U.S. Department of Energy Vehicle Technologies Program

On-Road Results from Charging Infrastructure and Grid Connected Vehicle Fleets

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U.S. DEPARTMENT OF ENERGY

Outline

- Intro to INL and AVTA

- Charging Infrastructure Demonstrations Results
  - ChargePoint America
  - The EV Project

- Plug-in Electric Vehicle Demonstrations Results
  - Chevrolet Volt E-REV
  - Ford Escape PHEV
  - Chrysler Ram PHEV
  - Chrysler Town & Country Touring PHEV

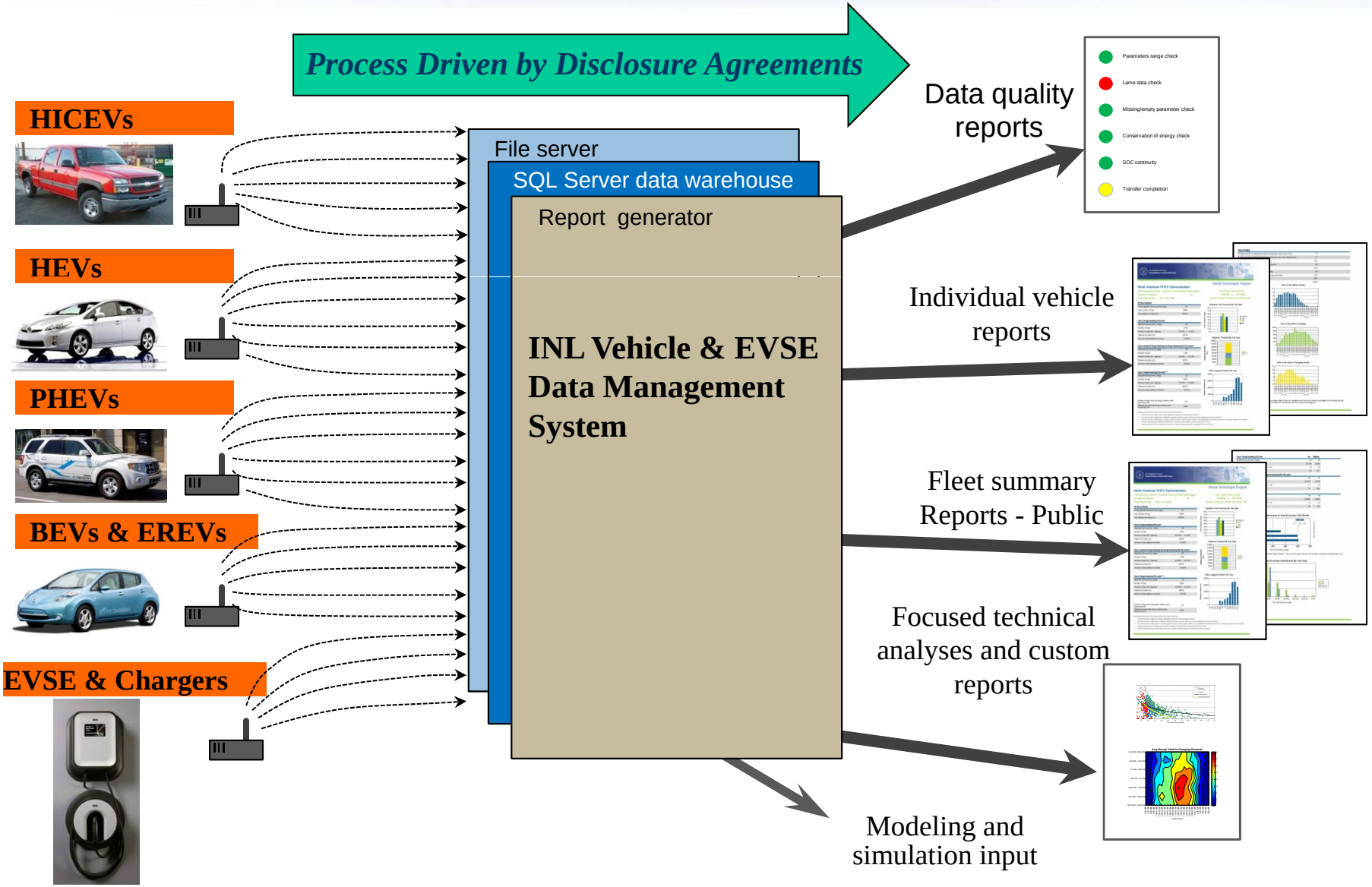
Idaho National Laboratory

- U.S. Department of Energy (DOE) Federal laboratory
- 890 square mile site with 4,000 staff
- Support DOE's strategic goal:
  - Increase U.S. energy security and reduce the nation's dependence on foreign oil
- Multi-program DOE laboratory
  - Nuclear Energy
  - Fossil, Biomass, Wind, Geothermal and Hydropower Energy
  - Advanced Vehicles and Battery Development
  - Homeland Security and Cyber Security

Advanced Vehicle Testing Activity (AVTA)

- Part of DOE's Vehicle Technologies Program
  - INL conducts the light-duty vehicle portion of the AVTA per DOE guidance
  - Many testing activities conducted with ECOtality North America
  - Support also provided to DOE Clean Cities
- The AVTA goal - Petroleum reduction and energy security
  - Conduct testing and evaluation of advanced vehicles and fueling infrastructure
  - Provide benchmark testing results to industry, government, and the general public

INL Vehicle/EVSE Data Management Process



Data Collection, Security and Protection

- All vehicle, EVSE, and personal raw data is legally protected by NDAs (Non-Disclosure Agreements) or CRADAs (Cooperative Research and Development Agreements)
  - Limitations on how proprietary and personally identifiable information can be stored and distributed
  - Raw data, in both electronic and printed formats, is not shared with DOE in order to avoid exposure to FOIA
  - Vehicle and EVSE data collection would not occur unless testing partners trust INL to strictly adhere to NDAs and CRADAs
  - Raw data cannot be legally distributed by INL

CHARGING INFRASTRUCTURE DEMONSTRATIONS

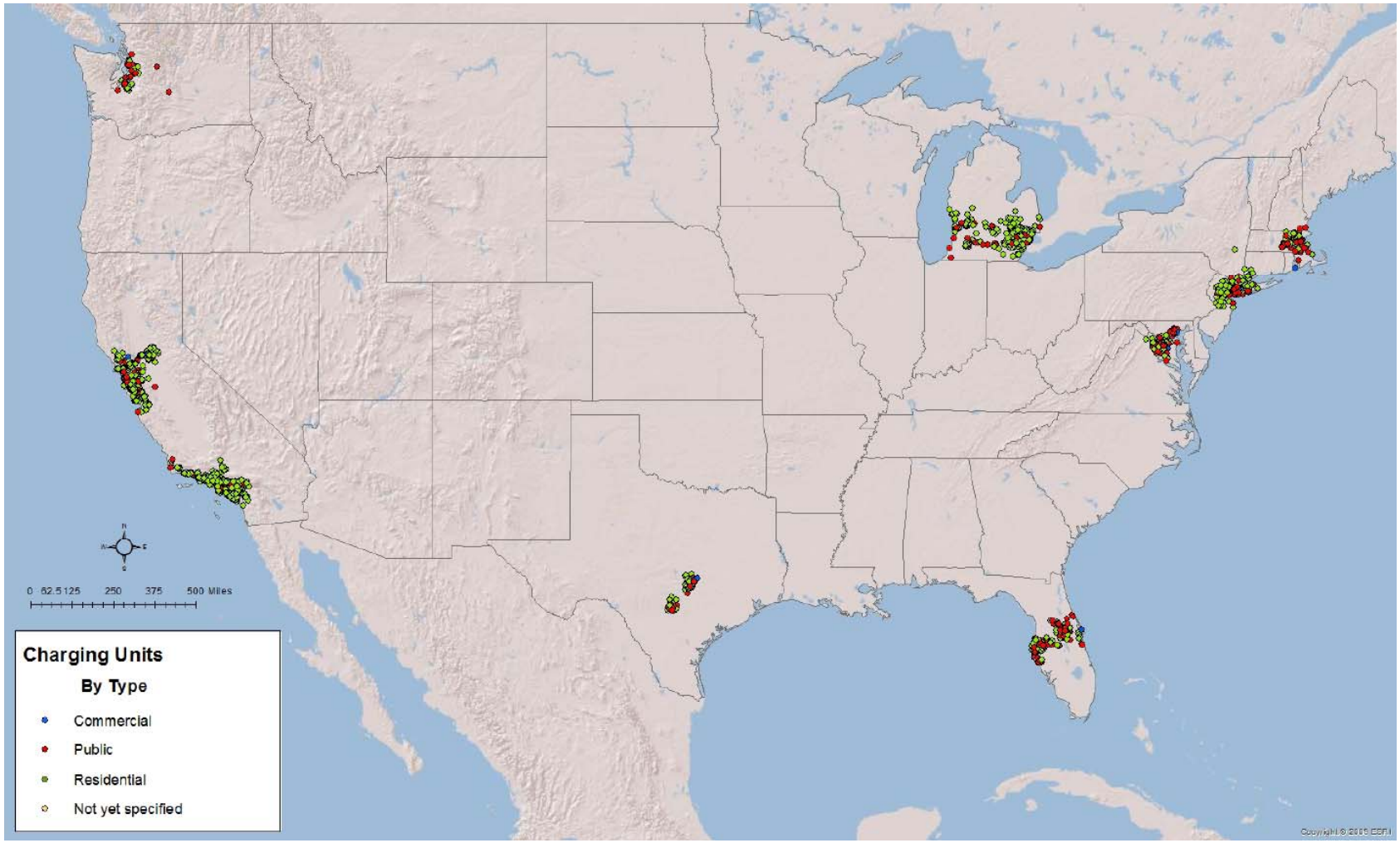
ChargePoint America Infrastructure Demo

- 3,900 residential and public electric vehicle supply equipment (EVSE)
- INL data collection from EVSE started May 2011
- Objective is to understand customer usage of residential and public EVSE

AC level 2 residential and commercial EVSE

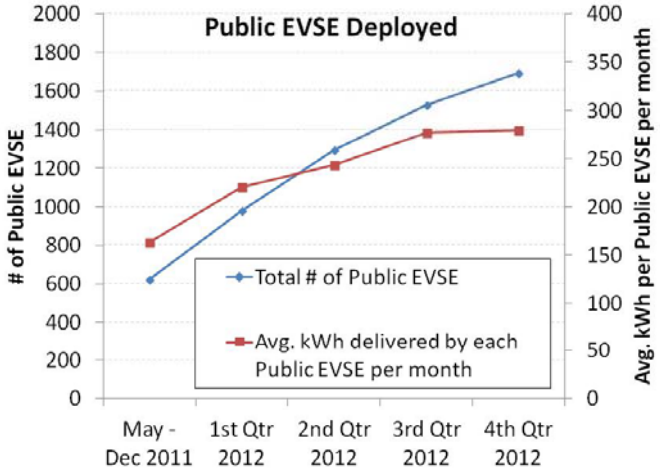
- 240 VAC single phase, 7.2 kW
- Single J1772 connector per EVSE
- Networked with data collection
- RFID authentication
- Charge scheduling via website

ChargePoint America Locations (Dec 2012)

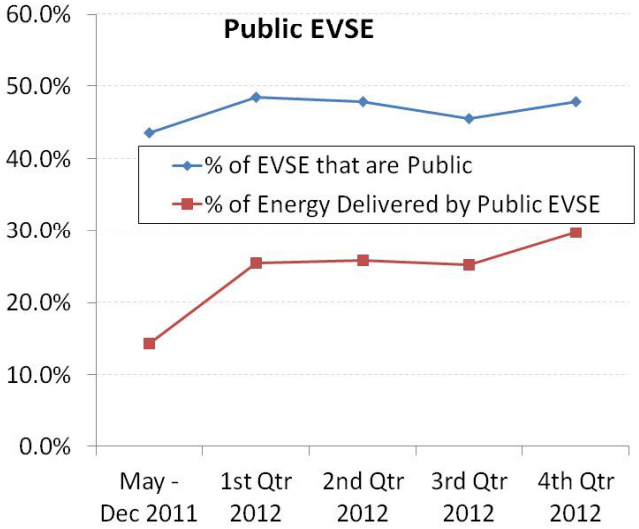


ChargePoint America Results

- Steady growth in EVSE deployment over the past two years
- Public EVSE
  - Utilization increasing over time
  - Increasing avg. energy delivered per EVSE
  - Account for nearly 50% of EVSE installed
  - Energy delivered is roughly 25%

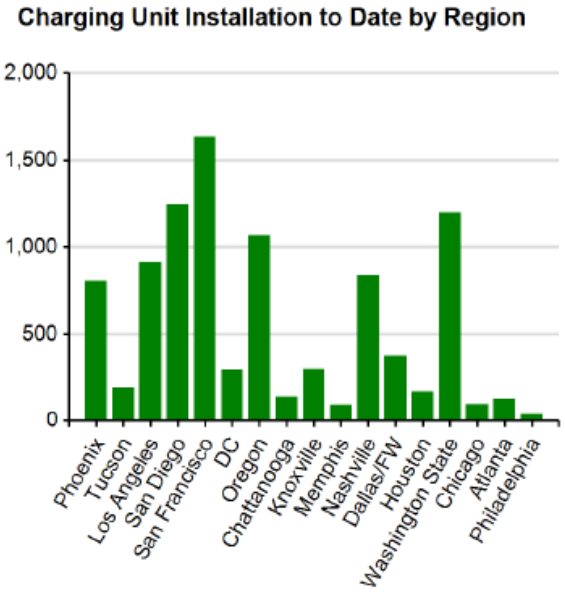


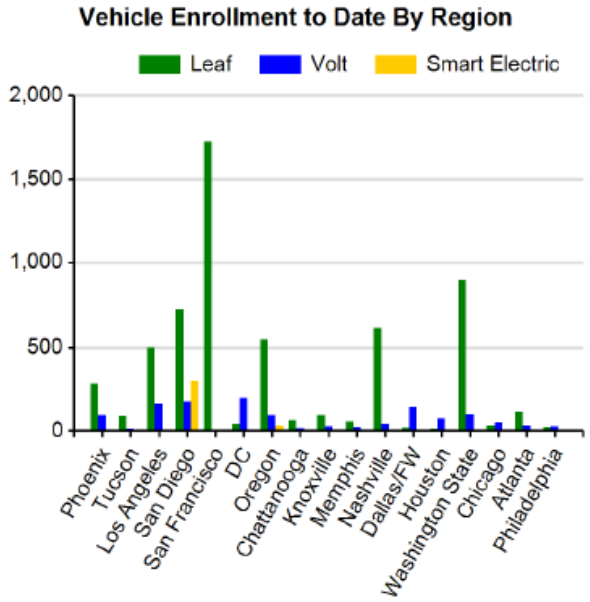
Charging Unit Usage - By Type	Residential	Private Commercial	Public	Not Specified	Total
Number of charging units[1]	1,687	155	1,693	6	3,541
Number of charging events[2]	137,188	5,825	58,928	157	202,098
Electricity consumed (AC MWh)	997.98	48.25	422.07	0.98	1,469.27
Percent of time with a vehicle connected	47%	24%	9%	24%	28%
Percent of time with a vehicle drawing power	9%	5%	4%	3%	6%



The EV Project Infrastructure Demo

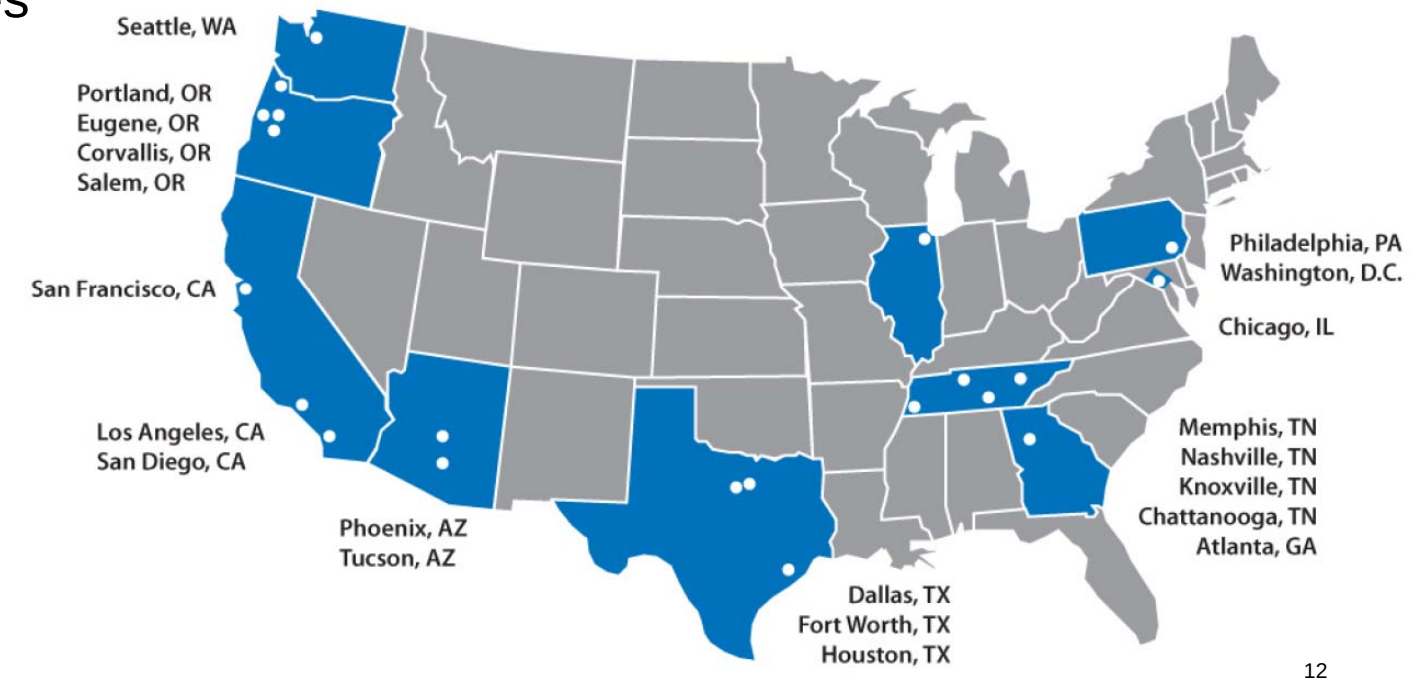
- >9,500 Blink residential and public EVSE and DC Fast Chargers
- >7,300 privately owned Nissan LEAF and Chevrolet Volts and Car2Go car share Smart Electric
- 14,500 AC MWh delivered
- 61,200,000 miles traveled
- ECOtality N.A. (Project Manager) is partially funding the EV Project
- INL vehicle and EVSE data collection started Jan 2011





The EV Project

- Objective:
  - Build mature EV charging infrastructure in multiple regions and study:
    - Infrastructure deployment process
    - Customer driving and charging behavior
    - Impact on electric grid
  - Create a learning laboratory to understand the infrastructure deployment requirements for the first 1 million grid-connected electric drive vehicles



Blink EVSE Specifications*

AC level 2 residential and commercial EVSE

- 240 VAC single phase, 7.2 kW
- Single J1772 connector per EVSE
- Networked with data collection
- Touch screen and website charge scheduling
- RFID authentication

DC level 2 commercial fast charger

- 480 VAC 3 phase, 60 kW
- Two CHAdeMo connectors per charger
- Networked with data collection
- Touch screen user interface, RFID authentication

* http://www.blinknetwork.com/brochures/l2-pedestal-charger/index.html
http://www.blinknetwork.com/chargers-residential.html
http://www.blinknetwork.com/brochures/dc-fast-charger/index.html

The EV Project – Vehicle Specifications

Nissan LEAF™

- Battery electric vehicle
- 24 kWh passively-cooled Li-ion battery pack
- AC level 2 (3.3 kW) charge rate via J1772 connector
- DC level 2 (50 kW) charge rate via CHAdeMO connector
- Data acquisition via vehicle telematics

http://www.nissanusa.com/leaf-electric-car/key-features

Chevrolet Volt

- All-electric capable EREV
- 1.4L 84 hp engine
- 16 kWh liquid-cooled Li-ion battery pack
- AC level 2 (3.3 kW) charge rate via J1772 connector
- Data acquisition via vehicle telematics (OnStar)

http://gm-volt.com/full-specifications/

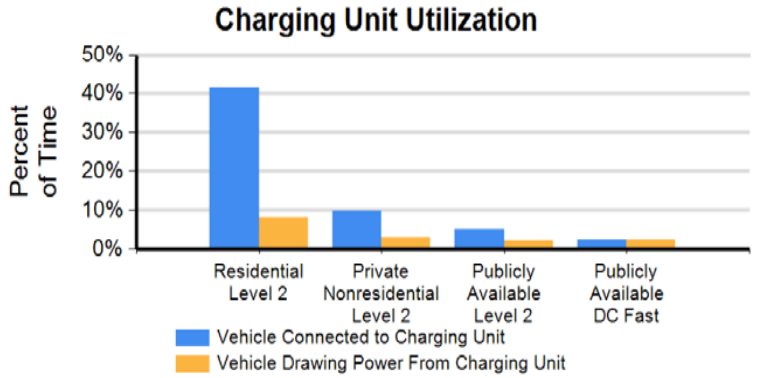
Smart Electric

- Battery electric vehicle
- 17.6 kWh Li-Ion pack
- AC level 2 (3.3 kW) charge rate via J1772 connector
- Data acquisition via vehicle telematics
- Operated as part of Car2Go car share

http://www.smartusa.com/models/electric-drive/overview.aspx

The EV Project - 4th Qtr 2012 Results

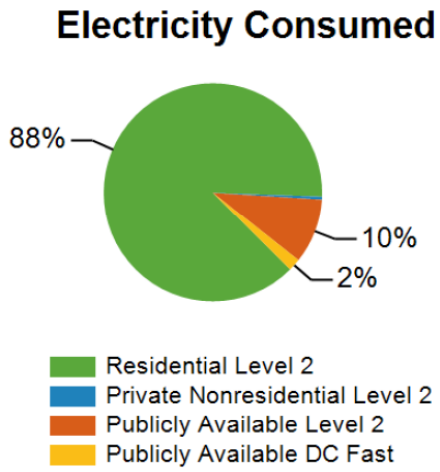
- 88% of energy and charge events are residential EVSE
- DCFC utilization increasing as compared to previous quarters
- Private Non-Residential EVSE results



EV Project Electric Vehicle Charging Infrastructure Summary Report

Region: ALL
Report period: October 2012 through December 2012
Number of EV Project vehicles in region: 4783

Charging Unit Usage	Residential Level 2	Private Nonresidential Level 2	Publicly Available Level 2	Publicly Available DC Fast	Total
Number of charging units[1]	4,819	78	1,988	54	6,939
Number of charging events[2]	341,828	1,699	36,990	8,089	388,606
Electricity consumed (AC MWh)	2,827.92	14.83	311.16	58.39	3,212.30
Percent of time with a vehicle connected to charging unit	42%	10%	5%	2%	31%
Percent of time with a vehicle drawing power from charging unit	8%	3%	2%	2%	6%



Public Level 2 EVSE usage

Contribution of car sharing fleets is large

All territories

Vehicles Charged	Car sharing fleet [1]	Nissan Leaf	Chevrolet Volt	Unknown
Percent of charging events	22%	20%	5%	54%
Percent of electricity consumed	34%	17%	3%	45%

San Diego

Vehicles Charged	Car2Go fleet [1]	Nissan Leaf	Chevrolet Volt	Unknown
Percent of charging events	54%	16%	3%	28%
Percent of electricity consumed	67%	12%	1%	20%

Oregon (Car2Go in Portland)

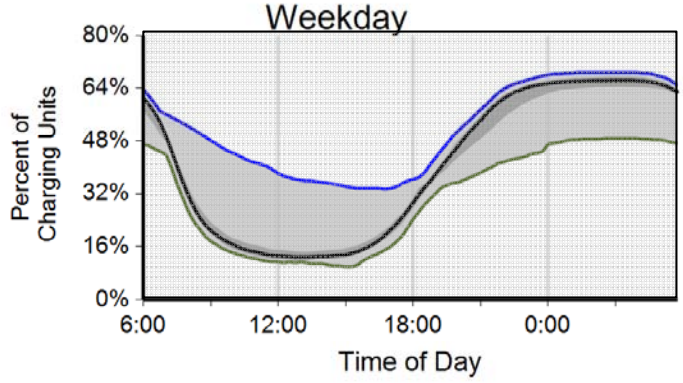
Vehicles Charged	Car2Go fleet [1]	Nissan Leaf	Chevrolet Volt	Unknown
Percent of charging events	5%	28%	4%	63%
Percent of electricity consumed	10%	26%	4%	60%

[1] Car2Go operates a car sharing fleet of Smart Fortwo Electric Drive vehicles in this region. Usage of publicly available EV Project charging units to charge these vehicles is included in this report.

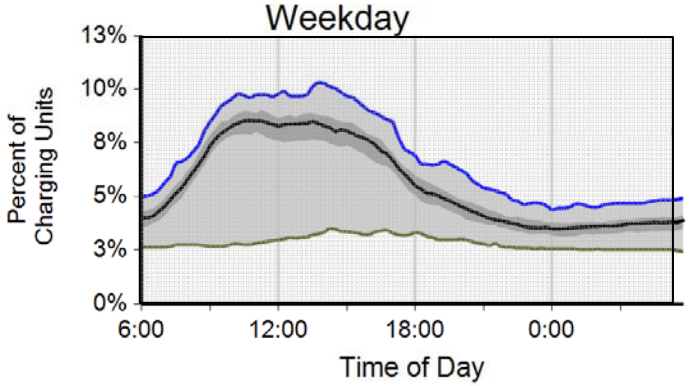
EV Project – EVSE Infra. Summary Report

- National Residential and Public Level 2 Weekday EVSE 4th Qtr 2012
- Time of Use (TOU) rates impact Residential, but not public Infrastructure

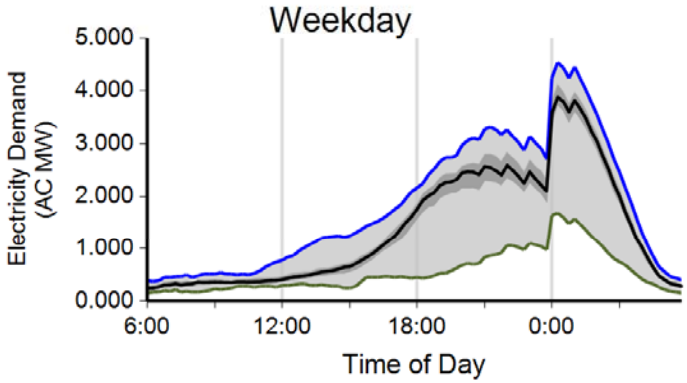
National Residential Connect Time



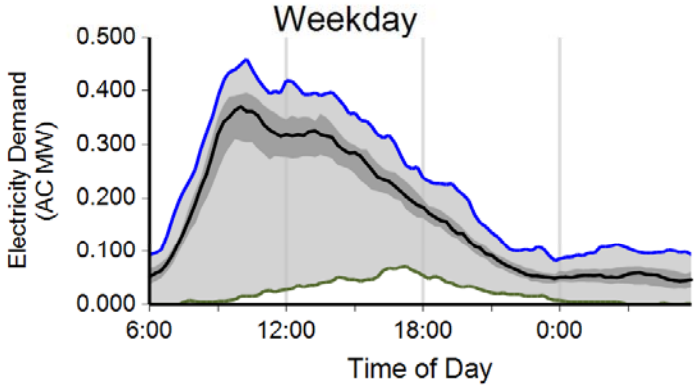
National Public Connect Time



National Residential Demand



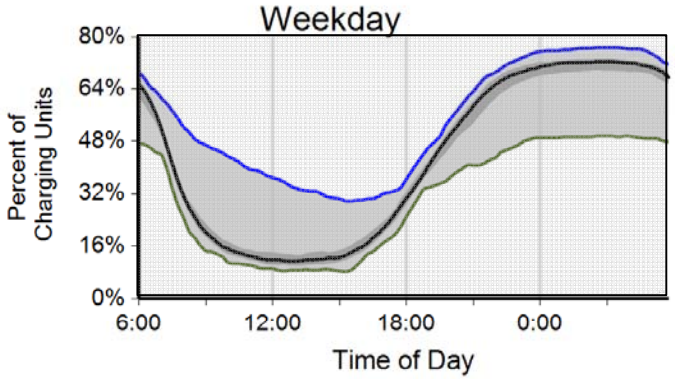
National Public Demand



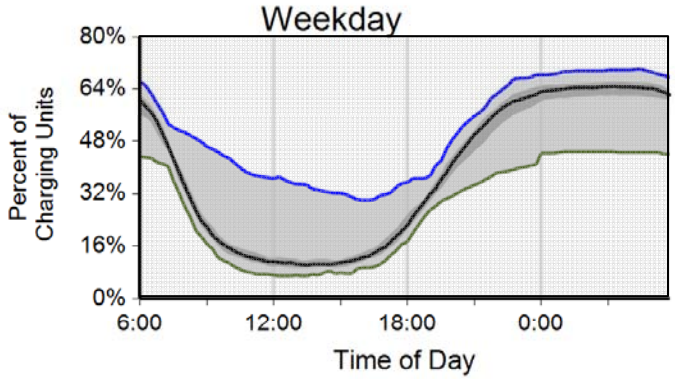
EV Project – EVSE Infra. Summary Report

- Residential Level 2 EVSE **Connect Time** Weekday 4th Quarter 2012
- San Diego and San Francisco, with TOU rates, are similar to national and other regional EVSE connect profiles

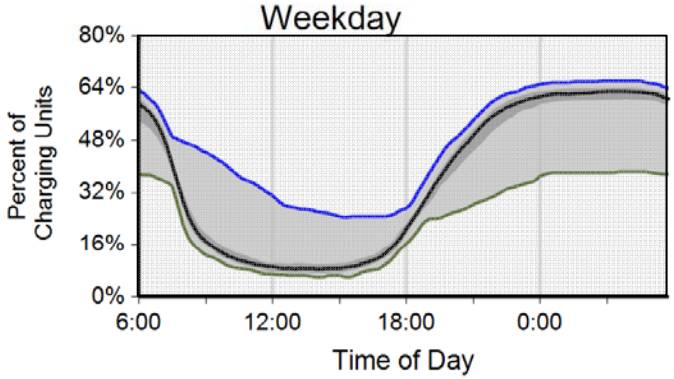
San Diego Connect Time



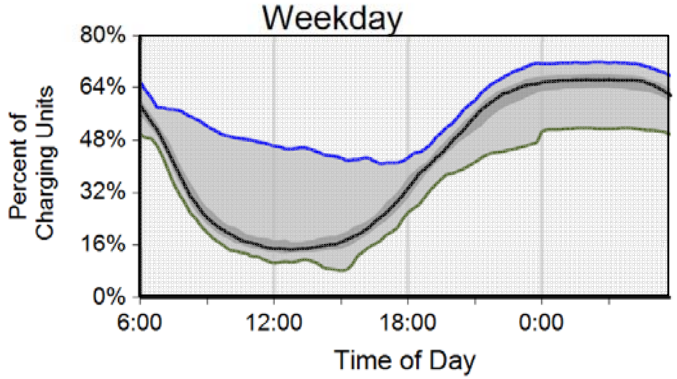
Los Angeles Connect Time



San Francisco Connect Time



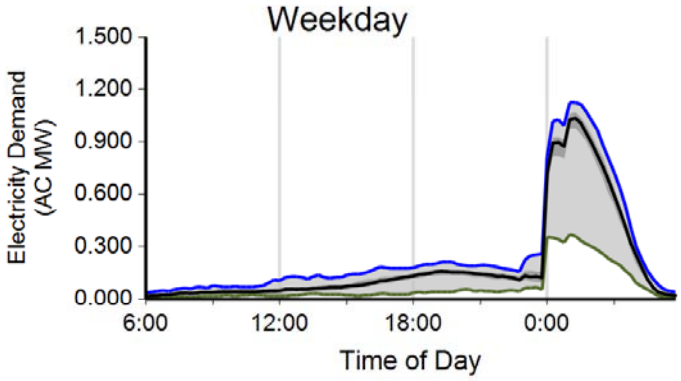
Washington State Connect Time



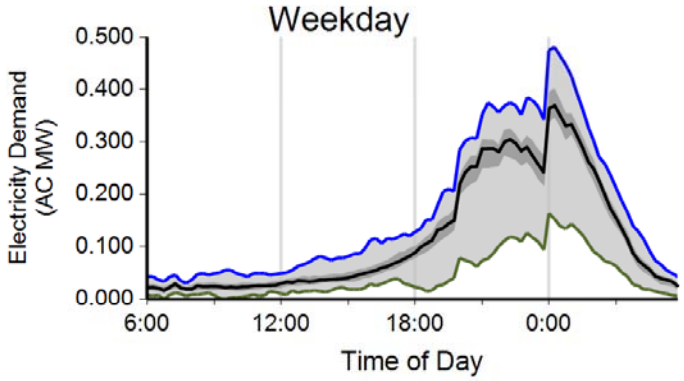
EV Project – EVSE Infra. Summary Report

- Residential EVSE Level 2 Weekday **Demand** 4th Quarter 2012
- TOU rates in San Diego and San Francisco clearly impact when vehicle charging start times are set

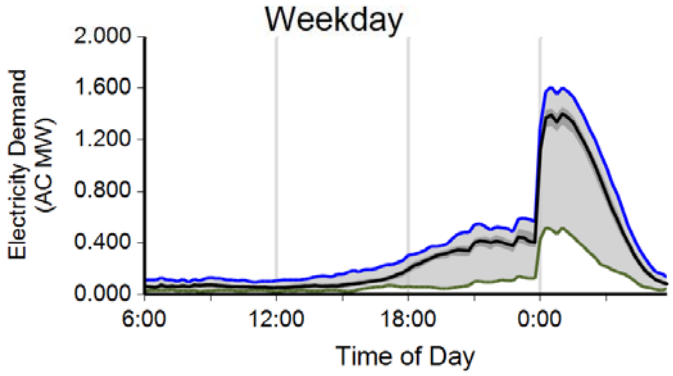
San Diego Demand



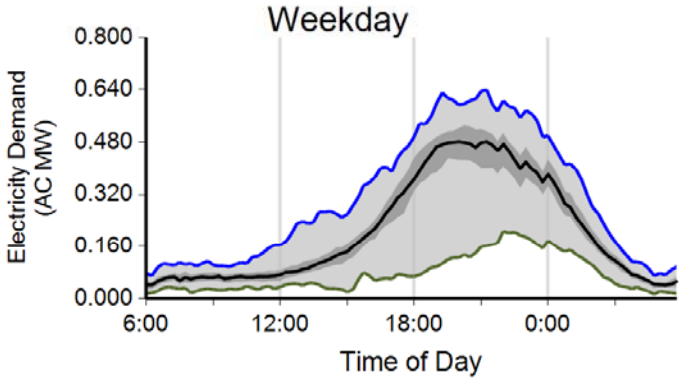
Los Angeles Demand



San Francisco Demand



Washington State Demand

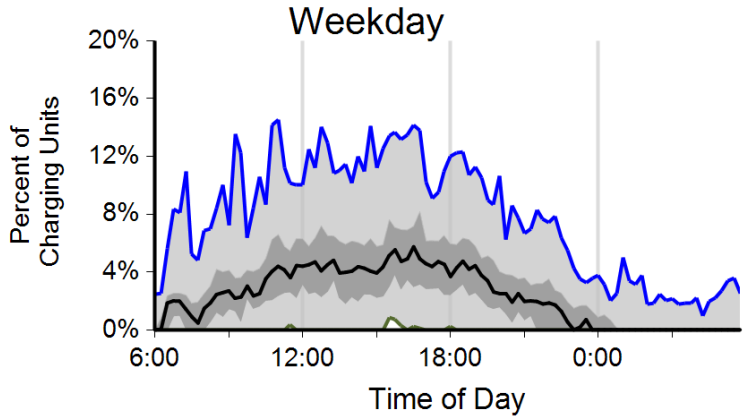


EV Project – EVSE Infra. Summary Report

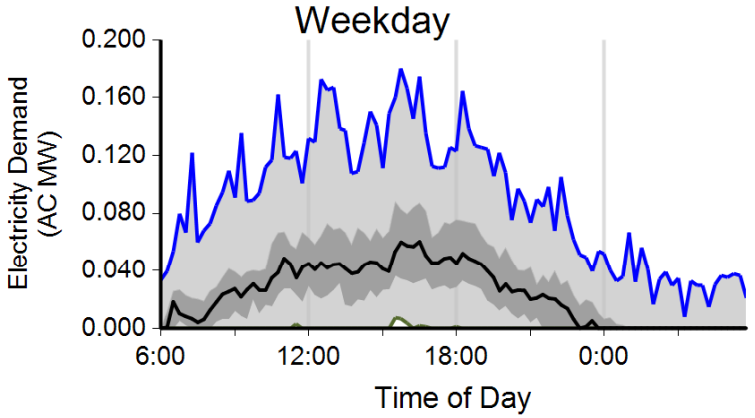
- DC Fast Chargers Weekday 4th Quarter 2012
- 54 DCFCs connected and demand profiles

- 1.9 avg. charge events per day per DCFC
- LEAF: 43% of charge events and 45% of energy delivered
- Unknowns: other charge events and energy by vehicles not in EV Project
- 19.3 minutes avg. time connected
- 19.3 minutes avg. time drawing energy
- 7.2 kWh average energy transferred per charge event

Weekday Connected Profile



Weekday Demand Profile



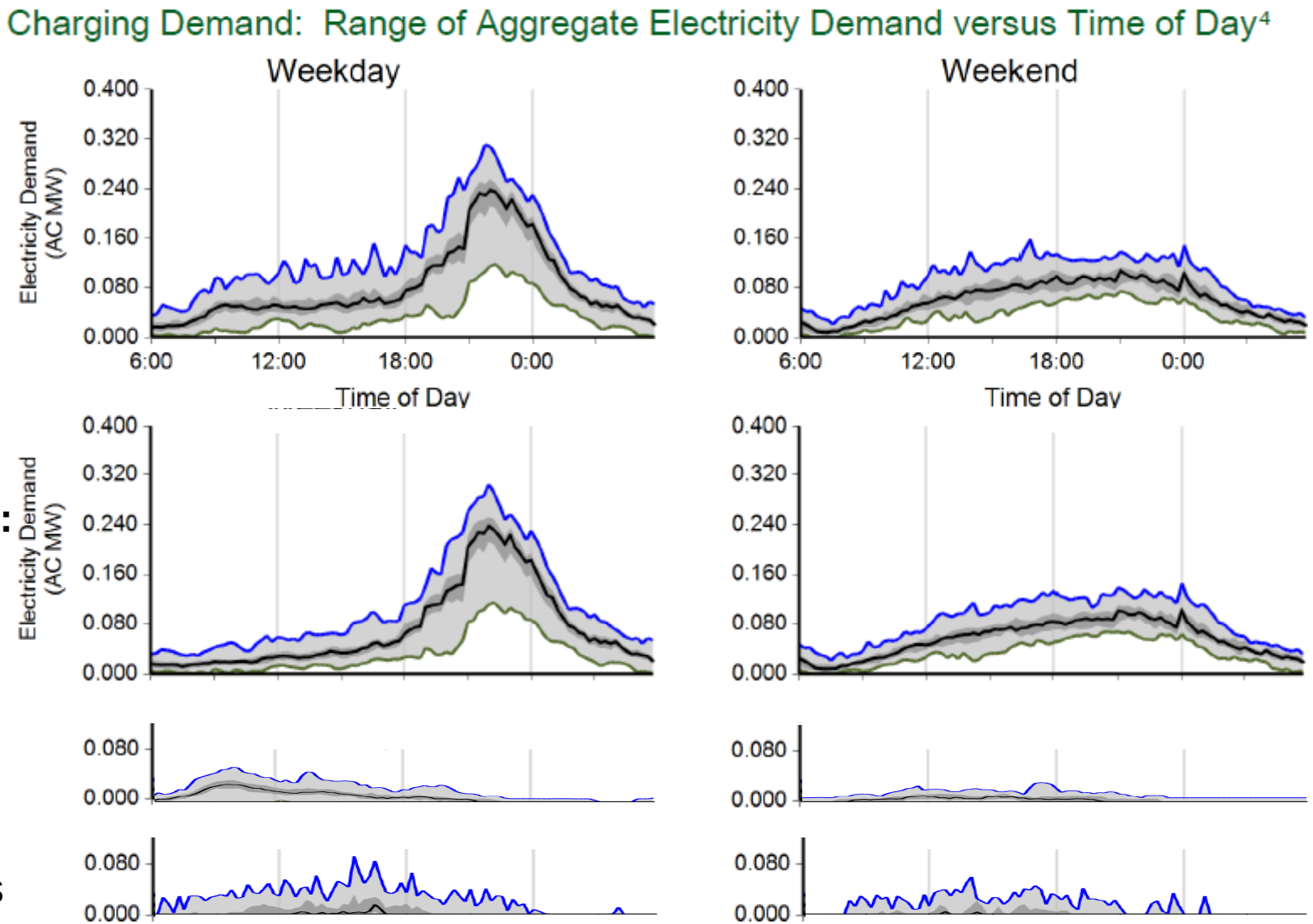
DCFC and L2 EVSE Usage – Phoenix

All EVSE

Residential L2:
273 units

Public L2:
292 units

DCFC: 12 units

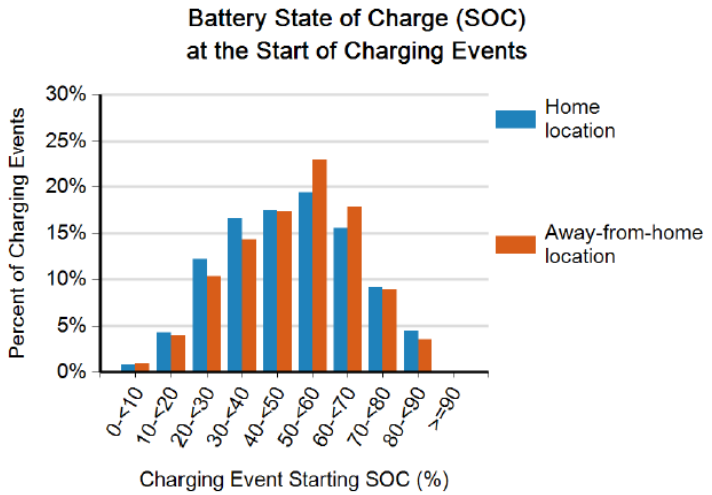


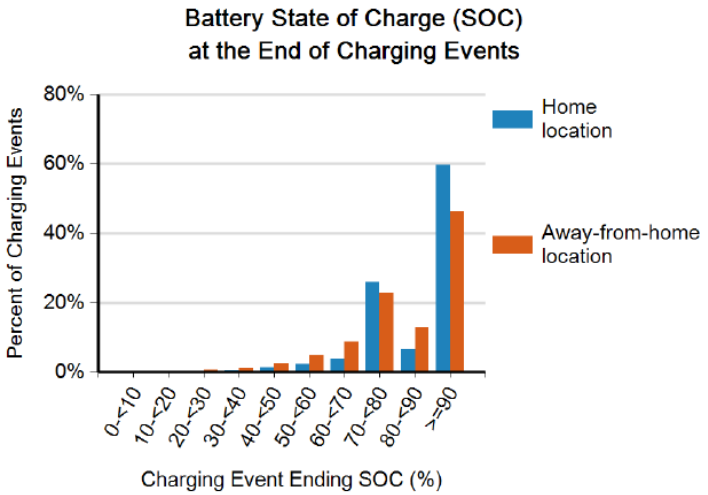
The EV Project – Nissan LEAF Results 4th Qtr 2012

- Owned / operated by private drivers
- 26.3 mile avg. distance between charging events
- Most charge events are completed
  - >90% SOC or 70% - 80% SOC
- >½ of charge events start between 40% - 70% SOC

Vehicle Usage

Number of trips [1]	969,853
Total distance traveled (mi)	6,724,952
Avg trip distance (mi)	6.9
Avg distance traveled per day when the vehicle was driven (mi)	29.2
Avg number of trips between charging events	3.8
Avg distance traveled between charging events (mi)	26.3
Avg number of charging events per day when the vehicle was driven	1.1



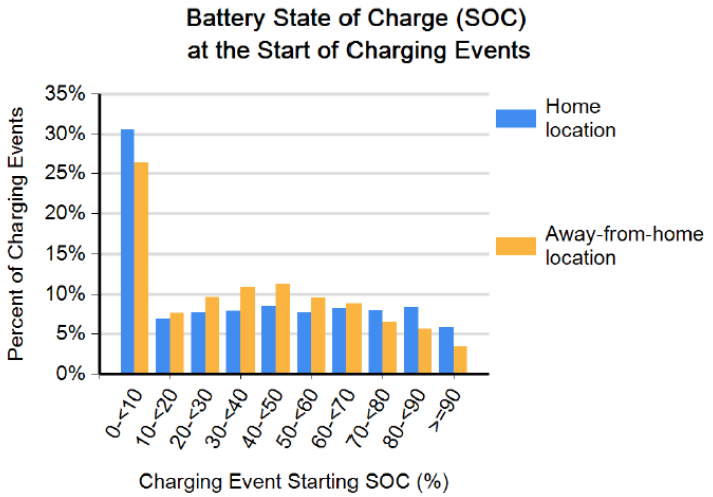


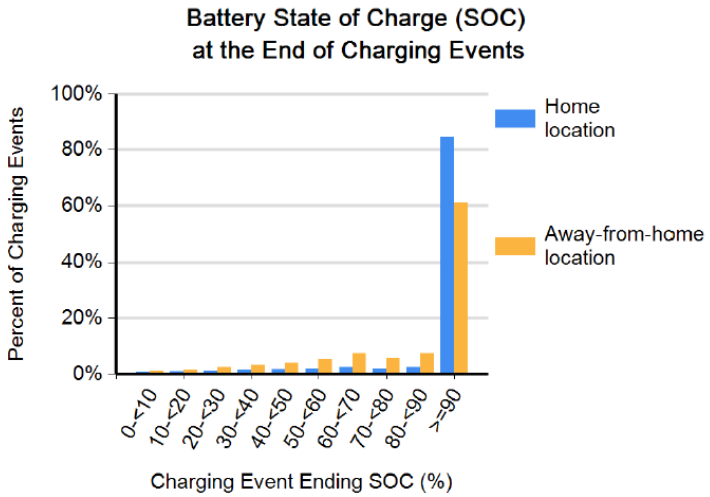
The EV Project – Chevy Volt Results 4th Qtr 2012

- Owned / operated by private drivers
- 126 MPG and 229 AC Wh/mi
- 28.2 mile avg. distance between charging events
- 25% - 30% of charge events start with vehicle fully depleted
- Most charge events are completed
  - end ≥90% SOC

Vehicle Usage

Overall fuel economy (mpg)	126
Overall electrical energy consumption (AC Wh/mi)	229
Number of trips[1]	369,118
Total distance traveled (mi)	3,001,976
Avg trip distance (mi)	8.1
Avg distance traveled per day when the vehicle was driven (mi)	40.5
Avg number of trips between charging events	3.5
Avg distance traveled between charging events (mi)	28.2
Avg number of charging events per day when the vehicle was driven	1.4





Summary – Infrastructure Demos

- Time-of-use rates in some areas are influencing drivers to schedule charging to operate during off peak times
- DCFC charging event are significant to demand
- Car share programs heavily utilize (and require) public EVSE infrastructure
- 1.1 to 1.3 avg. number of charges per day
- <30 miles avg. distance traveled between charge events
- EV Project vehicles connected much longer than needed to recharge
  - opportunities to shift charging times
- Significant opportunities to fully understand how the use of public infrastructure versus non-public infrastructure
- Only about 50% of EV Project data collected to date
- Additional “lessons learned” papers being developed

GRID CONNECTED VEHICLE DEMONSTRATION FLEETS

Chevrolet Volt Vehicle Demonstration

- 150 Volts in **commercial** fleets
- INL data collection started May 2011
- Objective is to demonstrate extended range electric vehicle (EREV) in diverse fleets to understand customer usage and impact on fuel economy

Chevrolet Volt Specs*

- All-electric capable EREV
- 111 kW and 54 kW electric motors
- 1.4L 84 hp engine
- 16 kWh liquid-cooled Li-ion battery pack
- AC level 2 (3.3 kW) charge rate via J1772 connector
- Navigation screen interface, website, and smart phone app for charge start/end scheduling
- Data acquisition via vehicle telematics (OnStar)

*http://gm-volt.com/full-specifications/

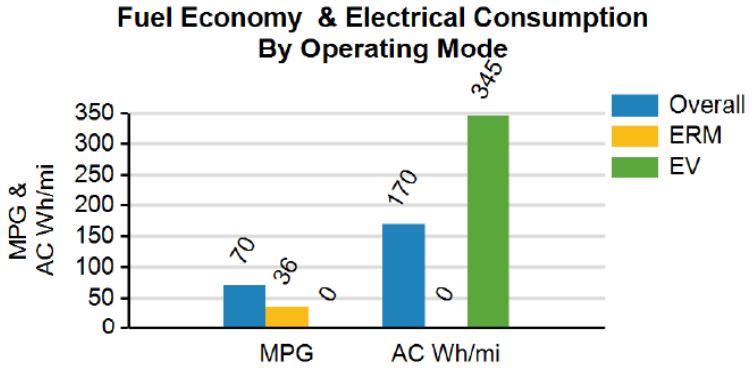
Chevrolet Volt Fleet Results

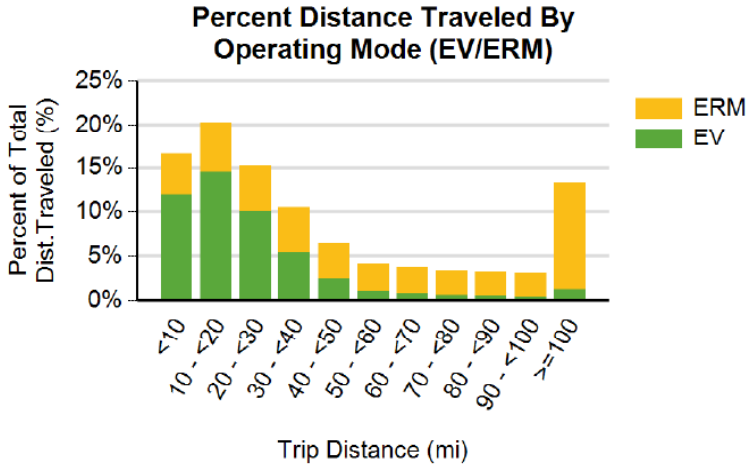
May 2011 through Dec 2012

- 150 vehicles
- 2,042,000 miles
- 346 AC MWh

- 49% of mile driven in EV mode
- 51% of miles driven in ERM mode

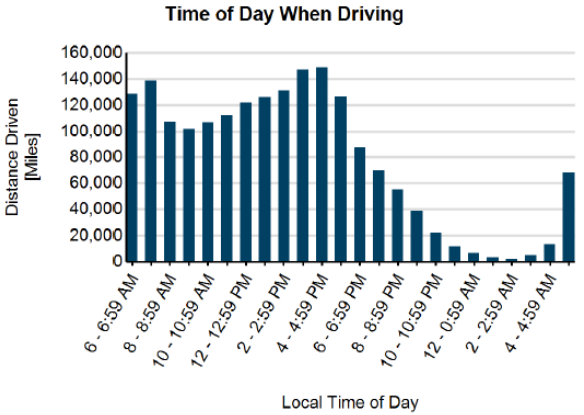
	Fuel Economy	Elec. Energy Consumption
Overall Fleet Results	70.5 MPG	170 AC Wh/mi
Electric-Only Trips (EV)	N/A	345 DC Wh/mi
Extended-Range Trips (ERM)	35.9 MPG	N/A

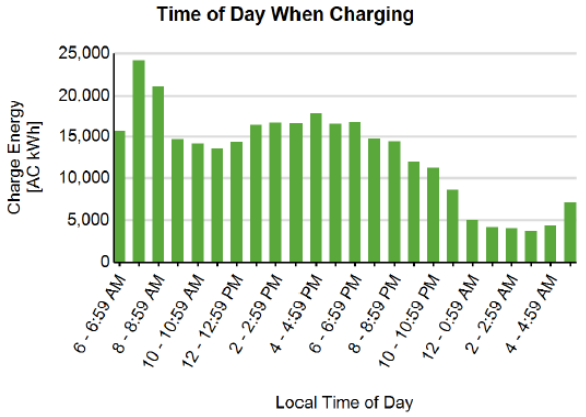


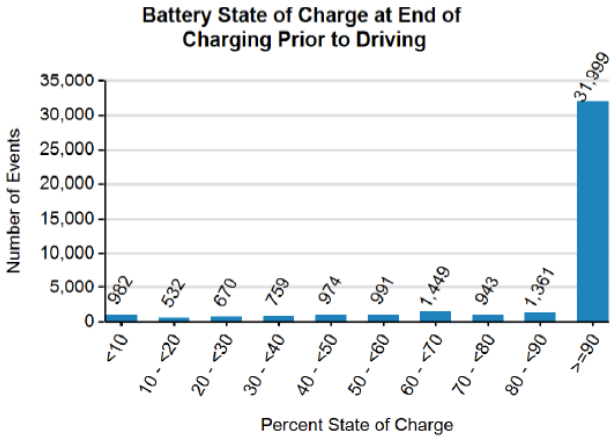


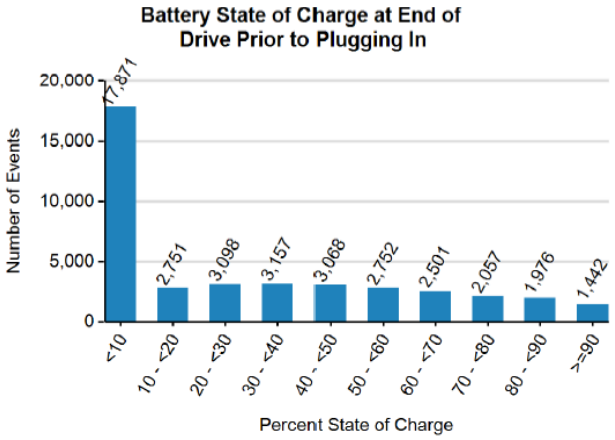
Chevrolet Volt Fleet Results

- 1.2 charging events per vehicle day driven
- 44 miles, 3.6 trips between charging events
- 3.1 hrs drawing power per charging event
- Usually driven during the day and plugged in following the drive (typical for commercial fleets)
- Most charge events are completed
  - end >90% SOC
- Nearly ½ of charge events start fully depleted









Ford Escape PHEV Advanced Research Fleet Demonstration

- 21 Escape PHEVs operating in **commercial** fleets
- INL data collection started Nov 2009
  - onboard data loggers and cellular communication data transfer
- Objective is to demonstrate Escape PHEV in diverse fleets to understand technology's ability to reduce petroleum use in real world applications

Ford Escape PHEV Specs*

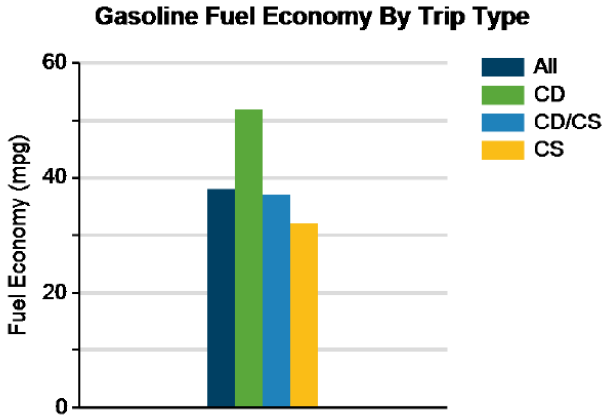
- Blended-mode PHEV (Flex Fuel E-85)
- Power split powertrain
- 11.5 kWh liquid-cooled Li-ion battery pack
- AC level 1 (1.4 kW) charge rate via J1772 connector
- Navigation screen interface for charge start/end scheduling
- Data acquisition via data logger with cellular modem

*http://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2011/veh_sys_sim/vss019_dannunzio_2011_o.pdf

Escape PHEV Fleet Results

November 2009 through December 2012

- 21 vehicles
- 593,000 miles, 59.6 AC MWh



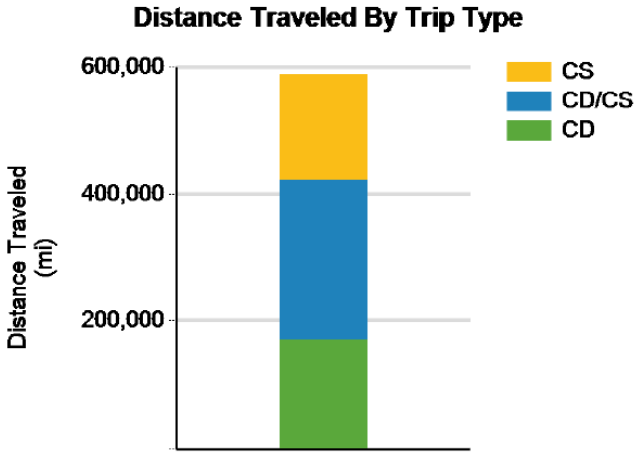
	Fuel Economy	Elec. Energy Consumption
Overall Fleet Results (All)	38 MPG	68 DC Wh/mi (100 AC Wh/mi)
Charge Depletion Trips (CD)	52 MPG	162 DC Wh/mi
Transition Trips (CD/CS)	37 MPG	54 DC Wh/mi
Charge Sustaining Trips (CS)	32 MPG	N/A

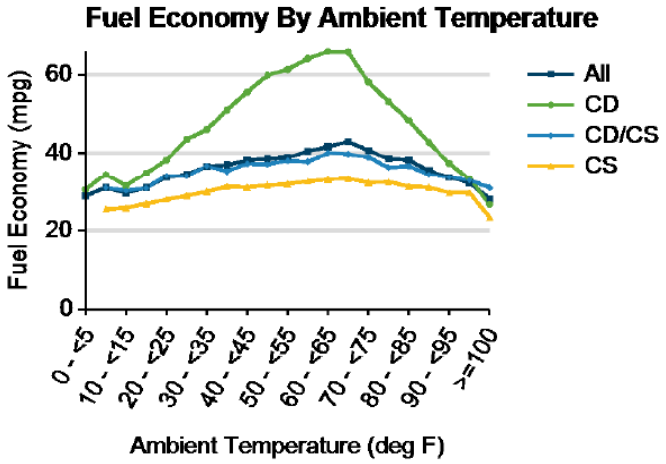
- Note: 63% improvement in MPG for CD trips as compared to CS trips
  - 52 MPG vs. 32 MPG

Escape PHEV Fleet Results

- ~50% of all miles driven in CD mode
- 29% of all miles driven in CD-only trips

- Significant variation (2x) in CD fuel economy due to ambient temperature variations
  - A/C load (cabin conditioning)
  - Engine on due to cabin heat request

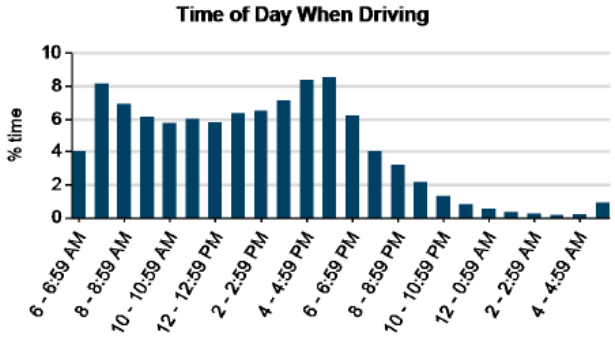


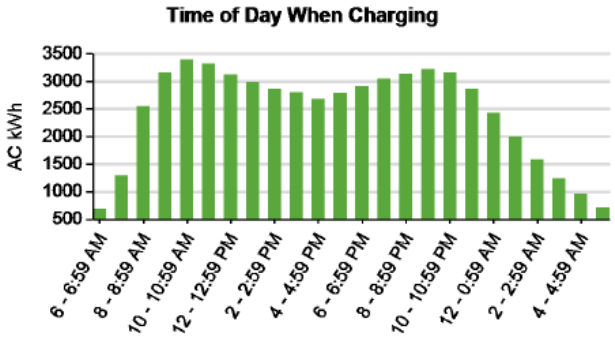


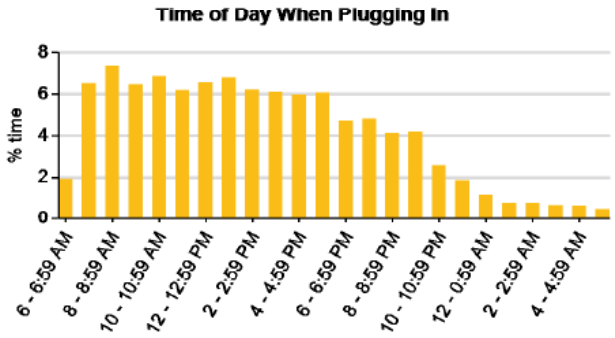
Escape PHEV Fleet Results

- Usually driven during the day and plugged in following the drive (typical for commercial fleets), with peak demand between 9:00 and 10:00 PM
- 1.9 charging events per vehicle day driven
- 30.4 miles, 2.6 trips between charging events
- 84 AC kWh consumed per vehicle month driven

- 7.4 hours plugged in during charge event
- 2.2 hours charging during charger event
  - 70% of time plugged-in but idle / stand-by







Chrysler Ram PHEV Demonstration

- 140 trucks in **commercial** fleets
- Data collection: July 2011 through Sept 2012
  - onboard data loggers and cellular communications data transfer
- Objective is to demonstrate plug-in hybrid electric vehicle (PHEV) pickup trucks in diverse fleets to understand customer usage

Ram PHEV Specifications*

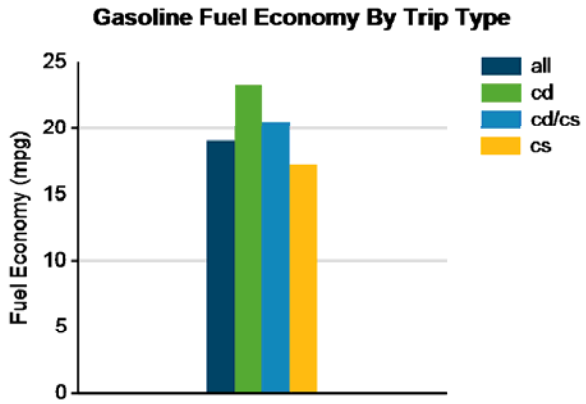
- Blended-mode PHEV
- Two-mode hybrid trans with two 65 kW motors
- 5.7L 345 hp engine
- 12.9 kWh liquid-cooled Li-ion battery
- AC level 2 (6.6 kW) charge rate via SAE J1772 connector
- Data acquisition via data logger with cellular modem

*http://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2011/veh_sys_sim/arravt067_vss_bazzi_2011_o.pdf

Ram PHEV Results

July 2011 through September 2012

- 111 vehicles
- 1,039,000 miles
- 93,374 AC kWh total charge energy

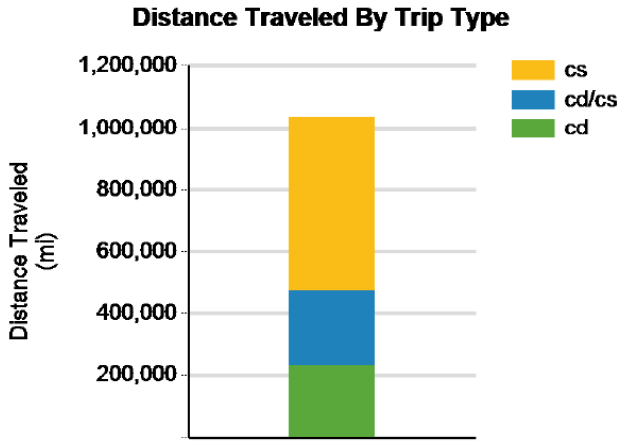


	Fuel Economy	Elec. Energy Consumption
Overall Fleet Results (All)	19 MPG	61 DC Wh/mi (90 AC Wh/mi)
Charge Depletion Trips (CD)	23 MPG	213 DC Wh/mi
Transition Trips (CD/CS)	21 MPG	68 DC Wh/mi
Charge Sustaining Trips (CS)	17 MPG	N/A

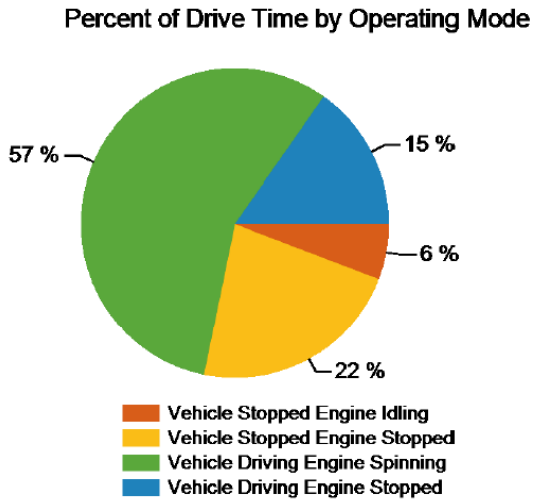
- Note: 35% improvement in MPG for CD trips as compared to CS trips
  - 23 MPG vs. 17 MPG

Ram PHEV Results

- Percent of Distance Traveled
  - 54% in Charge Sustaining Operation
  - 22% in Charge Depletion Only Operation

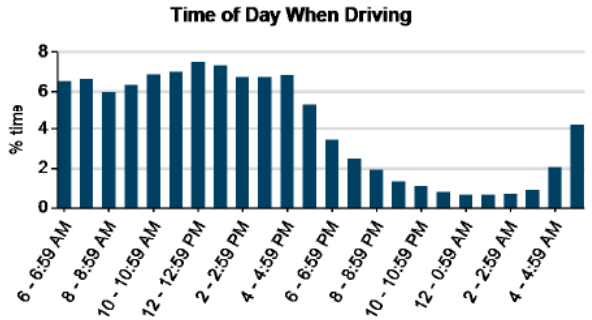


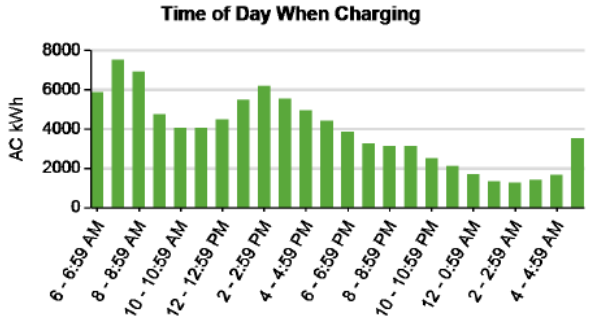
- Powertrain Operation results
  - 21% of time driving in EV-only mode (engine not spinning)
  - 76% of time engine is off while vehicle is stopped

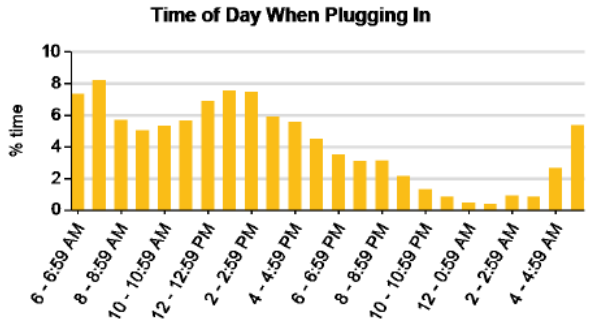


Ram PHEV Results

- 0.8 charging events per vehicle day driven
- 71 miles, 7.6 trips between charging events on average
- 76% of charging energy from L2 EVSE (24% from L1 EVSE)
- Most charging done during the day (typical for commercial fleets), with two peak demand times
  - 7:00AM to 9:00AM
  - 1:00 PM to 3:00 PM







Chrysler Town & Country Touring PHEV Demo

- 25 vehicles in **commercial** fleets
- INL data collection started April 2012
  - onboard data loggers and cellular communications
- Objective is to demonstrate plug-in hybrid electric vehicles (PHEV) in diverse fleets to understand customer usage

Town & Country Touring PHEV Specifications*

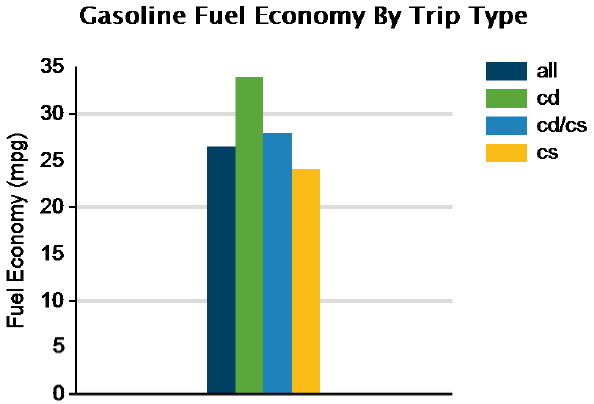
- Blended-mode PHEV
- Front wheel drive two-mode hybrid transmission
- 3.6L V6 290hp engine
- 12 kWh liquid-cooled Li-ion battery
- AC level 2 (6.6 kW) charge rate via SAE J1772 connector
- Data acquisition via data logger with cellular modem

*http://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2012/veh_sys_sim/vss063_bazzi_2012_o.pdf

Town & Country Touring PHEV Results

April 2012 through Sept 2012

- 23 vehicles
- 122,913 miles
- 6,113 AC kWh total charge energy

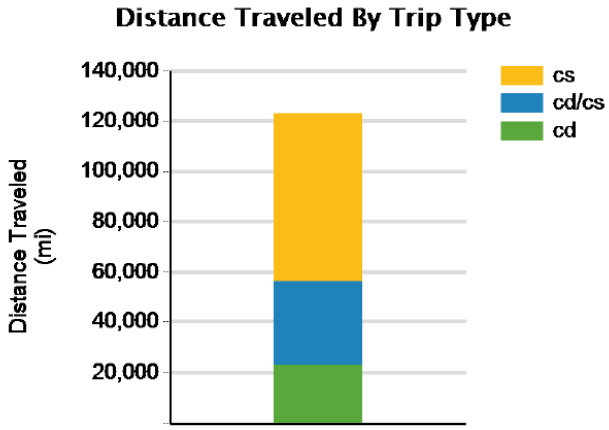


	Fuel Economy	Elec. Energy Consumption
Overall Fleet Results (All)	26 MPG	39 DC Wh/mi (50 AC Wh/mi)
Charge Depletion Trips (CD)	34 MPG	182 DC Wh/mi
Transition Trips (CD/CS)	28 MPG	30 DC Wh/mi
Charge Sustaining Trips (CS)	24 MPG	N/A

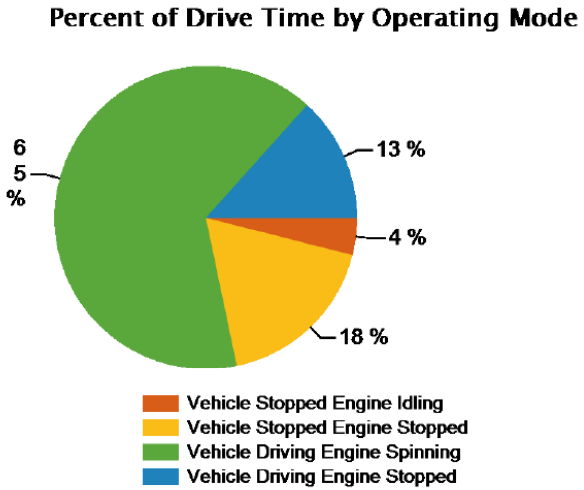
- Note: 42% improvement in MPG for CD trips as compared to CS trips
  - 34 MPG vs. 24 MPG

Town & Country Touring PHEV Results

- Percent of Distance Traveled
  - 54% in Charge Sustaining Operation
  - 19% in Charge Depletion Only Operation

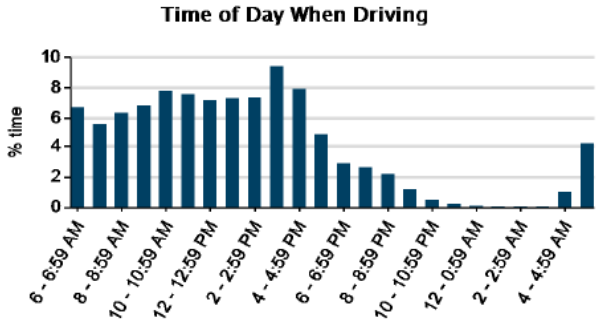


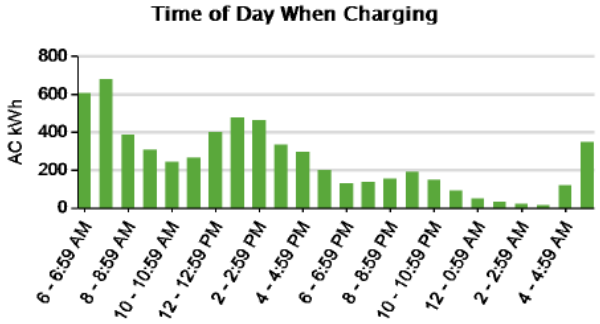
- Powertrain Operation results
  - 17% of time driving in EV-only mode (engine not spinning)
  - 82% of time engine is off while vehicle is stopped

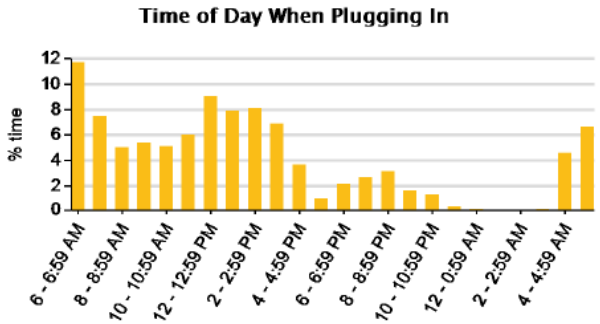


Town & Country Touring PHEV Results

- 0.6 charging events per vehicle day driven
- 110 miles, 9.5 trips between charging events on average
- 93% of charging energy from L2 EVSE (7% from L1 EVSE)
- Most charging done during the day (typical for commercial fleets), with two peak demand times
  - 6:00AM to 8:00AM
  - 12:00 PM to 3:00 PM







Summary – Vehicle Fleet Demos

- PHEVs show significant petroleum reduction in CD operation
  - Up to 2x fuel economy
- AC Wh/mi is higher than expected compared to DC Wh/mi due to small current draw while plugged-in but not charging (idle or stand-by)
  - DC to AC ratio of 68% to 78% variation across vehicles
  - 70% of time plugged-in but idle / stand-by (not charging)
- Commercial vehicle fleet operation is different from private vehicle operation
  - Miles between charges is greater
    - Commercial Fleet: 30 to 110 mi between charge events
    - Personal drivers: 26 to 28 mi between charge events
  - Time of day plugging-in / charging
    - Commercial Fleet: typically daytime charging
    - Personal drivers: typically overnight residential charging

Additional Information

Quarterly and project-to-date reports and other information available at **AVTA** website and at **The EV Project** website:

http://avt.inl.gov

http://www.theevproject.com/documents.php

Acknowledgements

This work is supported by the U.S. Department of Energy's EERE Vehicle Technologies Program

BACK UP SLIDES

L2 Access Fees Structure

- 4th Quarter is first widespread implementation of simple and low cost access fees
- Blink member
  - Affiliate credit card with free Blink RFID “In Card”
  - Level 2 access fee of $1.00 per hour of connect time
- Guest - No Blink RFID “In Card” required
  - Guest Code using quick reservation code or website
  - Level 2 access feel of $2.00 per hour of connect time
- Future pricing
  - Pricing to reflect regional electricity rates
  - Cover electricity costs in all cases

DC Fast Charge (DCFC) Fees Structure

- Encourage DCFC use with initial free charging
- Implement DCFC access fees by region in 1st Quarter 2013
- Initial fee structure simple and low cost
  - Accommodate varying vehicle charge rates
  - Accommodate select limitation of charging output power
- Blink member
  - $25 per month unlimited use or $5.00 per session
- Guest
  - $8.00 per session