2014 DOE Annual Merit Review
Advancing Transportation Through Vehicle Electrification – Ram 1500 PHEV
DOE Funded Project

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Chrysler Group LLC

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Project ID # ARRAVT067

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview – Ram 1500 Project

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Timeline

- Project Start Date: September 2009
- Project End Date: December 2014
- Phase I: 99% Phase II: 56% (budget perspective)

Budget

- Total Project Funding
  - DOE: $48,000,000
  - Chrysler/Partner: $49,408,996
- Funding received FY10 : $ 9.79M
- Funding received FY11 : $17.77M
- Funding received FY12 : $ 7.69M
- Funding received FY13 : $ 5.28M
- Funding received FY14 : $ 3.58M
- Chrysler/Partner Share(1): $45.40M

(1) As of March 31, 2014

Barriers

Current:

- Battery performance across extreme ambient conditions

Resolved:

- Charging System Integration
- Vehicle to Grid Interface
- Understanding customer acceptance and usage patterns for PHEV technology

Development Partners & Key Suppliers (Phase II in Bold)

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

Demonstration Partners

• **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

Overview – RAM 1500 PHEV Project Objectives

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Phase I:

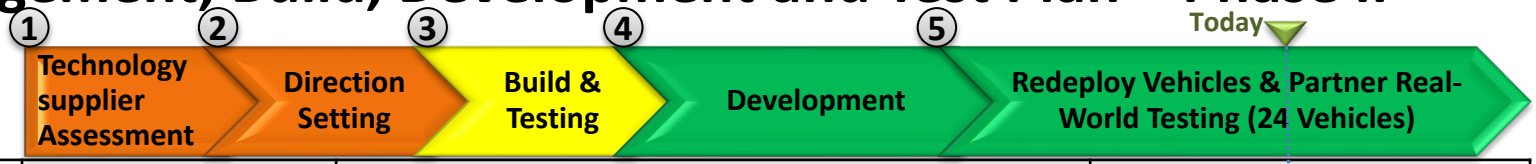
- Demonstrate 140 pickup trucks in diverse geographies and climates, spanning across the United States, and a range of drive cycles and consumer usage patterns applicable to the entire NAFTA region
- Verify plug-in charging mode performance based on charger and battery model
- Verify AC power generation 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

Phase II:

- Demonstrate the viability of the high voltage energy storage system with a new cell technology for a new production application
- Test advanced Li-Ion Battery technologies, Smart Charging, DC Charging, Reverse Power Flow, and Electrified Powertrain Control Systems
- Demonstrate 24 pickup trucks in diverse geographies and climates

Approach – Ram 1500 PHEV Project Plan

Project Management, Build, Development and Test Plan – Phase II



	2012					2013											2014											
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	J	F	M	A	M	J	J	A	S	O	N	D
Milestones – Battery/Vehicle Development – Battery/Vehicle Build – Battery Develop Milestones – Vehicle Deployment/Testing			Vehicles Returned Supplier Selection		12/5/2012 Preliminary Design Review		Battery Development	3/4/2013 Critical Design Review (CDR) - Build Volumes Frozen	4/12/2013 Lab Packs Available	Battery Upgrade	5/24/2013 DV Test Packs/Hot Trip Packs Available	Vehicle Rework	7/12/2013 Development Vehicle Packs Available		Vehicle Demo Redeployment	8/13/2013 Fleet Retrofit 1st Pack Available					Software Update		End Deployment Return 19 Vehicles		Retain 7 Vehicles at 3 partner sites thru Sep	Retain 1 Vehicle at ANL DC Charging thru Dec	Project Complete		
Task 1: Project Management																												
Task 2: Project Preparation & Planning																												
Task 3: Initial Development Builds																												
Task 4: Supplier Readiness Review																												
Task 5: Pre-Demonstration Build																												
Task 6: Fleet Build																												
Task 7: On-Going Vehicle Operation & Testing																												
Task 8: Data Collection & Analysis																												
Task 9: Advanced Energy Storage System Development																												

Note: Project has been extended through December 2014 to complete DC charging and V2G

Approach – RAM 1500 PHEV Project Milestones

Month / Year	Milestone or Go/No-Go Decision	Description	Status
July 2013	Milestone	Demonstrate Reverse Power Flow and A.C Power Generation at the Launch of Smart Grid Interoperability Center at Argonne National Laboratory	Complete
July 2013	Milestone	Upgrade High Voltage battery packs are available for vehicle testing	Complete
August 2013	Milestone	Ram 1500 PHEV deployment vehicle battery retrofit begins	Complete
October 2013	Milestone	Begin redeployment of retrofitted Ram 1500 PHEVs to partners	Complete
Ongoing	Milestone	Customer field evaluations and data review	On Schedule
August 2014	Milestone	Start returning deployed vehicles to Chrysler LLC for decommissioning	On Schedule
Dec 2014	Milestone	Project Completion and all vehicles returned and decommissioned	On Schedule
March 2015	Milestone	Phase II Close-Out	On Schedule

Approach – Uniqueness

Uniqueness of the approach for the RAM 1500 PHEV – Phase II

- Using relevant timing and milestones from the Chrysler Product Creation Process, CPCP, to complete the project
- Continue testing unique features on the RAM 1500 PHEV:
  - ✓ Reverse Power Flow – Provides external power (120v and 240v)
  - ✓ Smart Charging – Vehicle to grid interface through ERPI's multipurpose router
  - ✓ DC Charging – Reduction of onboard vehicle charger size/weight as well as fast charging

Relevance – Ram 1500 PHEV Program Results

Analysis & Learning: Capturing Lessons Learned

Data Formatted by:
Fleet, Site, Vehicle & time period

Thermal:
- HV Battery Cell Temps Monitoring
- Thermal System Operating Modes Monitoring
- Thermal Systems Function Monitoring
- AC Operation Monitoring

Charger:
- Charge Function Monitoring
- V2G Monitoring

Battery:
- Voltage Monitoring
- Current Monitoring
- HV Power Monitoring
- Energy Usage Monitoring
- SOC Monitoring

Drive / FE:
- Mode / Gear Monitoring
- ICE Operation Monitoring
- 12 volt Function Monitoring
- Regenerative Brake Monitoring
- Trip / Usage Monitoring

Developed optimization plan within customer usage profiles. Applied lessons learned to Phase II redeployment and future Electrification applications

Relevance – RAM 1500 PHEV Program Results

Federal and Partners Real World Test Data – Phase I

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><tr><th>Test</th><th>Test Mode</th><th>Standard</th><th>Results</th></tr><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></table>	California Exhaust Emission Standards And Test Procedures, as amended December 2, 2009	**GREEN**
FUEL ECONOMY	Charge Depleting City **32 MPG**	– Charge Depletion: – **City: 37.4 MPG**; **Hwy: 32.5 MPG**	SAE J 1711 as published	**GREEN**

Real World Results

	RAM 1500 PHEV Status	Background
Partners FUEL ECONOMY & Mileage Accumulation (Real World)	• Charge Depletion: Accumulated Miles – **58,079** – **City**: **23** mpg; **Hwy**: **27** mpg • Charge Depletion / Charge Sustaining: Accumulated Miles – **26,942 (CD) / 47,004 (CS)** – **City**: **20** mpg; **Hwy**: **22** mpg • Charge Sustaining: Accumulated Miles – **133,195** – **City**: **17** mpg; **Hwy**: **20** mpg	• Data taken from **47** partner vehicles deployed throughout the United States • Partners Total Mileage : **265,131** November 2011 to March 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 INL Data November 2011 through March 2012

Relevance – Ram 1500 PHEV Program Results

Federal and Partners Real World Test Data – Phase II

Federal Test Procedures Results

Objective	Target	Status	Procedure	R/G/Y
RANGE	EAER 10	EAER 12 Achieved	California Exhaust Emission Standards And Test Procedures, as amended December 2, 2009	GREEN

Real World Results

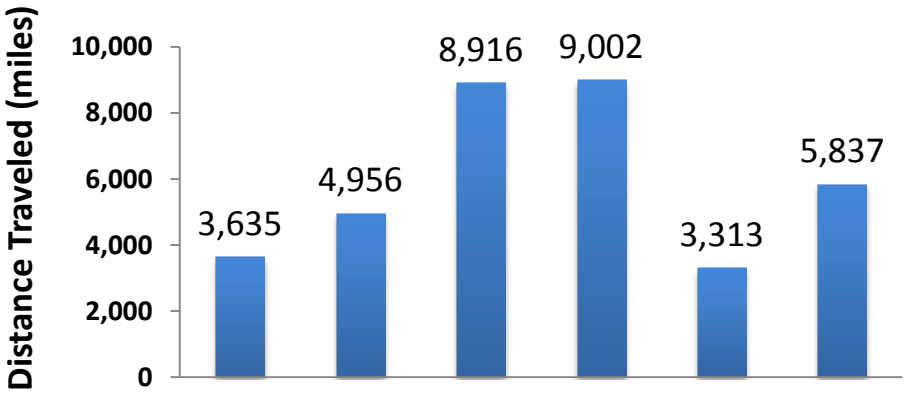
	RAM 1500 PHEV Status	Background
Partners FUEL ECONOMY & Mileage Accumulation (Real World)	• Charge Depletion: Accumulated Miles – **112,423** – **City**: **23** mpg; **Hwy**: **26** mpg • Charge Depletion / Charge Sustaining: Accumulated Miles – **11,977 (CD) / 22,515 (CS)** – **City**: **19** mpg; **Hwy**: **21** mpg • Charge Sustaining: Accumulated Miles – **52,855** – **City**: **16** mpg; **Hwy**: **19** mpg	• Data taken from **23** partner vehicles deployed throughout the United States • Partners Total Mileage : **84,419** November 2013 through Feb. 2014 • Vehicle fuel economy is based on customer usage and may not be representative of maximum potential fuel economy

- **Real world data was acquired from INL data November 2013 through March 2014**
- **Results for FE also remained consistent in all modes and combinations of City/Highway and Charge Depletion (CD) / Charge Sustaining (CS)**

Relevance – Ram 1500 PHEV Program Results

Deployment Phase I Partners Total Distance Traveled (miles)–Phase I

Phase I Average Accumulated Mileage per vehicle by Deployment Location
November 2011 through March 2012 in Miles



* Primarily used for grid communication testing

	SMUD	Detroit Edison	Duke Energy	Tristate	National Grid	Centerpoint Energy	EPRI	Argonne Nat. Lab
Avg. Time (hrs.) Charging/Event	2.3	1.9	2.8	2.9	2.3	3.3	*	*
Avg. Number of Charges/Veh./Day	0.91	2.4	0.53	1.3	0.56	1.4	*	*
# of Veh.	14	10	10	6	2	5	1	1
Service Months	5	5	5	5	5	5	5	5

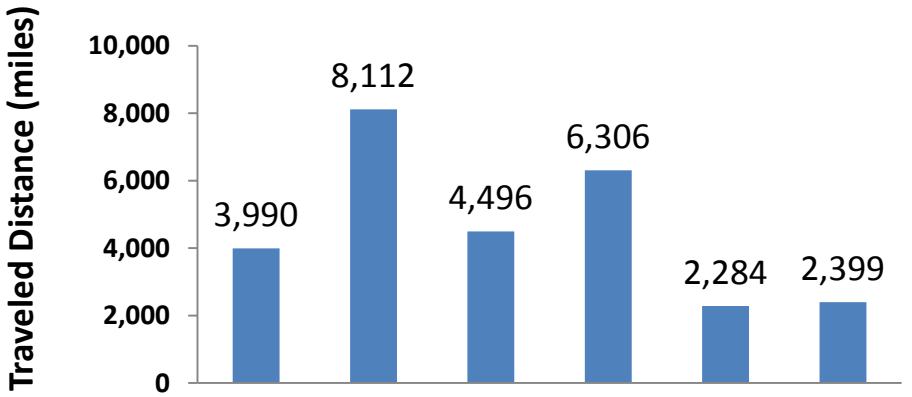
Total Deployed Fleet Average Mileage Accumulated per Vehicle	**5,943 miles per vehicle**
Charge Depletion Average Accumulated Miles per Vehicle	**1,236 miles (CD) per vehicle**
Charge Depletion / Charge Sustaining Average Accumulated Miles per Vehicle	**509.4 miles (CD) 1000 miles (CS) per vehicle**
Charge Sustaining Accumulated Miles per Vehicle	**2,833 miles (CS) per vehicle**

*INL reported period from fleet deployment date through November 2011 through March 2012

Relevance – Ram 1500 PHEV Program Results

Deployment Phase II Partners Total Distance Traveled (miles)–Phase II

Phase II Average Accumulated Mileage per vehicle by Deployment Location
November 2013 through March 2014 in Miles



* Primarily used for grid communication testing

	SMUD	Detroit Edison	Duke Energy	Tri-State	National Grid	Center Point Energy	EPRI	Argonne Nat. Lab
Avg. Time (hrs.) Charging/Event	1.5	2.3	1.4	1.2	1.0	2.9	*	*
Avg. Number of Charges/Veh./Day	0.80 ↓	0.80 ↓	1.1 ↑	1.1 ↓	1.0 ↑	1.4 ↓	*	*
# of Veh.	5	5	5	3	2	2	1	1
Service Months	5	5	5	5	5	5	5	3

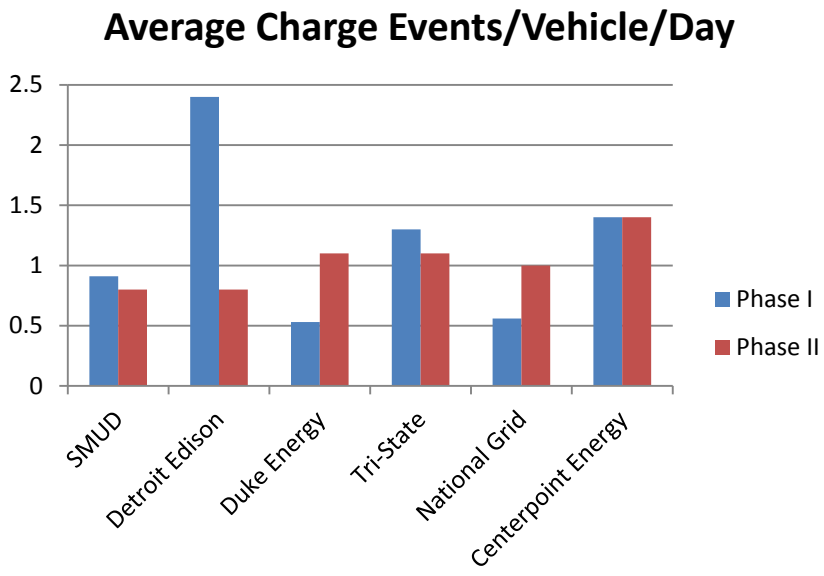
Total Deployed Fleet Average Mileage Accumulated per Vehicle	4,597 miles per vehicle
Charge Depletion Average Accumulated Miles per Vehicle	1,092 miles (CD) per vehicle
Charge Depletion / Charge Sustaining Accumulated Miles per Vehicle	521.7 miles (CD) 978.9 miles (CS) per vehicle
Charge Sustaining Accumulated Miles per Vehicle	12,299 miles (CS) per vehicle

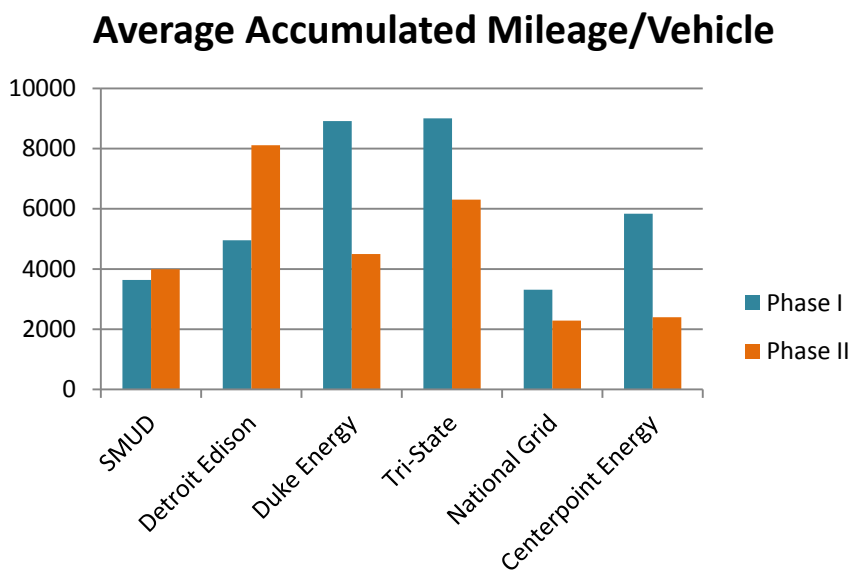
*INL reported period from fleet deployment date from November 2013 through March 2014

Relevance – Ram 1500 PHEV Program Results

Deployment Partners Distance Traveled & Charging Events – Phase I/II

Charging Events and Distance Travelled by Deployment Location



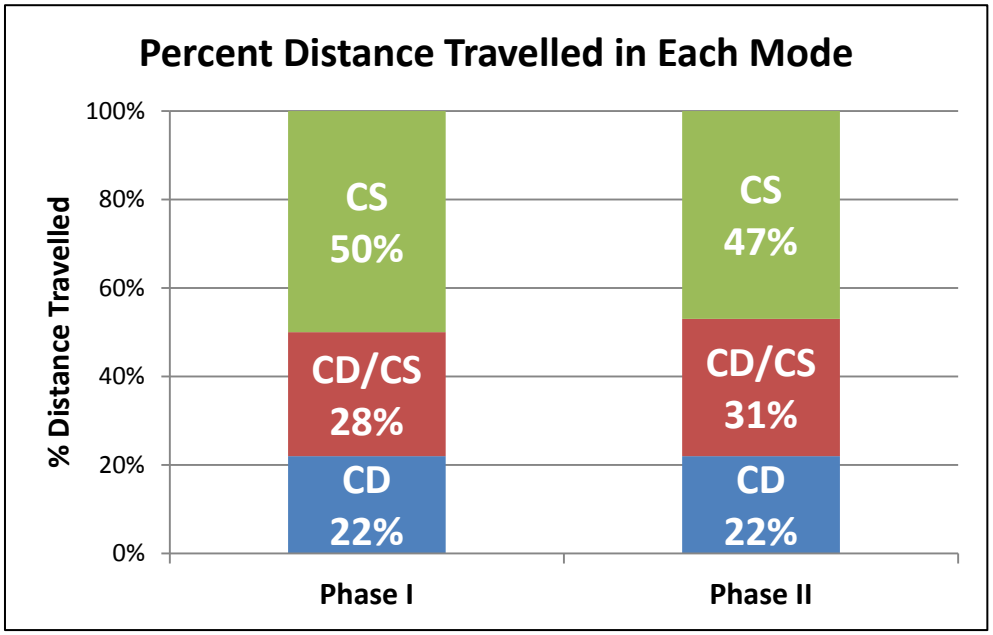


- The Phase I data spans November 2011 through March 2012
- The Phase II data spans November 2013 through March 2014

Relevance – Ram 1500 PHEV Program Results

Analysis & Learning: Lessons Learned

Phase I/II Percent Distance Travelled in Charge Depleting (CD), Charge Depleting/Charge Sustaining (CD/CS) and Charge Sustaining (CS) Modes



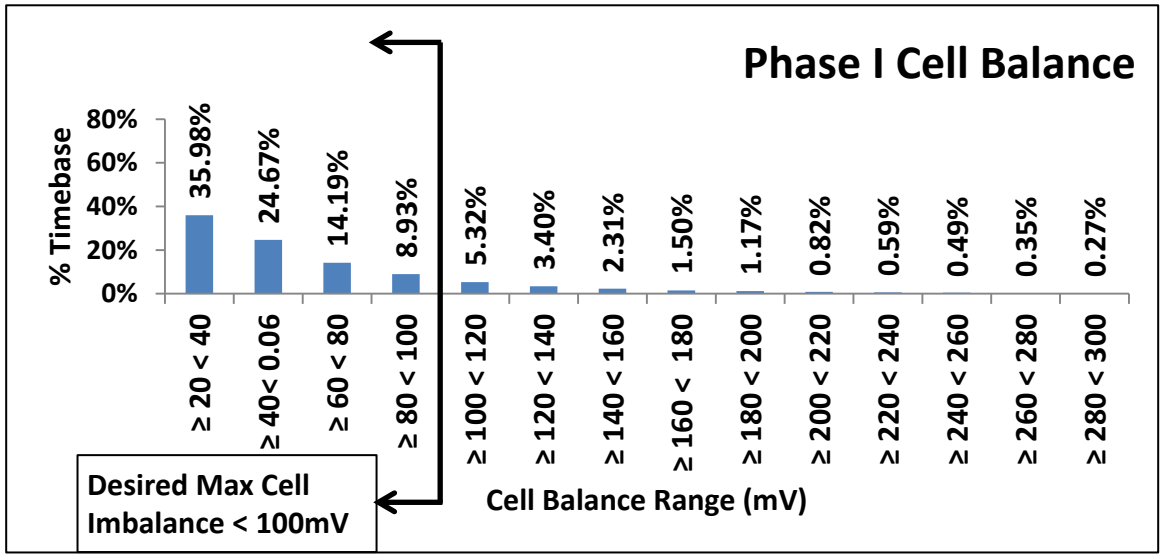
- The charge depletion mode (CD) did not change
- The mixed mode (CD/CS) increased 3 percentage points
- The charge sustaining mode (CS) decreased 3 percentage points
- Drivers / customers were adequately trained to achieve optimal fuel economy
- Reduced number of trips between charge cycles

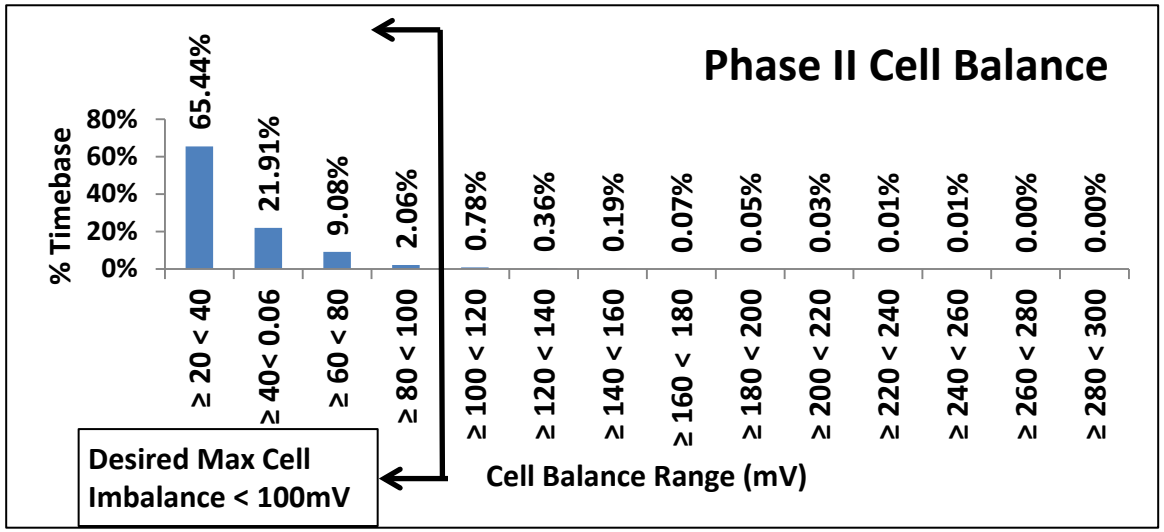
INL reporting periods: Phase I Nov 2011 – Mar 2012; Phase II Nov 2013 – Mar2014

Relevance – Ram 1500 PHEV Program Results

Analysis & Learning: Lessons Learned

Phase I and Phase II Cell Balance Comparison





Data source details:

- Phase I data from November 2011 through March 2012
- Phase II data from November 2013 through March 2014
- The data includes the twenty two VINs deployed in both Phase I and Phase II

Data analysis details:

- Desired maximum cell imbalance is 100mV
- In Phase I, 84 percentage points fell below the 100 mV limit
- In Phase II, 98 percentage points fell below the 100 mV limit

Key takeaway:

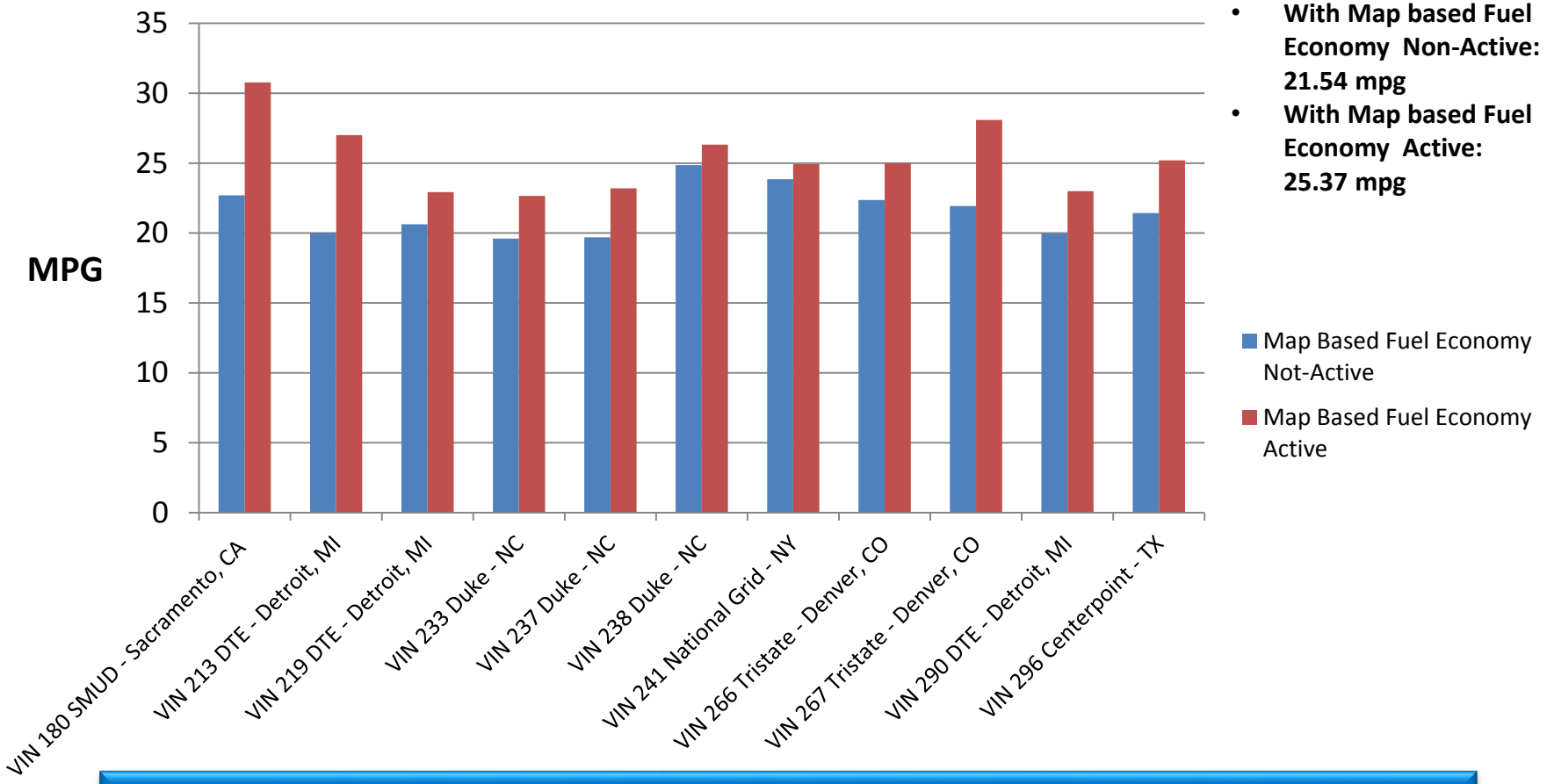
The desired cell imbalance improvement has been achieved

Relevance – Ram 1500 PHEV Program Results

Analysis & Learning: Lessons Learned – Phase II

Map Based Fuel Economy Active Vs. Non Active Fuel Economy (MPG) Comparison)

(Data from November 1, 2013 through March 31, 2014)



Overall MPG

- **With Map based Fuel Economy Non-Active: 21.54 mpg**
- **With Map based Fuel Economy Active: 25.37 mpg**

Overall MPG with Map Based Fuel Economy Active – 25.37 (17.8% Increase)

Technical Accomplishments – Phase II

Vehicle Build & Test Accomplishments

- Completed cell and battery pack bench testing
- Completed the vehicle retrofit and battery upgrade process for vehicles to be used for Chrysler Group LLC internal testing
- Successfully demonstrated Reverse Power Flow and A.C Power Generation at the launch of the Smart Grid Interoperability Center at Argonne National Laboratory in July 17, 2013

- Completed Validation Trip from Las Vegas to Denver September 23rd through October 1st of 2013
  - Performed real world validation of test cell work (hot, cold, altitude, grades, towing)
  - Verified consistent SOC reporting with the new battery pack performance

Vehicle Deployment Accomplishments

- Completed fuel economy test at Chrysler Proving Ground in March 2014 on the Ram 1500 PHEV to establish EAER-10
- Completed vehicle deployment

Technical Accomplishments – Phase II

Smart Charging

- Completed lab facilities at Chrysler Group LLC (web back-up and cellular service installed) and validated the Smart Charging feature
- Updated communication gateways with appropriate authentication for the utility servers
- The partner sites have completed EVSE Communication Modules installation and network equipment
- Updated deployed vehicles with improved software in March 2014
  - Resolved issues with Multi-Protocol Router signals at 2-7 MHz
  - Separated process connection of processing Web interface and MPR Utility data
- These completed tasks enabled the monitoring and evaluation of the Smart Charging methods and user interface structure

Reverse Power Flow

- Parameters used for Reverse Power Flow are:
  - Selectable power levels of 2.4 kw (37%), 3.3 kw (50%), 4.9 kw (75%) or 6.6 kw (100%) of HV battery energy
  - Calculated time duration based on the HV battery State of Charge
  - Reverse Power Flow event will cease when the minimum battery State of Charge of 22% is reached
- Collected usage data from partners for reverse power flow

DC Charging

- Project extended for completion of development DC charging with the following parameters:
  - Level 1 at 370V DC/ ≤ 30 amp/ ≤ 11 kw
  - Level 2 at 370V DC/ ≤ 74 amp/ ≤ 27 kw
- Completed schematics and flow diagrams for documentation and analysis
- Complete build of specialized hardware May 2014
- Argonne National Labs will create validated software

Collaborations & Partnerships – Deployment

Idaho National Laboratory – Phase II Real World Data: Cumulative from November 2013 through March 2014

Advanced Vehicle Testing Activity — Idaho National Laboratory

Chrysler RAM PHEV Fleet - Phase 2

Center Point Energy, TX

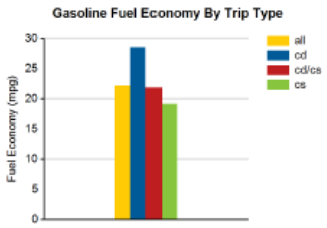
Number of vehicles: 2
Reporting period: November 2013 through March 2014
Date range of data received: 12/17/2013 to 3/28/2014
Number of vehicle days driven: 86

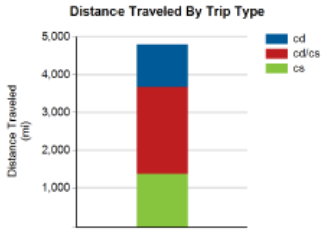
All Trips Combined	
Overall gasoline fuel economy (mpg)	22
Overall AC electrical energy consumption (AC Wh/mi)[1]	127
Overall DC electrical energy consumption (DC Wh/mi)[2]	85
Overall DC electrical energy captured from regenerative braking (DC Wh/mi)	37
Total number of trips	281
Total distance traveled (mi)	4,797

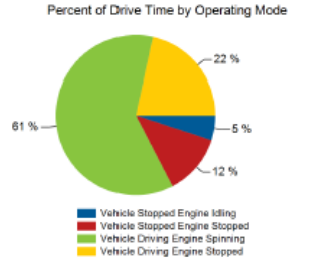
Trips in Charge Depleting (CD) mode[3]		
Gasoline fuel economy (mpg)		29
DC electrical energy consumption (DC Wh/mi)[4]		222
Number of trips		120
Percent of trips city | highway	96% |	3%
Distance traveled (mi)		1,128
Percent of total distance traveled		24%

Trips in both Charge Depleting & Charge Sustaining (CD/CS) modes[5]		
Gasoline fuel economy (mpg)		22
DC electrical energy consumption (DC Wh/mi)[6]		71
Number of trips		83
Percent of trips city | highway	83% |	16%
Distance traveled CD | CS (mi)	806 |	1,488
Percent of total distance traveled CD | CS	17% |	31%

Trips in Charge Sustaining (CS) mode[7]		
Gasoline fuel economy (mpg)		19
Number of trips		78
Percent of trips city | highway	91% |	8%
Distance traveled (mi)		1,375
Percent of total distance traveled		29%







Ram 1500 – Highlights

- Overall fuel economy = **19**
- Charge depleting FE = **23**
- Mixed CD / CS FE = **20**
- Charge Sustaining FE = **17**
- Charge Events = **0.91** (per day per vehicle when driven)
- Average charge event = **1.71** hours

- Total number of trips (Key cycles) = 9,014
- Total distance traveled = **112,423** miles

- Vehicle stopped / engine stopped = **12** %
- Vehicle driving / engine stopped = **22** %

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

Collaborations & Partnerships – Development

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Ram 1500 PHEV Development and Content Partners – Phase II

MICHIGAN DEARBORN	• Studied the State of Health Estimation of Lithium-Ion Polymer Batteries for Plug-in Hybrid Electric Vehicles – SoC Independent Method Using Multi-Scale Kalman Filtering • Studied the battery modeling using data-driven bias-correction approach for electric vehicles application • Studied the efficiency optimization and Loss Minimization Based Charging Strategy Research for Lithium-ion Battery • Completed dynamometer testing of EV motors for Chrysler's EV projects • Completed manufacturing of back support and tombstone for dynamometer testing
MICHIGAN STATE	• Completed developing an online implementation of the iterative learning predictive algorithm to estimate the desired power for a hybrid powertrain, validating it through online HIL simulations, and optimizing the parameters of the proposed iterative predictive algorithm • The above results have been summarized into a paper, entitled "Adaptive Recursive Prediction of the Desired Torque for a Hybrid Powertrain," and it has been submitted to IEEE Transaction on Vehicular Technology in Q4, 2013.
EPRI ELECTRIC POWER RESEARCH INSTITUTE	• Provided Multi-Protocol Router and EVSE Com Modules for redeployed vehicles and development of Smart Grid
SMUD SACRAMENTO MUNICIPAL UTILITY DISTRICT The Power To Do More.	• Finalizing data collection, analysis and reporting for vehicle to grid
UCDAVIS UNIVERSITY OF CALIFORNIA	• Completed collecting and analyzing information from driver and fleet manager interviews and from data recording instrumentation onboard the PHEVs to maximize benefits of PHEVs

Collaborations & Partnerships – Deployment

Phase II Deployment Partners for RAM 1500 PHEV Project

Partner	# of Redeployed Vehicles	Vehicle Status	Features Included			Feature Set Status
			Smart Charging	Reverse Power Flow	Map Based Fuel	
SMUD	5	In Service	Yes		Yes	Map Based Fuel Economy: • Phase II will use Phase I's implementation. Hardware installation completed during vehicle preparation Reverse Power Flow: • Reverse Power Flow active during Phase II to re-validate the battery pack Smart Charging: • Smart Charging active during Phase II. MPRs were installed during vehicle preparation • 24 PHEVs with Smart Charging feature • 12 PHEVs with Map-Based Fuel Economy feature • 10 PHEVs with Reverse Power Flow feature
			Yes			
			Yes			
			Yes	Yes		
			Yes	Yes		
Detroit Edison	5	In Service	Yes		Yes	
			Yes	Yes		
			Yes		Yes	
			Yes		Yes	
			Yes	Yes		
Duke Energy	5	In Service	Yes		Yes	
			Yes		Yes	
			Yes		Yes	
			Yes	Yes		
			Yes	Yes		
Tri-State	3	In Service	Yes	Yes		
			Yes		Yes	
			Yes		Yes	
National Grid	2	In Service	Yes		Yes	
			Yes		Yes	
CenterPoint Energy	2	In Service	Yes	Yes		
			Yes		Yes	
EPRI	1	In Service	Yes	Yes		
ANL	1	In Service	Yes	Yes		
Totals	**24**		**24**	**10**	**12**	

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Future Work – Phase II of Project

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PHEV Real-World Validation

- Monitor the following functionalities during Phase 2 of the project:
  - Reverse Power Flow – Multiple activations (Level 2, 240V service) per week
  - Smart Charging – Multiple charge events with communication with grid for price and demand response load control data for fastest, cheapest or optimized (time and price) charge event
  - Scheduled Charging – Delayed charge event to avoid grid/home peak periods
  - DC Charging – Reduction of onboard vehicle charger size/weight as well as fast charging
- Continue capturing fleet data to validate calibration and controls.
- Apply the learning of the advanced technologies to future programs to attain greenhouse gas reduction benefits and zero emissions vehicle compliance.

Summary – Key Objectives

Continuation of the project will enable Chrysler Group LLC to achieve the remaining project goals during Phase II

	Original Project Goals	Phase II (In Process)	Comments
System Design Objectives	Producing controllable traction forces under different battery conditions	✓	Continue to monitor performance during Phase II
	Displacing fuel efficiently in all driving scenarios	✓	Continue to monitor performance during Phase II
	Achieving efficient charge-sustaining operations	✓	Continue to monitor performance during Phase II
	Verify plug-in charging mode performance	✓	Continue to monitor performance during Phase II
	Verify AC power generation mode	✓	Continue to monitor performance during Phase II
	Prove that the system solution represents optimal cost-benefit trade-offs	✓	Continue to monitor performance during Phase II
Vehicle Verification	Continue to monitor vehicle functional objectives	✓	Continue to monitor performance during Phase II
	Demonstrate drivability and safety	✓	Continue to monitor performance during Phase II
Fleet Demonstration Objectives	Profile vehicle usage and customer profiles	✓	Continue to monitor performance during Phase II
	Prove product viability in “real-world” conditions	✓	Continue to monitor performance during Phase II
	Rate based charge control interface	✓	Smart Charging and Scheduled Charging – Extensive testing is being conducted during Phase II of the project
	Bi-directional (communication and power) charger interface	✓	Reverse Power Flow (RPF) – Extensive testing is being conducted during Phase II of the project
	Confirm that PHEV technology is viable for mass production	✓	Continue to monitor performance during Phase II
	Optimize fuel economy	✓	Continue to monitor performance during Phase II
	Continued Data Analysis and Lessons Learned	On-Going	Continue to monitor performance during Phase II

Summary

Phase II:

- Created Core Competency “Green” Technology jobs and have a plan in place to sustain them toward future development of electrification programs
- Completed hiring of critical resources with specialty in electrification technology as part of the DOE funded project
- Currently leveraging the same resources and competency to develop a future electrified programs that will be in production. Electrified PT within the Chrysler Group is the Center of Competency for electrification for Fiat Chrysler Automobiles
- The associated learning from the project helped develop and launch the F500 BEV vehicle
- Completed the upgraded battery and retrofitted vehicle validation testing requirements
- Successfully demonstrated Reverse Power Flow and Smart Charging
- Successfully demonstrated the PHEV All Electric Equivalent drive cycle.
- Demonstrated capability to meet ATPZEV emission requirements in a pick-up truck application
- Completed Deployment of the RAM 1500 vehicles to demonstration partners
- Continually working with demonstration partners in Phase II of the RAM 1500 PHEV DOE project to collect data

Technical Back-Up Slides

Relevance Back-up – Program Results

Vehicle Performance:
Fuel Economy by Demonstration Partner during Phase I/II

Location	FE CD City	FE CD Highway	FE CD/CS City	FE CD/CS Highway	FE CS City	FE CS Highway	FE Avg. (For Period)
SMUD	22/25	27/27	20/18	21/22	17/15	20/19	20/19
Detroit Edison	22/20	26/23	20/19	21/20	17/16	18/18	20/18
Duke Energy	24/22	26/26	20/19	22/23	17/17	20/20	20/20
Tri-State	23/24	27/26	22/21	22/22	18/17	20/20	22/21
National Grid	16/21	25/25	18/21	18/22	16/16	18/18	17/18
CenterPoint Energy	24/28	28/32	21/21	24/25	15/18	20/22	21/22

Source: Idaho National Labs Report
Phase I data from November 2011 through March 2012
Phase II data from November 2013 through March 2014

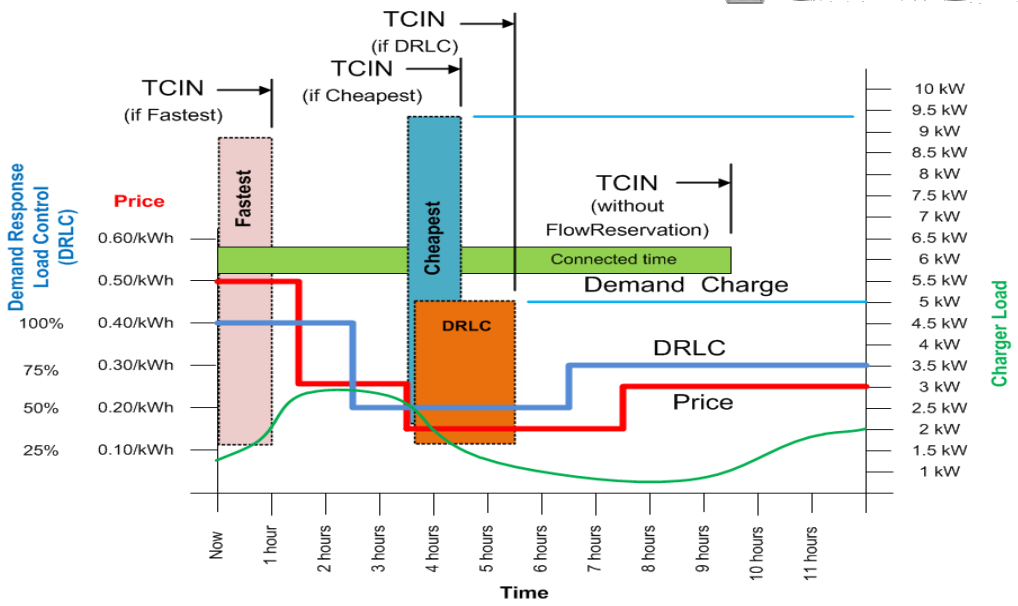
CD = Charge Depleting
CS = Charge Sustaining

Phase I FE/Phase II FE

Smart Charging Objectives – offer choices

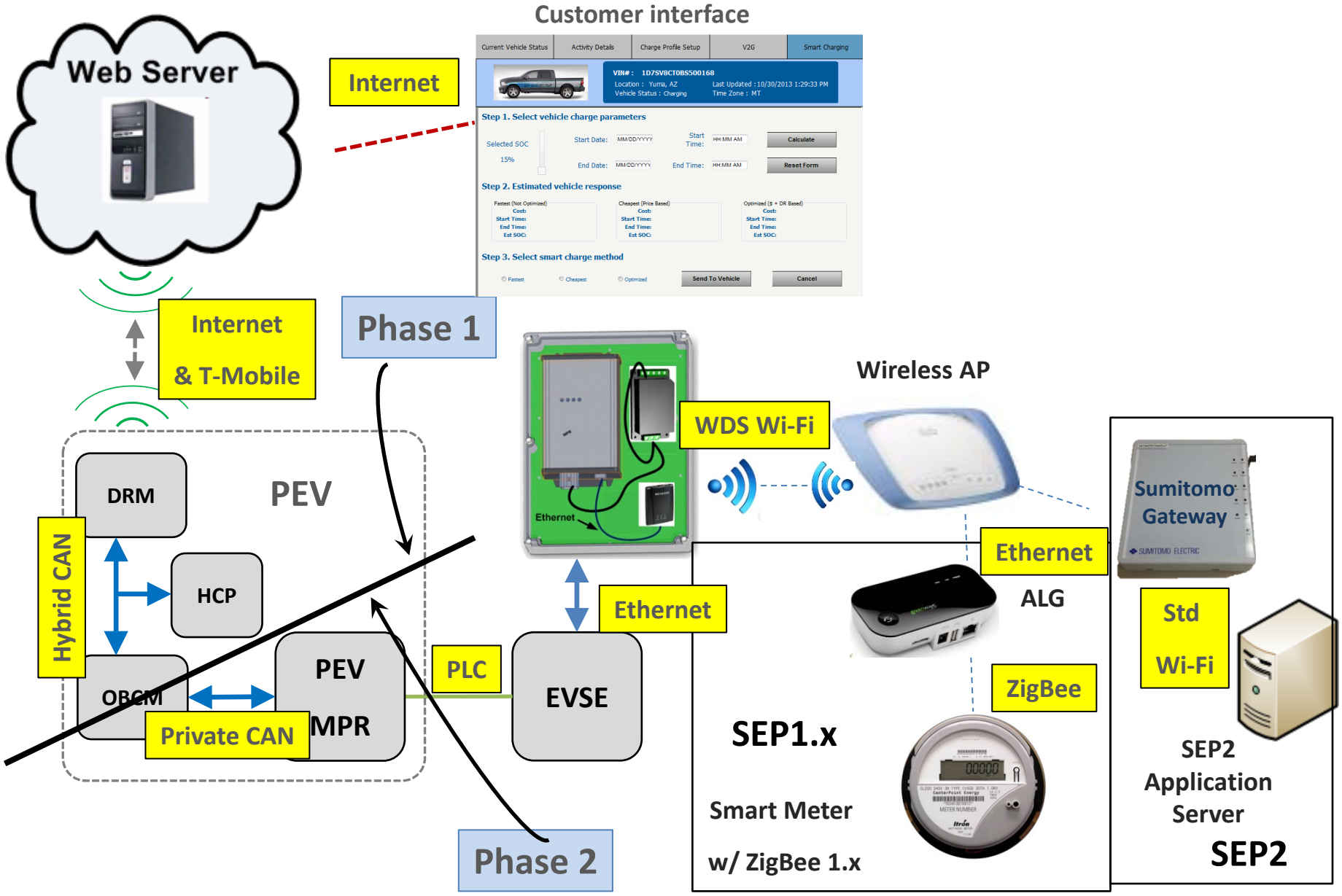
DRLC – Demand Response Load Control – Management of charging load based on peak power/cost restrictions at charging site

TCIN – Time Charge Is Needed – User required end of charge event to drive vehicle



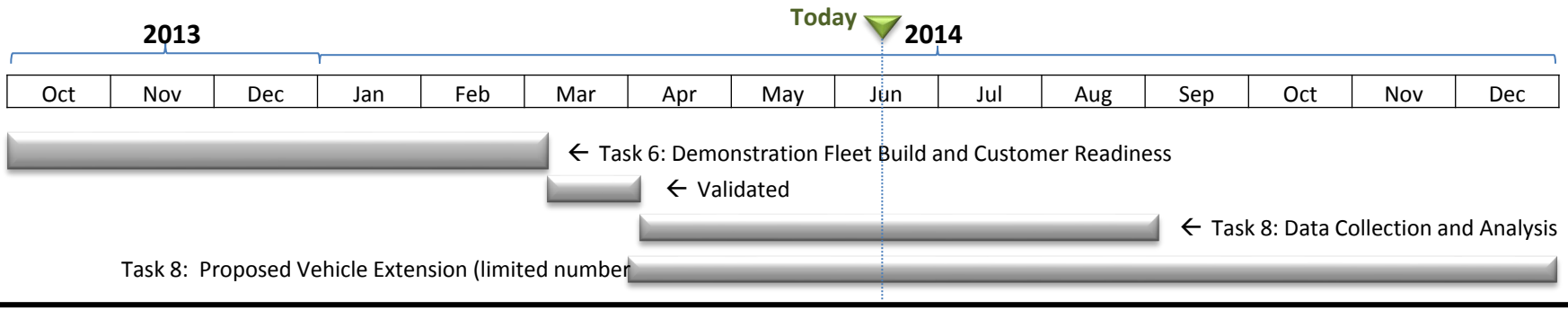
- **The vehicle will automatically download Price and Demand Response Load Control tables from the utility when plugged into a Smart Charging-enabled EVSE.**
- **The user specifies the desired charge start time, end time and final state-of-charge.**
- **The vehicle computes three charge profiles from the data supplied:**
  Fastest: The vehicle charges in the shortest possible time, regardless of cost.
  Cheapest: The vehicle delays charging until it can charge for the lowest possible price within the specified time period.
  Optimized: The vehicle may delay charging and/or adjust the rate of charging to find the best possible balance between the time required to charge and the cost of charging to the desired SOC.
- **The vehicle presents the projected price, start time, and end time for each charge profile via the interactive portal, allowing the user to select their preferred charging mode.**

Smart Charging Communication Path



Technical Back-Up Slides – Functionality

Rate Based Charge Control Interface – Smart Charging



Phase II: Accomplishments

Chrysler Validation

- Completed lab (Web back up and T-Mobile installed). Validated Charging, Power Panel, Scheduled Charge & RPF, started Smart Charging
- Resolved issues with Vehicle MPRs, Sumitomo Gateway (had com but not authentication), G2H ALG and Utility server
- Resolved issues with no utility packets in State C (charging) but received in State B (connected). Captured PLC signal with spectrum analyzer and increased 1.5 VPP signal to 20VPP to override noise at 2-7 MHz level.
    - Short term solution is to "go to State C but not charge for 5 min". Won't solve DRLC Ack, FlowReservation or DER.
    - Longer term, EPRI is working Qualcomm for PID updates to not transmit in this range

Phase II: Site Updates and Objectives

Site Updates:

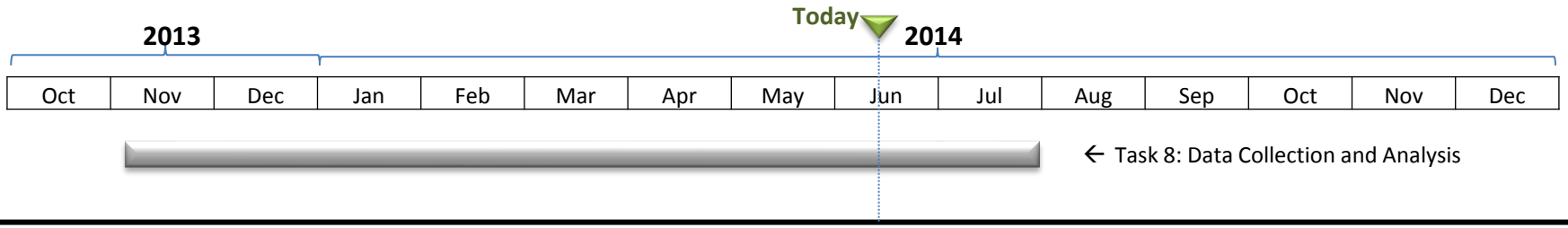
- EVSE Com modules installed
- AMI Net meters being installed for RPF
- Either ALG or Gateway installed and functioning.
- Desire limited extension at some sites (RPF vehicles)
    - Allows up to 8 months for Task 8, instead of 4
    - Helps justify time and expense for meter upgrades, com network updates, transformer installations, etc.

Deployment

- Updated DTE vehicles 2rd week in April
- Updated remainder nationwide 3rd week in April

Technical Back-Up Slides – Functionality

Bi-Directional (communication and power) Charger Interface – Reverse Power Flow



Phase II: Technical Parameters

Level 2 (Required)

- 240V AC
- Selectable power levels of 2.4, 3.3, 4.9 or 6.6 kw HV battery energy
- Calculated time duration based on current HV battery State of Charge
- Reverse Power Flow event will cease when the minimum battery State of Charge of 22% is reached

Phase II: Accomplishments

Documentation and analyses

- Collected data and analyzed usage on Power Panel and RPF.

Validation

- Validated RPF with Smart Charging software.

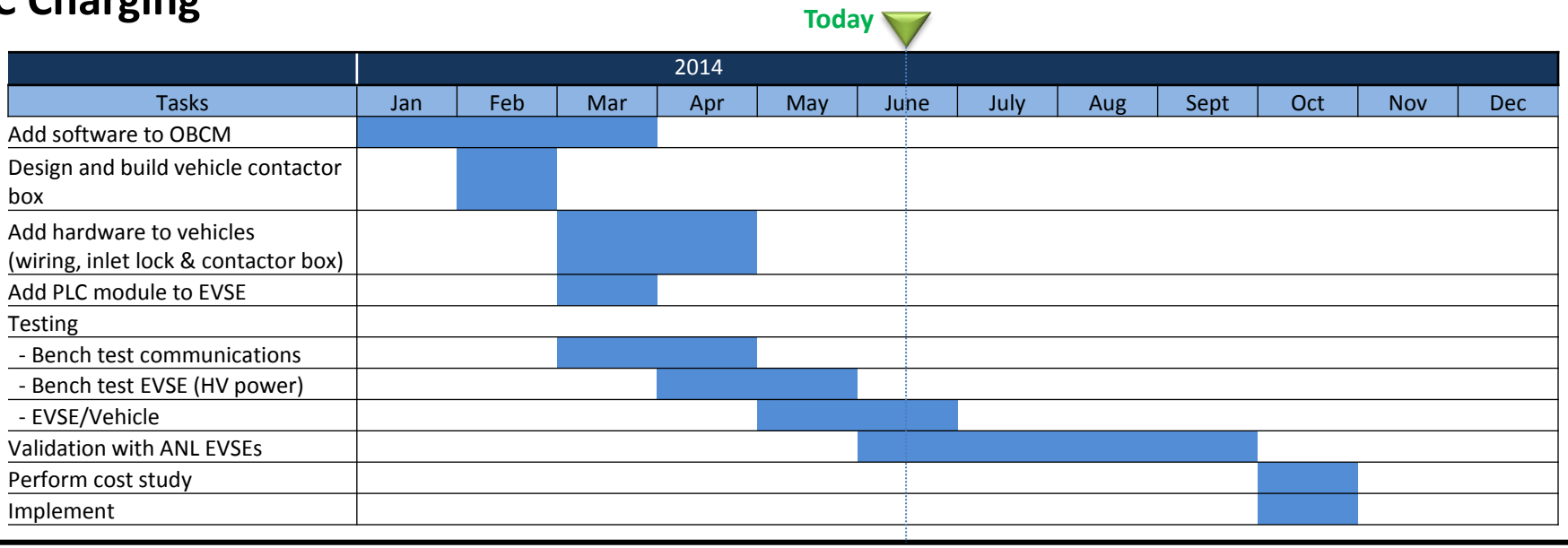
Phase II: Remaining Objectives

Deployment

- Add additional SEP2 Function set to demonstrate advanced features into the MPR's. This includes a portion of the DER Function set for RPF/charge cycles. This demonstrates how the PEV can interface with Solar and other sources in the home to balance loads.

Technical Back-Up Slides – Functionality

DC Charging



Phase II: Technical Parameters

DC Level 1

- Voltage 370V DC
- Rated Current ≤ 30 amp
- Rated Power ≤ 11 kw

DC Level 2

- Voltage 370V DC
- Rated Current ≤ 27 amp
- Rated Power ≤ 74 kw

Phase II: Accomplishments

Documentation and analyses

- Schematics are complete
- Flow Diagrams complete

Build

- Completed contactor box
- Mounted Combo Inlet

Validation

- ANL s/w validated on two competitive vehicles

Phase II: Remaining Objectives

Documentation and analyses

- Complete low level & application level software.
- Finish vehicle wiring updates

Validation

- Bench test, then with DC EVSE

Deployment

- Update the Argonne National Laboratory vehicle