Test Mode	Standard	Results	FTP City	CD & CS	SULEV	Passed ✓	US06	CS	SULEV	Passed ✓	SC03	CS	SULEV	Passed ✓	Highway	CS	SULEV	Passed ✓	50 F City	CS	SULEV	Passed ✓	20 F Cold	CS	SULEV	Passed ✓	Evaporative	CS	PZEV	Passed ✓	Purge Volume	CS	PZEV	Passed ✓	California Exhaust Emission Standards And Test Procedures, as amended December 2, 2009	GREEN
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FUEL ECONOMY	Charge Depleting City 32 MPG	– Charge Depletion: – City: 37.4mpg; Hwy: 32.5 mpg	SAE J 1711 as published	GREEN																																				

Real World Results

	RAM 1500 PHEV Status	Background
FUEL ECONOMY & Mileage Accumulation (Real World)	<ul style="list-style-type: none"> Charge Depletion: Accumulated Miles – 175,126 – City: 22 mpg; Hwy: 26 mpg Charge Depletion / Charge Sustaining: Accumulated Miles – 65,619 (CD) / 111,533 (CS) – City: 19 mpg; Hwy: 21 mpg Charge Sustaining: Accumulated Miles – 341,354 – City: 16 mpg; Hwy: 19 mpg 	<ul style="list-style-type: none"> Data taken from 108 partner vehicles deployed throughout the United States Total mileage : 693,632 (April 2012) Vehicle fuel economy is based on customer usage and may not be representative of maximum potential fuel economy

Real world data was acquired using April 2012 INL report data

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RAM 1500 PHEV Program Results – Relevance



Project Management, Build and Development Plan

Project Phase



Timeline



Milestones

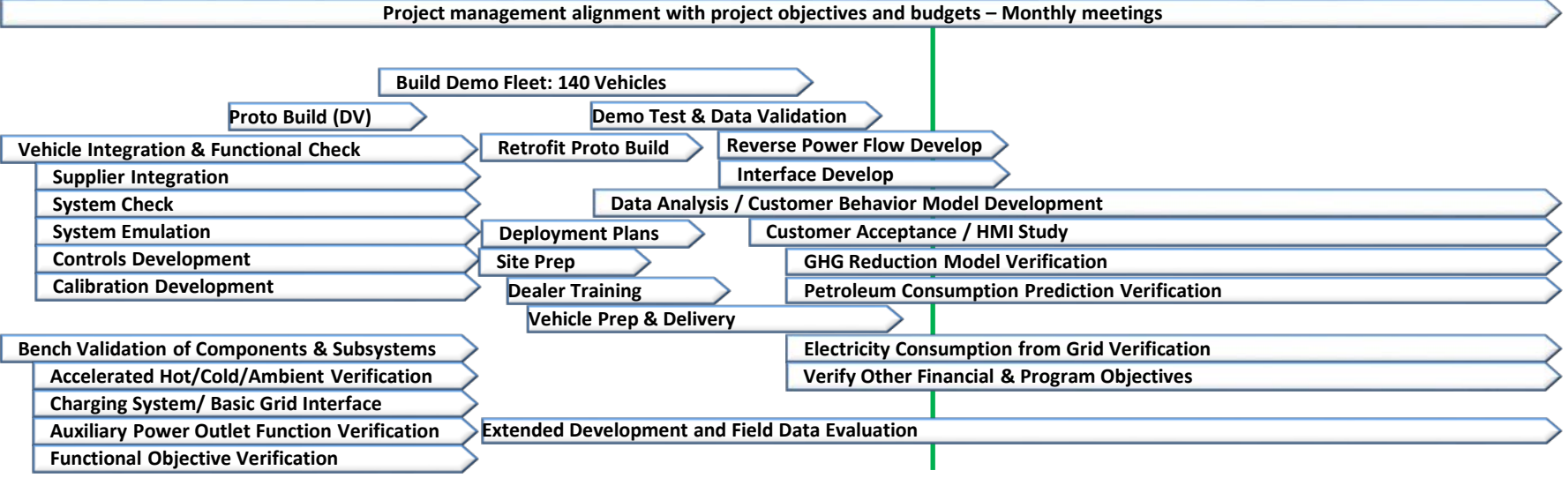


Development test trips:

- Hot: Red
- Cold: Blue
- Altitude: Green
- CPCP: Black
- Compliance: Grey



Key Deliverables



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RAM 1500 Project Milestones – Approach



Month / Year	Milestone or Go/No-Go Decision – Status
End of September 2012	Go / No-Go Decision: Release Smart Grid to the RAM 1500 PHEV Fleet
Continually	Milestone: Update Customer Interface Server; HMI Studies
Continually	Milestone: Enhance data reporting capabilities
Continually	Milestone: Field issues resolution

RAM 1500 Technical Specifications – Approach



Plug-in Hybrid Technical Specifications

RAM 1500 PHEV



- 6000 pounds towing and 32% grade capability.
- Only full size truck with Advanced Technology Partial Zero Emissions

- Hybrid Drive System Technology**
 - Next Generation Lithium Ion Battery
- Charge Times**
 - 2hrs at 220V
 - Up to 15hrs at 110V
 - Full Hybrid system function w/o Plug-in
- Fuel Economy (City)**
 - Charge Depleting 32MPG
- Electric Drive Range (City)**
 - 20 miles equivalent
- Range**
 - 655 miles
- Transmission**
 - Advanced Technology Plug-in Hybrid
- Brakes**
 - Regenerative Brake System

- Auxiliary Power**
 - 6.6kW Continuous Through:
- Power Panel**
 - Pickup Bed
 - 2 – 120V, 20A duplex
 - 1 – 240V, 20A plug
- AC Power Generation**
 - 120V / 240V, 60Hz AC
- Silent Mode**
 - 120V / 240V, 60Hz AC
- Exterior Dimensions**
 - Vehicle Length**
 - 227.5"
 - Overall Height**
 - 74.8"
 - Body Width**
 - 79.4"
- Ground Clearance**
 - 7.7" @ Curb Weight
- Approach / Departure**
 - 19.2° / 21.9°
- Breakover**
 - 15.2°
- Track**
 - 68.1" Front
 - 67.5 Rear
- Turning Diameter**
 - 45.3' Curb to Curb
- Wheelbase**
 - 140"

- Powertrain**
 - Engine Size / Type**
 - 5.7L HEMI® V8
 - Maximum Power**
 - 399 Horsepower
 - Maximum Torque**
 - 390 ft-lb @ 4300 rpm
 - Transfer Case**
 - 4x4
 - Axles**
 - 3.27 Axle Ratio
 - 9.25 Light Duty Rear Axle
 - Automatic Front Axle Disconnect (enhances fuel economy)
- Capacities / Weights**
 - Curb**
 - 6,411 lbs.
 - Fuel Tank Capacity**
 - 26 gallons
 - GCWR**
 - 12,100 lbs.
 - GVWR**
 - 7,200 lbs.
 - Payload**
 - 789 lbs.
 - Towing Capacity**
 - 6,000 lbs.
 - Cargo Box**
 - 5'7" with Ram Box

- Wheels / Tires**
 - Wheels**
 - 17" x 7.0" Aluminum Wheels (Steel Spare)
 - Tires**
 - P265/70R17 BSW All Season Tires
 - Full Size Spare Tire
- Interior Dimensions**
 - Passenger Volume**
 - 120.9 Cubic Feet
 - Seating Capacity**
 - 6 Passenger 3F/3R
- Safety**
 - Electronic Stability Program**
 - Traction Control
 - ABS
 - Brake Assist
 - Electronic Roll Mitigation
 - Hill Start Assisted
 - Trailer Sway Control
 - Air Bags**
 - Advanced Multistage Front
 - Supplemental Side Curtain
 - Supplemental Front and Rear Curtain



- Features the unique utility and functionality of on-board AC power
- Is a low cost alternative to aftermarket commercial grade diesel generators
- Eliminates the need for a separate generator fuel supply

Chrysler Group LLC reserves the right to make changes at any time, without notice or obligation, in prices, specifications, equipment, colors and materials, and to change or discontinue models. The data contained within this brochure should be regarded as approximate. Please note that some models and options may not be available in all markets. The vehicle's emissions are not fully certified and will have an exemption label displayed.

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RAM 1500 PHEV Technology – Approach



120V / 240V AC
Power Panel 6.6 Kw



J1772
Charge Port
Level I / II



Controls

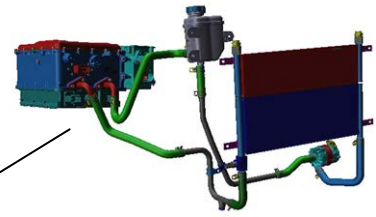
- E Motors
- Battery
- Hybrid Vehicle
- Transmission



6.6 Kw Charger /
Inverter



5.7 L HEMI® V-8 Engine
• 345 hp Gas Engine
• 399 hp Total Hybrid System



HV Battery Li-Ion
12.9 kWhr
Liquid Cooled



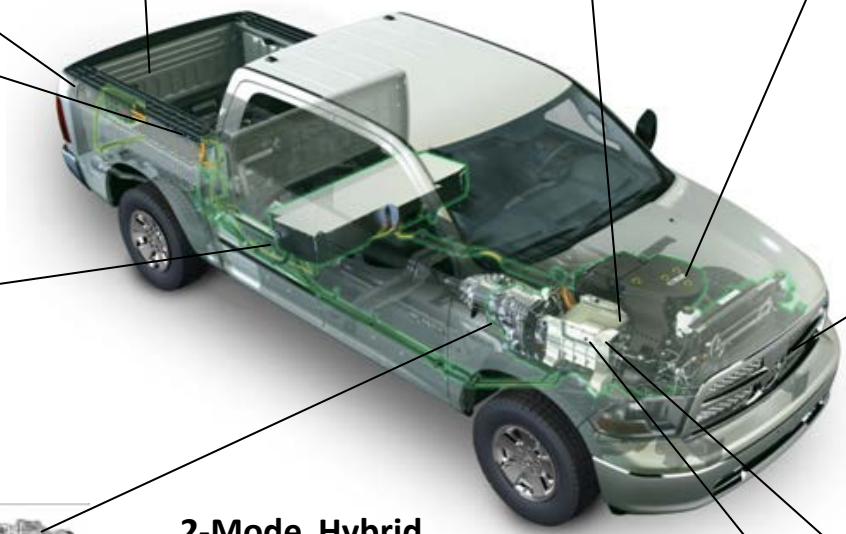
Thermal Systems

2-Mode Hybrid
Transmission
• 2 EVT Modes
• 4 Fixed Gears
• 65 Kw Motors



Power
Electronics
Inverter and
DC /DC

Electric Motors



Uniqueness of the approach for the RAM 1500 PHEV

- Used relevant timing and milestones from the Chrysler Product Creation Process, CPCP
- Design, develop and deploy a Plug-In hybrid Pickup Truck, the RAM 1500 PHEV
- Design vehicle to not only accept power from the grid; but, under circumstances, provide power to the grid
- RAM 1500 PHEV Unique Features being Implemented:
 - ✓ Reverse Power Flow – Provides external power (120v and 240v)
 - ✓ Scheduled Charging – Web site charging control to allows user to schedule charge events
 - ✓ NAVTEQ – Optimized charge depletion: based on learned trip drive and charge cycles
 - ✓ Power Panel – 120 & 240 volt AC generation provides up to 6.6 kW of power through the panel
 - ✓ Smart Grid – Vehicle to grid interface through ERPI's multipurpose router

RAM 1500 PHEV Technical Accomplishments – Completed Prior to May 2011

- Development and validation utilized augmented Chrysler Group LLC vehicle development process, CPCP, for a production intent program.
 - ✓ Augmented development process with modified testing procedures to address specific plug in Hybrid Technologies
- Facility Based Testing: hot static cell, hot drive cell, cold static cell, cold drive cell, altitude chamber, engine dynamometer, transmission dynamometer, NHV cell, EMC cell, end of line; bench Testing: vibration, SOC, thermal, charge / discharge cycling
- Road trips:
 - ✓ Development testing and verification: hot trip to 125F, cold trip to -20F, altitude trip to 12,000 ft
- Initiated Durability testing: powertrain, high mileage, two charge cycles per day.
- Initiated demonstration fleet vehicle build
- Started vehicle deployment

Quick review of some of the items completed and presented during the review prior to May 2011

Phase I: PHEV Development – Completed After May 2011

- Development and validation utilized the standard Chrysler Group LLC Vehicle Development Process for a production intent program.
 - ✓ Designed and built all development and test vehicles
 - ✓ Augmented development process with modified testing procedures to address specific plug in Hybrid Technologies
- Continued Facility Based Testing: hot static cell, hot drive cell, cold static cell, cold drive cell, altitude chamber, engine dynamometer, transmission dynamometer, NHV cell, EMC cell, end of line, emissions test facility; bench Testing: vibration, SOC, thermal, charge / discharge cycling
- Impact Testing: Successfully Completed for FMVSS compliance
- Completed PHEV system controls and calibrations: Created, developed and verified control systems and supporting calibrations to achieve program targets for RAM 1500 PHEV vehicle.
- Verification Road trips: Hot trip – Mid July 2011 to Mid August 2011; Cold Trip Dec 2011
- Development testing and verification: hot trip to 125F, cold trip to -20F, altitude trip to 12,000 ft
- Completed Durability testing: powertrain, high mileage, two charge cycles per day
- Developed Delayed Charge feature: help manage charge power consumption and infrastructure concerns with large fleets.
- Developed Reverse Power Flow: feature to allow up to 6.6kW support of power grid.
- Developed NAVTEQ system: optimizes charge depletion of HV battery to fit customer use profile for repetitive drives

With most of the PHEV development completed, the Chrysler team is focusing on implementing additional and enhancing current functionality in the RAM 1500 PHEV

Phase II: Build & Launch Preparation – Completed After May 2011

- Updated all development and test vehicles
- Completed and executed all pre-build requirements for the Demo fleet are established
- Built 140 demonstration fleet vehicles
- Prepared all customers receive the fleet vehicles. Includes:
 - ✓ Customer Training
 - ✓ Site preparation
- Completed Dealership Training
- Conducted a minimum of 900 customer miles on each vehicle as a pre-deployment verification.
- Conducted engineering evaluation of each vehicle

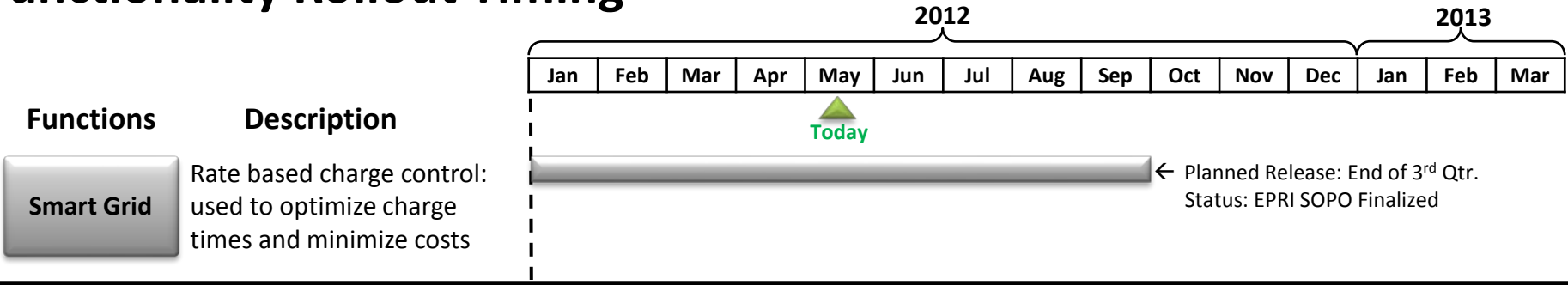
All RAM 1500 PHEV's have completed the build phase

Phase III: Demonstration Phase – Completed After May 2011

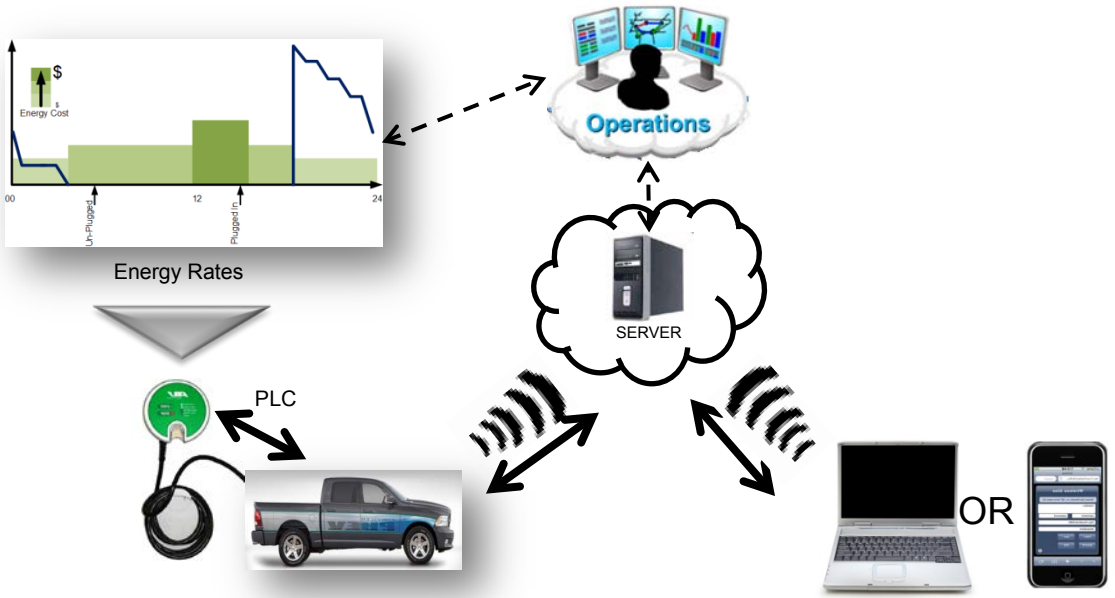
- Identified partners for the 140 RAM 1500 PHEV Demonstration fleet
- Deployed 108 and are in process of deploying another 17 vehicles to the demonstration partners
- Capturing deployed fleet data that supports Calibration and Controls development
 - ✓ Enhancing Data Reporting Capabilities
- Work with Idaho National Labs to refine fleet reports and conduct report validation
- Developed data analysis tools and data storage (Performant / MicroStrategy)
- Field partners issues resolution support
- Field data analysis and evaluation to further enhance the vehicle's features and functionalities

With deployment partners identified, the Chrysler team is capturing usage data and enhancing data reporting capabilities

Functionality Rollout Timing



Smart Grid Overview



Description
<ul style="list-style-type: none"> • Combination of wireless (“cloud”) and wired (power line communication via a multi-protocol router) control • Used to optimize charging while minimizing charging costs • Development is in conjunction with EPRI • Utility Interface with time of use rates • Implement by end of 3rd quarter 2012

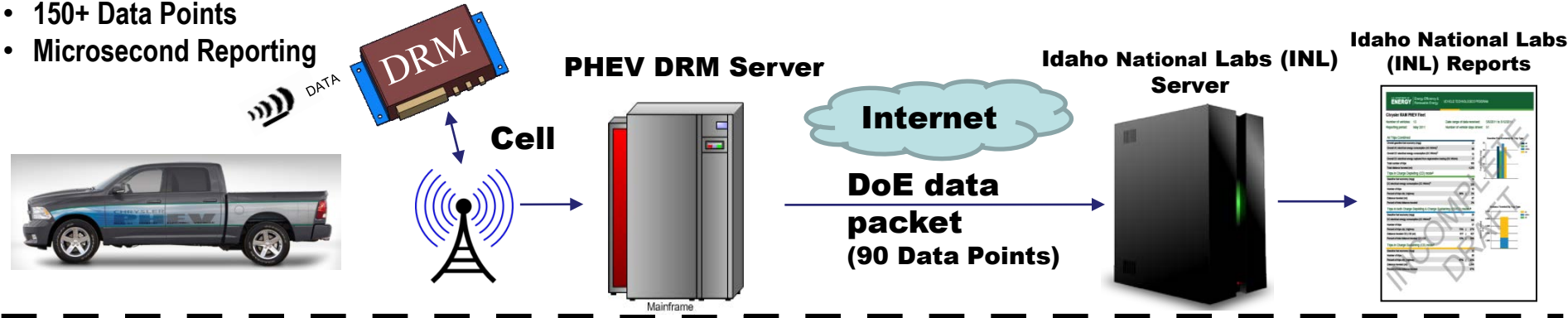
Only remaining functionality planned for roll out

Initial Fleet Deployment Implementation – May 2011

- Remote Software Flash
- Remote Diagnostics
- Near Real Time Data Upload
- 150+ Data Points
- Microsecond Reporting

STATUS:

- Chrysler's PHEV server sends the DoE required Unlimited Rights data to Idaho National Labs (INL) for the purpose of data processing and reporting.



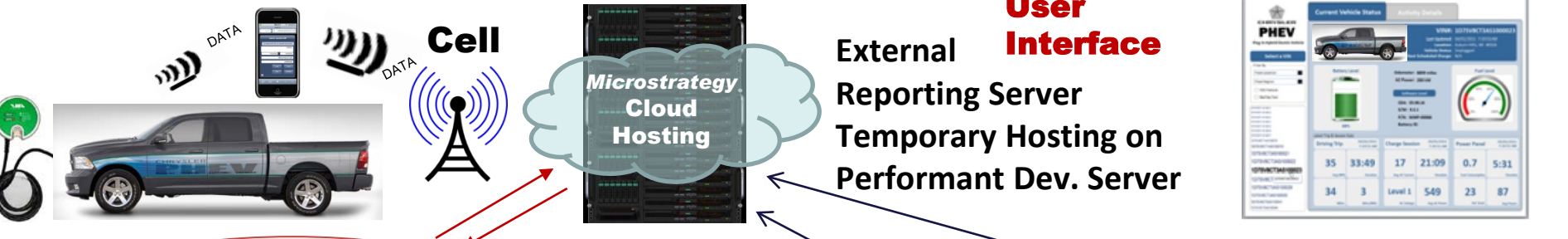
Enhanced Data Reporting Server

Copy of DoE Data

Plus Engineering Only Data

Dashboard User Interface

2nd Quarter 2012 Implementation



User Interface

- * Scheduled Charging
- * Smart Grid Charging

Demo Partners Access only DOE Data for their fleet

Engineering Full Access to Fleet Data



Idaho National Laboratory Data: Cumulative as of April 30, 2012

U.S. DEPARTMENT OF **ENERGY** | Energy Efficiency & Renewable Energy | VEHICLE TECHNOLOGIES PROGRAM

Chrysler RAM PHEV Fleet

Number of vehicles: 108 Date range of data received: 7/1/2011 to 4/30/2012
 Reporting period: Jul 11 - Apr 12 Number of vehicle days driven: 12425

All Trips Combined

Overall gasoline fuel economy (mpg)	19
Overall AC electrical energy consumption (AC Wh/mi) ¹	101
Overall DC electrical energy consumption (DC Wh/mi) ²	69
Overall DC electrical energy captured from regenerative braking (DC Wh/mi)	45
Total number of trips	77,676
Total distance traveled (mi)	693,160

Trips in Charge Depleting (CD) mode³

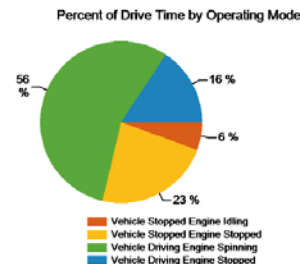
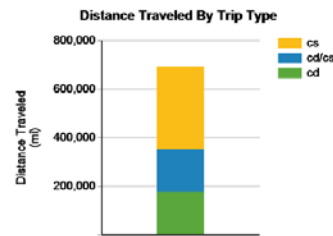
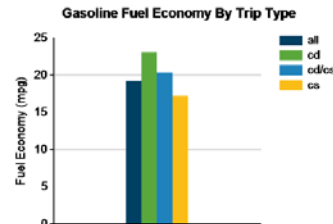
Gasoline fuel economy (mpg)	23
DC electrical energy consumption (DC Wh/mi) ⁴	210
Number of trips	32,475
Percent of trips city highway	94% 6%
Distance traveled (mi)	175,126
Percent of total distance traveled	25%

Trips in both Charge Depleting & Charge Sustaining (CD/CS) modes⁵

Gasoline fuel economy (mpg)	20
DC electrical energy consumption (DC Wh/mi) ⁶	69
Number of trips	8,887
Percent of trips city highway	75% 25%
Distance traveled CD CS (mi)	111,53 3
Percent of total distance traveled CD CS	9% 16%

Trips in Charge Sustaining (CS) mode⁷

Gasoline fuel economy (mpg)	17
Number of trips	36,314
Percent of trips city highway	90% 10%
Distance traveled (mi)	341,354
Percent of total distance traveled	49%



Ram 1500 - Highlights

- Overall fuel economy = 19
- Charge depleting FE = 23
- Mixed CD / CS FE = 20
- Charge Sustaining FE = 17
- Charge Events = 0.88 (per day per vehicle when driven)
- Average charge event = 2.36 hrs.
- Total number of trips (Key cycles) = 77,676
- Total distance traveled = 693,160 miles
- Vehicle stopped / engine stopped = 23%
- Vehicle driving / engine stopped = 16%

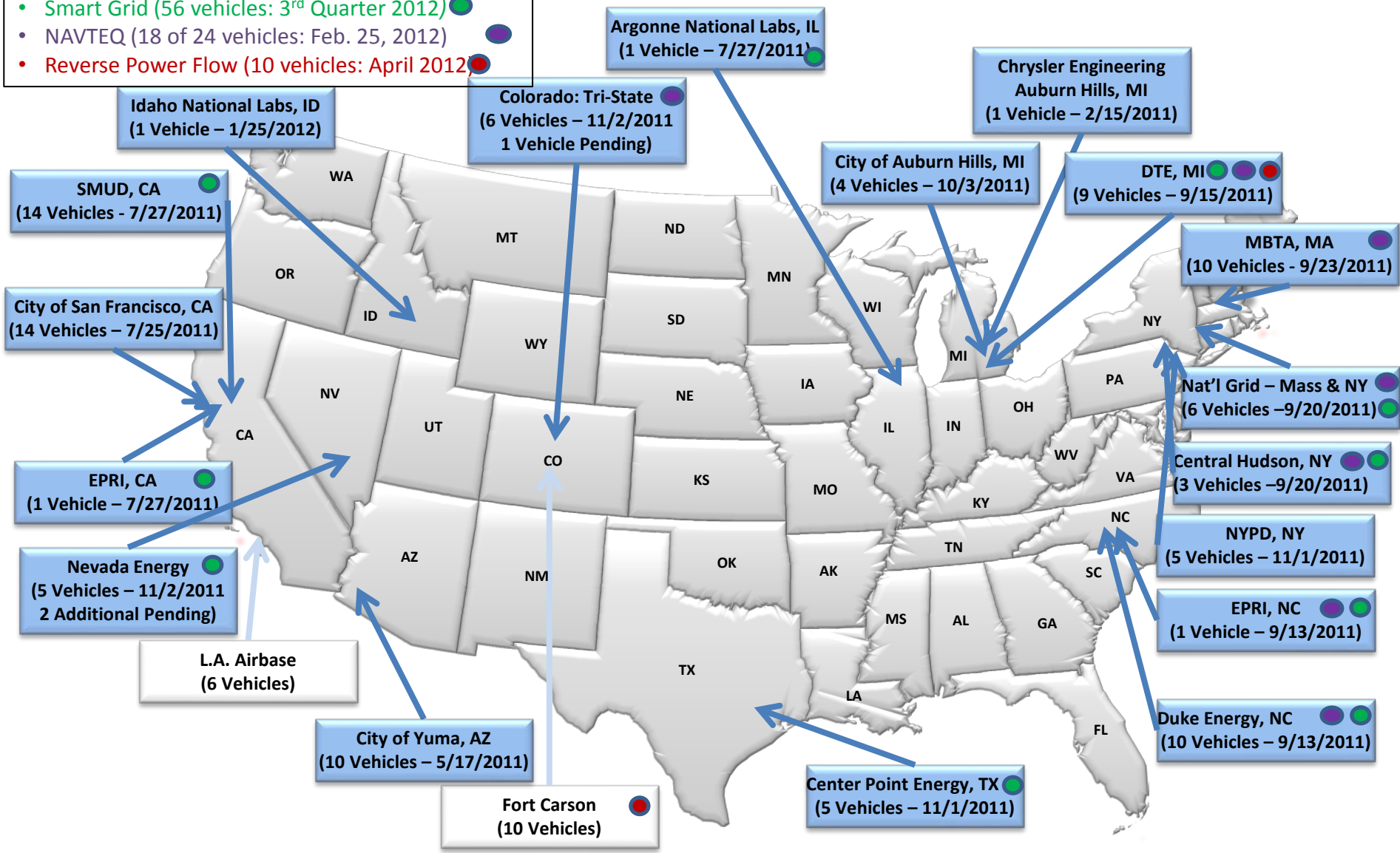
• RAM 1500 PHEV performance data is collected from across the entire fleet
 • Real-world statistics are being used to capture customer behavior

Collaborations & Partnerships



123 Vehicle Deployed with Locations & Deployment Dates

- Smart Grid (56 vehicles: 3rd Quarter 2012) ●
- NAVTEQ (18 of 24 vehicles: Feb. 25, 2012) ●
- Reverse Power Flow (10 vehicles: April 2012) ●



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Development partners are participating in a variety of roles



- Working on hybrid energy storage involving lithium ion batteries
- Studying soft switching that can help improve efficiency in onboard chargers



- Detailed powertrain and vehicle system models have been derived and improved
- System parameters were identified using HIL models and have been validated by experimental data



- EPRI will use two 2011 RAM PHEVs in connection with Chrysler's project to demonstrate and evaluate performance of advanced plug-in hybrid- electric vehicle technologies across a range of geographic, climatic and operating environments.



- Providing a test facility with infrastructure to charge and discharge PHEVs
- Perform data collection, analysis and reporting of data.



- Providing infrastructure in the Sacramento, CA area to charge and discharge PHEVs
- Perform data collection, analysis and reporting of data.



- Assisting the City of San Francisco in finding fleet applications best suited to maximize the benefits of PHEVs.
- Collecting and analyzing information from driver and fleet manager interviews and from data recording instrumentation onboard the PHEVs in order to recommend improvements to the vehicle design.
- Researchers will also assist the City of San Francisco in the strategic placement of charging infrastructure.

- Behr has completed the thermal system design and parts delivery
- Electroveya is nearing the completion of their work, based on budget; in discussion with continuing field support for critical issues

Fleet Service: Servicing the fleet is conducted through a five step process⁽¹⁾

1. Diagnosing the Issue
2. Kick off Problem Resolution (System focus)
3. Track Problem
4. Resolve Issue (System Focus)
5. Repair & Cascade to Fleet

Major Issues and Barriers Addressed

1. Battery Performance:
Implemented a software feature that monitors battery cell temperatures. The feature then responds to those cell delta temperature differences, and then determines the optimal operating mode
2. Thermal Management Integration:
Implemented a liquid and air cooling system. This system uses an air / liquid heat exchanger
3. Charging System Integration:
Implemented fully integrated air cooled 6.6kW charger that works on both Levels 1 & 2 EVSEs.
4. Understanding customer acceptance and usage patterns for PHEV technology:
Ongoing HMI and customer feedback analysis that focuses on the development of a customer behavior model. Analysis will be conducted throughout the demonstration period

Notes: (1) See first Technical Backup Slide in the Appendix for details

Phase III: PHEV Vehicle Demonstration

- Continue capturing deployed fleet data to support calibration and controls development
- Enhance data reporting capabilities
- Implement Smart Grid
- Update fleet partners interface server; allows the partners to interface directly with the server. Access the vehicle data, Scheduled Charging, Reverse Power Flow and Vehicle to Grid Control

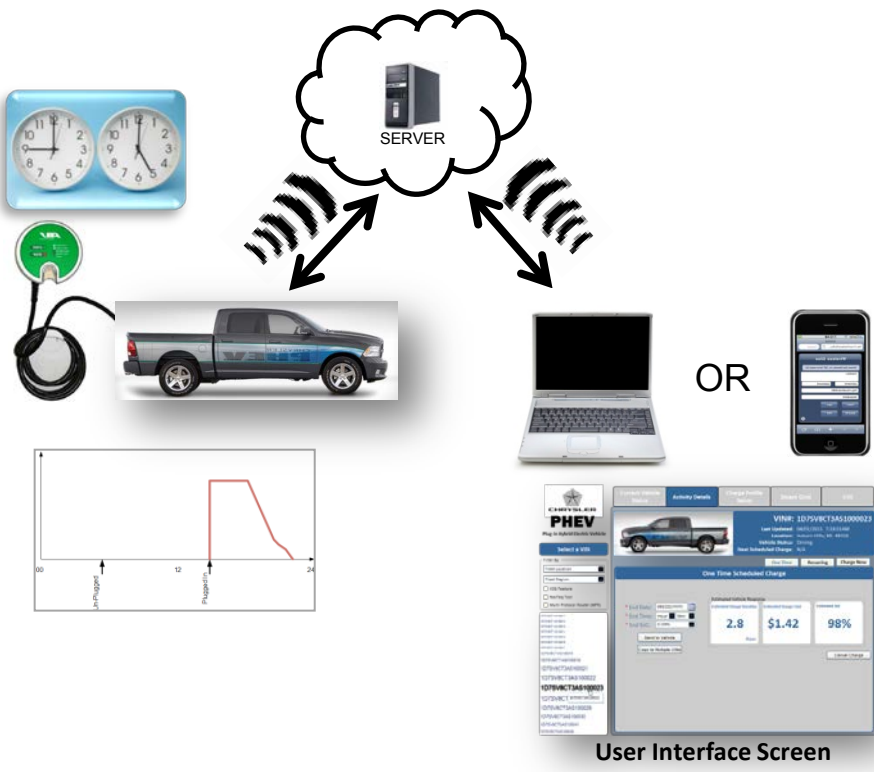
- Successful development, execution, and validation of the PHEV technology on engineering vehicles.
- Successful completion of the demonstration fleet vehicles. Deployed 108 and are in process of deploying another 17 vehicles; 4 vehicles will be deployed at a later date to existing partners; and 11 will be retained at Chrysler for future development.
- Successfully demonstrated the PHEV 20-miles All Electric Equivalent drive cycle.
- Successfully overachieved the fuel economy target of 32 mpg in charge depleting cycle.
 - ✓ Collected real world data with real world results
- Demonstrated capability to meet ATPZEV emission requirements.
- On track to meet program milestones and project deliverables.
- Created Core Competency “Green” Technology jobs and have a plan in place to sustain them toward future development of electrification programs

Technical Back-Up Slides

Technical Description and Functionality

- Optimize battery vs. engine power usage based on learned driving and charging history without any driver intervention.
- Current configuration is based on one previous learned trip (Charge event to charge event)
 - Average fuel economy gain is 30%
 - Requires regular charging to leverage charge depleting driving
 - Ideal for a commuter type driving, less than 50 miles, to enable route learning
- Deployed February 25, 2012

Scheduled Charging Overview

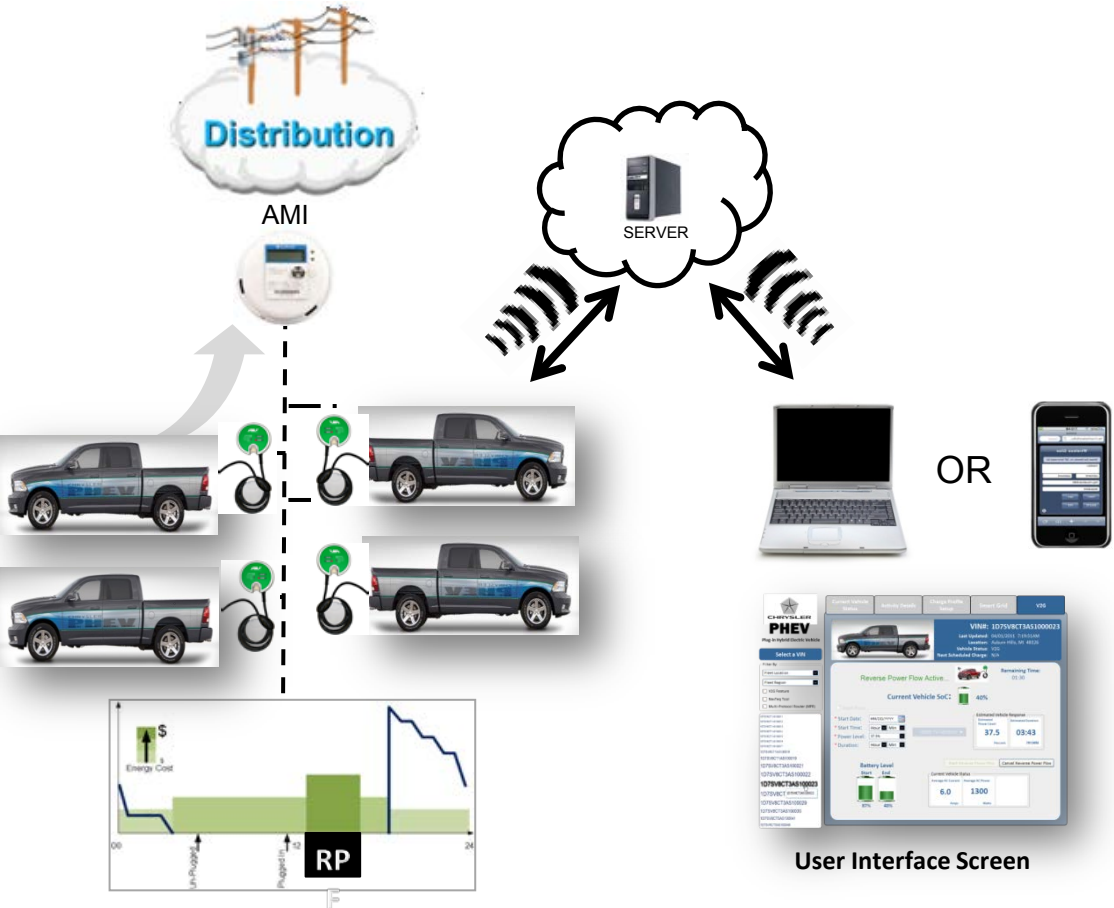


Description
<ul style="list-style-type: none">• Web site control of the starting and duration of vehicle charging• Allows users to schedule charging events as necessary• Minimal customer input required (Date, Start Time, End Time, Desired SOC)• Minimal system input• Expected to be released to fleet by the May 15, 2012

Scheduled Charging Take-Away's

- End user and / or fleet manager can stagger start and stop charge times to ensure vehicle is ready when needed and infrastructure limitations are managed

Reverse Power Flow Overview

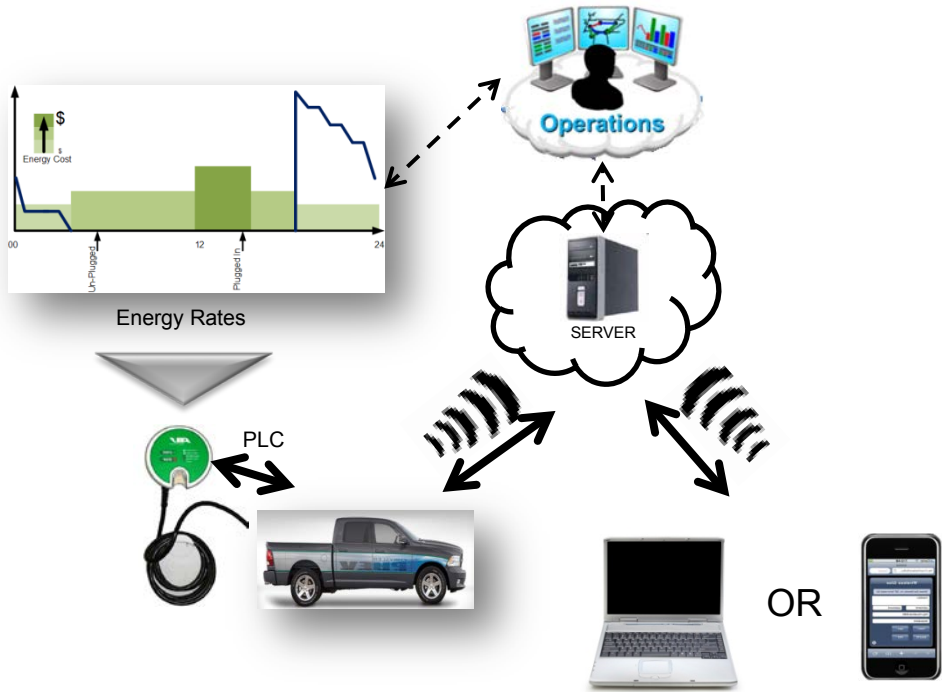


Description
<ul style="list-style-type: none">• Vehicle to Grid function at four power output levels (37, 50 , 75 & 100% of 6.6kW)• Hardware and software functionality successfully demonstrated; NextEnergy• Web based control of charge flow, duration and arbitration• Complete retrofit of remaining 9 vehicles by end of March 2012• Deploy first of 10 vehicles May 31, 2012

Reverse Power Flow Take-Away's

- Consumer can purchase energy during off-peak and use or sell back during peaks demand
- Home / Grid stabilization
- Supplement an existing micro-grid

Smart Grid Overview



Description
<ul style="list-style-type: none">• Combination of wireless (“cloud”) and wired (power line communication via a multi-protocol router) control• Used to optimize charging while minimizing charging costs• Development is in conjunction with EPRI• Utility Interface with time of use rates• Implement by end of 3rd quarter 2012

- Achieve optimized charge @ lowest cost
- Grid stabilization
- Networking for utility management of multiple vehicles on same transformer / sub-station