

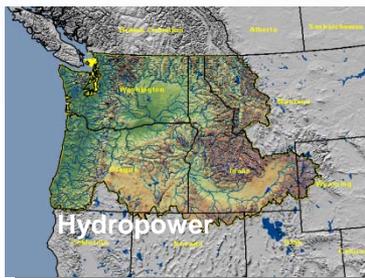
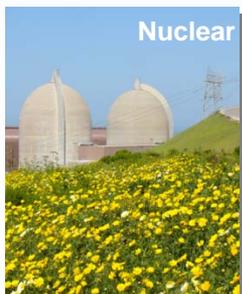
# **U.S. Department of Energy Vehicle Technologies Program's Plug-in Electric Vehicle and Charging Infrastructure Demonstrations**

**John Smart**

**IEEE Power & Energy Society General  
Meeting Electric Vehicle Super Session  
Detroit, MI  
July 26, 2011**

# Idaho National Laboratory

- Eastern Idaho based U.S. Department of Energy (DOE) Federal laboratory
- 890 square mile site with 3,600 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
  - Energy Critical Infrastructure Protection



# AVTA Participants and Goals

- **Participants**
  - **The Advanced Vehicle Testing Activity (AVTA) is part of DOE's Vehicle Technologies Program**
  - **The Idaho National Laboratory (INL) conducts the AVTA per DOE guidance**
  - **100+ fleets and organizations as testing partners**
  - **Some of these AVTA vehicle testing activities are conducted with ECOtality North America**
- **The AVTA goal - Petroleum reduction and energy security**
  - **Perform testing and Provide benchmark data to technology modelers, research and development programs, vehicle manufacturers (via VSATT), and target and goal setters**
  - **Assist fleet managers in making informed vehicle and infrastructure purchase, deployment and operating decisions**

# Presentation Outline

- **US DOE's Transportation Electrification Demonstrations**
- **INL's role with data collection and reporting**
- **Recovery Act data collection projects**
- **EV Project background and results to date**
- **Ford PHEV Escape demo results to date**
- **Other data collection activities**

# **DOE's Transportation Electrification Demonstrations under American Recovery and Reinvestment Act (ARRA)**

# ARRA Transportation Grants

- **\$2 Billion in DOE grants to establish advanced battery, power electronics and motors manufacturing**
- **\$400 Million for Transportation Electrification Demonstration, Infrastructure, and Education**
  - **8 awards totaling over \$360M for grid-connected vehicle and infrastructure demonstrations**
    - **13,000 vehicles from 9 OEMs and over 22,000 charging stations are being deployed across America**
    - **Vehicle performance and grid impact data are being gathered and analyzed to support the development of vehicle technologies and grid infrastructure**
  - **10 awards totaling \$39M to establish comprehensive educational and outreach programs**

# Transportation Electrification Demonstration Activities

## ECOtality North America - AWARD: \$114.8M The EV Project infrastructure demonstration

- Demonstration of 5,700 Nissan Leaf EVs and 2,600 Chevy Volt EREVs
- Deployment of 15,000 Level 2 electric vehicle supply equipment (EVSE) charging Stations (EVSE) and 300 fast chargers, in 16 metropolitan areas
- Full instrumentation of vehicles and infrastructure for comprehensive data-collection and analysis effort



## Coulomb Technologies - AWARD: \$15M ChargePoint Amercia infrastructure demonstration

- Deployment of approximately 4,000 public and private charging stations in up to 9 U.S. Cities
- Locations will be coordinated with OEM deployment of 400 grid connected vehicles



# Transportation Electrification Demonstration Activities (cont'd)

## General Motors - AWARD: \$30.5M Chevrolet Volt vehicle demonstration

- Develop, analyze, and demonstrate 145 Chevy Volt EREVs for electric utilities and 500 Volt EREVs to consumers
- Manufacturing in Detroit, MI; Deployment in conjunction with several utility partners



## Chrysler, LLC - AWARD: \$48M Ram PHEV vehicle demonstration

- Development, validation, and deployment of 140 PHEV Dodge Ram pickups
- Deployment of vehicles through 11 partner fleets across a wide range of geographic, climatic, and operating environments



# Transportation Electrification Demonstration Activities (cont'd)

## South Coast Air Quality Management District - AWARD: \$45.4

- Development of a fully integrated production PHEV system for Class 2-5 vehicles (8,501-19,500 lbs GVWR).
- Demonstration of 378 trucks and shuttle buses through network of partner fleets
- SCAQMD based in Diamond Bar, CA; Manufactured in Galesburg, MI, and Elizabethtown, KY



## Smith Electric Vehicle - AWARD: \$32M

- Develop and deploy up to 500 medium-duty electric trucks.
- Manufacturing in Kansas City, MO; Deployment in conjunction with 20 launch partners representing a range of commercial and public sector markets, geographies, and climates



# Transportation Electrification Demonstration Activities (cont'd)

## Navistar, Inc. - AWARD: \$39.2M

- Develop, validate, deploy 950 advanced Battery Electric delivery trucks (12,100 lbs GVWR) with a 100-mile range
- Manufacturing in Elkhart Co., IN; Deployment in Portland, Chicago, and Sacramento



## Cascade Sierra Solutions - AWARD: \$22.2M

- Deployment of truck stop electrification infrastructure at 50 sites along major US interstate corridors
- Provide 5,450 rebates of 25% of the cost for truck modification to incorporate idle reduction technologies



# Transportation Electrification Distribution



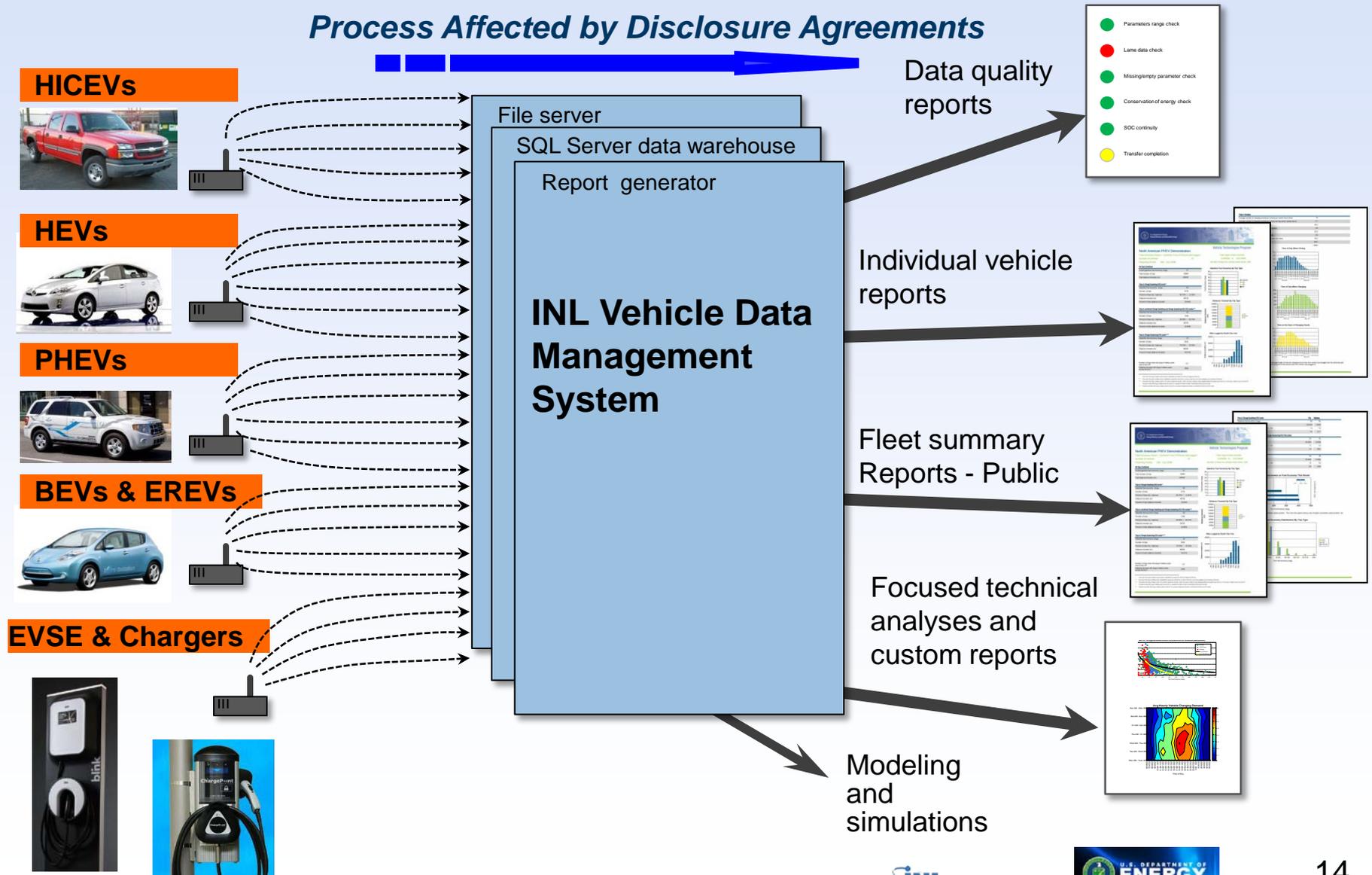
# **INL Data Collection Activities in Support of DOE's Transportation Electrification Demonstrations**

# INL Data Collection Support

- **INL tasked with data collection, analysis, and reporting for five light-duty vehicle and infrastructure deployment projects funded by DOE:**
  - **EV Project:**
    - **8,300 Leaf BEVs and Volt EREVs,**
    - **15,300 ECOtality Level 2 EVSE and fast chargers.**
  - **4,700 Level 2 EVSE deployed by Coulomb**
  - **140 Chrysler Ram PHEV Pickups**
  - **145 Chevrolet Volt Extended-range electric vehicles**
  - **21 Ford Escape PHEV SUVs**
- **Data is being collected from all vehicles and charging units**
- **Raw data and personal information protected by numerous Non Disclosure Agreements with project partners**

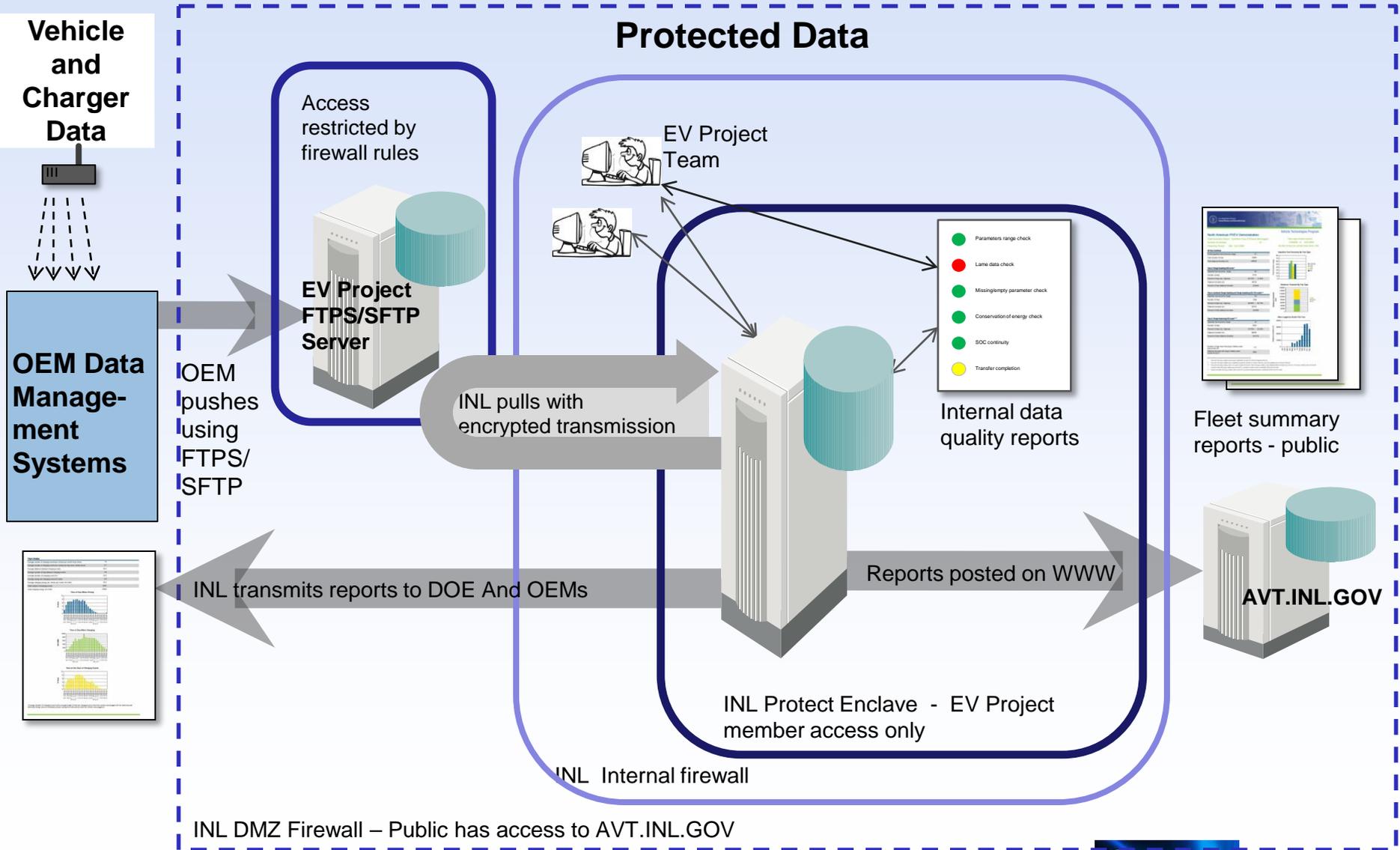
# Vehicle/EVSE Data Management Process

*Process Affected by Disclosure Agreements*

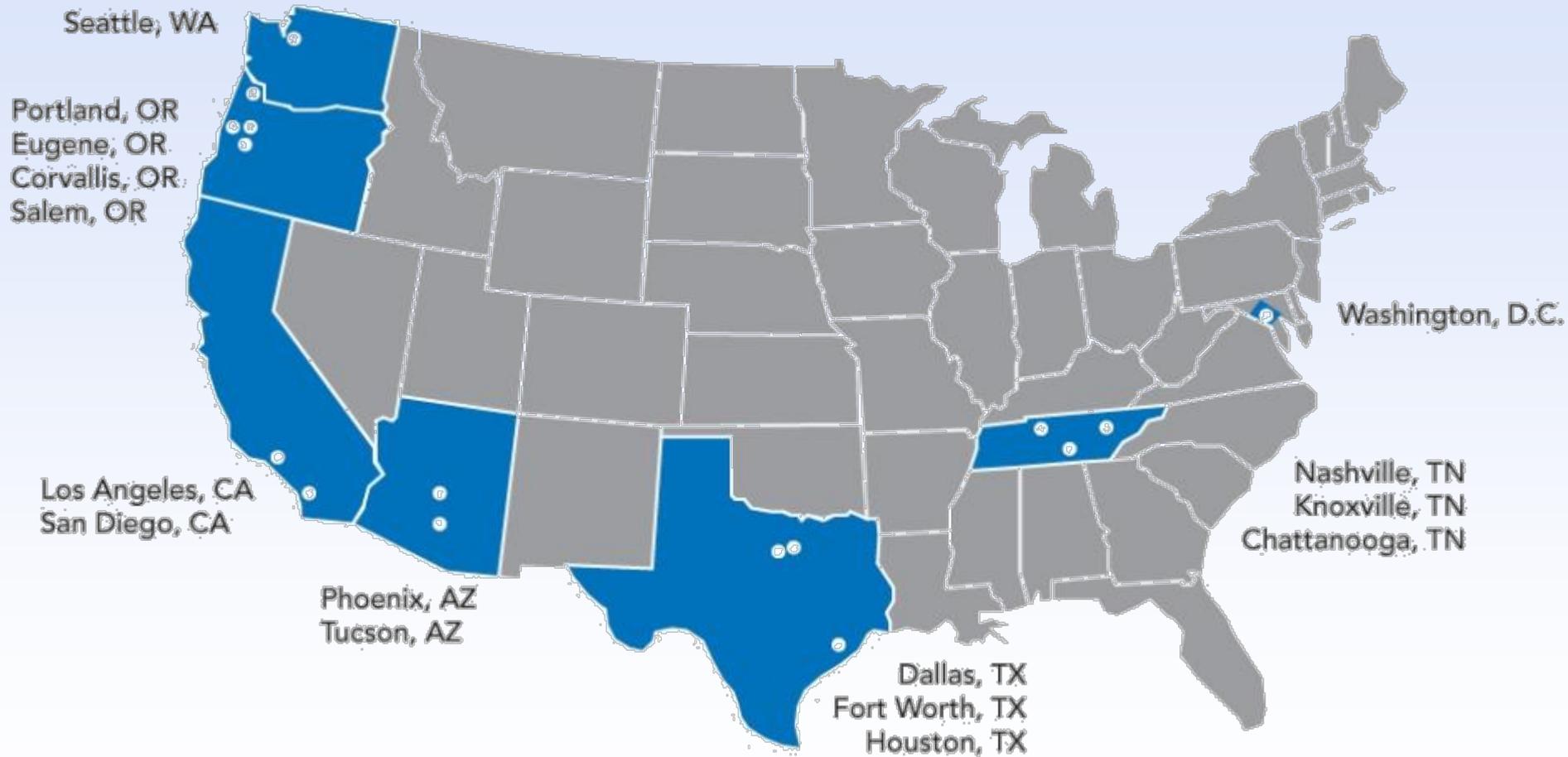


# INL Data Management System - Push

(Nissan, GM, Chrysler, Coulomb)



# EV Project Locations (Largest Data Collection Activity)



# EV Project Residential Infrastructure

- Deploy 8,300 battery electric vehicles
  - 5,700 Nissan Leaf battery EVs
  - 2,600 Chevrolet Volt extended range EVs
- Install 8,300 level 2 residential EVSE



# EV Project Commercial Infrastructure

- Install ~5,300 level 2 EVSE
  - Retail locations
  - Municipal locations
  - Employer locations
- Deploy 200 Dual Port DC Fast Chargers





## Objective of the EV Project

- **Build mature EV charging infrastructure in nine regions and study:**
  - **Infrastructure deployment process**
  - **Customer driving and charging behavior**
  - **Impact on electric grid**
- **Provide lessons learned to enable mass deployment of plug-in electric vehicles and charging infrastructure**

## EV Project Nissan Leaf Vehicle Summary Report

Region: All

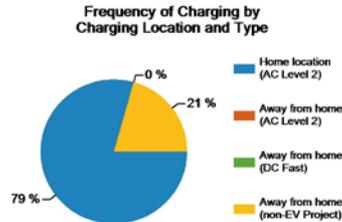
Number of vehicles: 35

Reporting period: January 2011 through March 2011



### Vehicle Usage

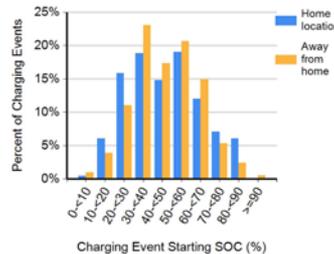
Number of trips	3,364
Total distance traveled (mi)	21,706
Avg trip distance (mi)	5.8
Avg distance traveled per day when the vehicle was driven (mi)	32.5
Avg number of trips between charging events	3.3
Avg distance traveled between charging events (mi)	21.5
Avg number of charging events per day when the vehicle was driven	1.5



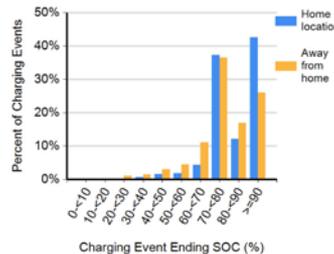
### Charging Location and Type

	Home charging location		Away-from-home charging locations	
	AC level 2 charging	AC level 2 charging	DC fast charging	Non-EV Project charging <sup>1</sup>
Total number of charging events	800	0	0	208
Percent of all charging events	79%	0%	0%	21%
Total time plugged-in (hr)	8,126	0	0	—
Percent of all time plugged-in at EV Project charging units	100%	0%	0%	—
Total electricity consumed (AC MWh)	5.25	0	0	—
Percent of all electricity consumed from EV Project charging units	100%	0%	0%	—

Battery State of Charge (SOC) at the Start of Charging Events



Battery State of Charge (SOC) at the End of Charging Events



### Charging Completeness

	Home charging location		Away-from-home charging locations	
	AC level 2 charging	AC level 2 charging	DC fast charging	Non-EV Project charging <sup>1</sup>
Number of complete charging events <sup>2</sup>	199	0	0	54
Percent of charging events of the same type and location	43%	0%	0%	26%
Number of partial charging events <sup>3</sup>	268	0	0	154
Percent of charging events of the same type and location	57%	0%	0%	74%

<sup>1</sup> Charging level, time plugged-in, and electricity consumed are not available from Non-EV Project charging units. Charging level could be AC level 1, AC level 2, or DC fast charging.

<sup>2</sup> Complete charging events end with battery state of charge at 90% to 100% (for charging events with SOC reported)

<sup>3</sup> Partial charging events end with battery state of charge below 90% (for charging events with SOC reported)

# EV Project – Nissan Leaf Quarterly Usage Report

# EV Project – Nissan Leaf Usage Report

Region: All

Number of vehicles: 35

Reporting period: January 2011 through March 2011

## Vehicle Usage

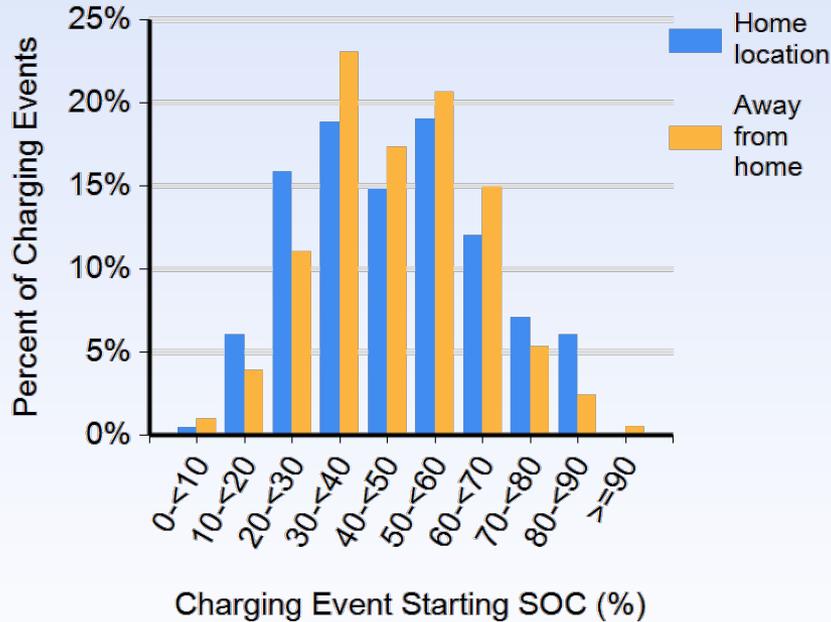
Number of trips	3,364
Total distance traveled (mi)	21,706
Avg trip distance (mi)	5.8
Avg distance traveled per day when the vehicle was driven (mi)	32.5
Avg number of trips between charging events	3.3
Avg distance traveled between charging events (mi)	21.5
Avg number of charging events per day when the vehicle was driven	1.5

# EV Project – Nissan Leaf Usage cont'd

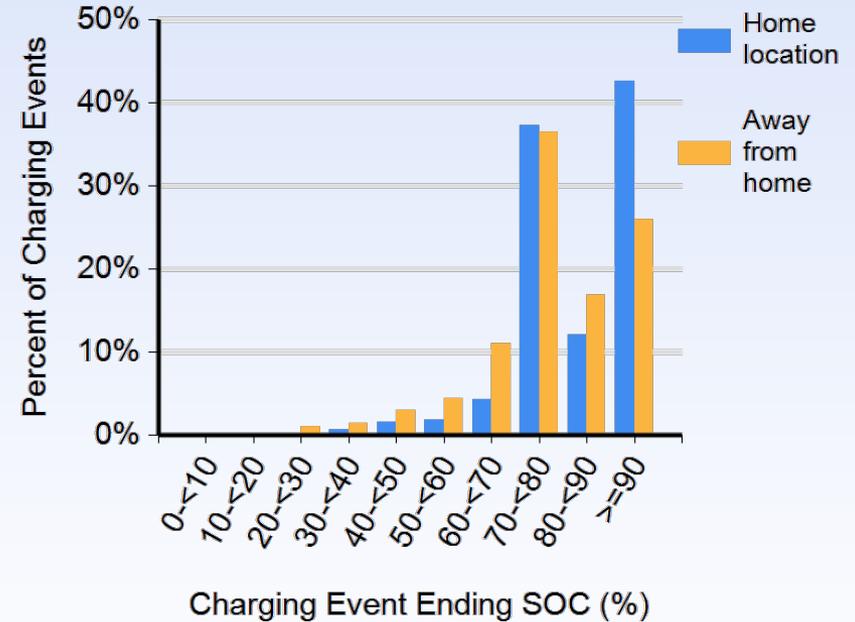
Charging Location and Type	Home charging location	Away-from-home charging locations		
	AC level 2 charging	AC level 2 charging	DC fast charging	Non-EV Project charging <sup>1</sup>
Total number of charging events	800	0	0	208
Percent of all charging events	79%	0%	0%	21%
Total time plugged-in (hr)	8,126	0	0	—
Percent of all time plugged-in at EV Project charging units	100%	0%	0%	—
Total electricity consumed (AC MWh)	5.25	0	0	—
Percent of all electricity consumed from EV Project charging units	100%	0%	0%	—

# EV Project – Nissan Leaf Usage – cont'd

Battery State of Charge (SOC) at the Start of Charging Events



Battery State of Charge (SOC) at the End of Charging Events



# EV Project Electric Vehicle Charging Infrastructure Summary Report

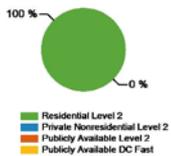


Region: All  
 Report period: January 2011 through March 2011  
 Number of EV Project vehicles in region: 35

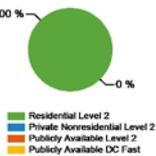
## Charging Unit Usage

	Residential Level 2	Private Nonresidential Level 2	Publicly Available Level 2	Publicly Available DC Fast	Total
Number of charging units <sup>1</sup>	35	0	0	0	35
Number of charging events <sup>2</sup>	800	0	0	0	800
Electricity consumed (AC MWh)	5.25	0.00	0.00	0.00	5.25
Percent of time with a vehicle connected to charging unit	36%	0%	0%	0%	36%
Percent of time with a vehicle drawing power from charging unit	7%	0%	0%	0%	7%

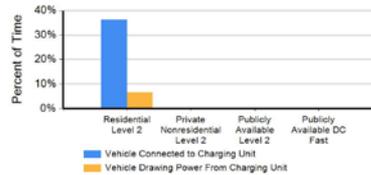
Number of Charge Events



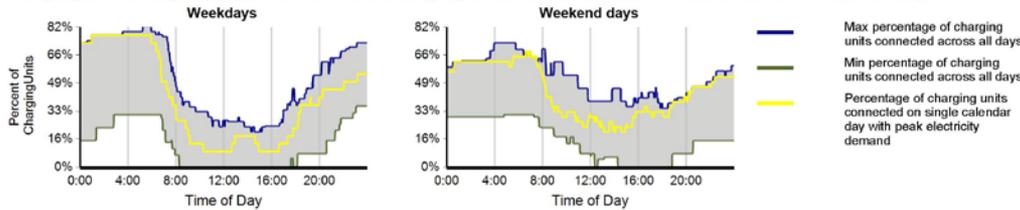
Electricity Consumed



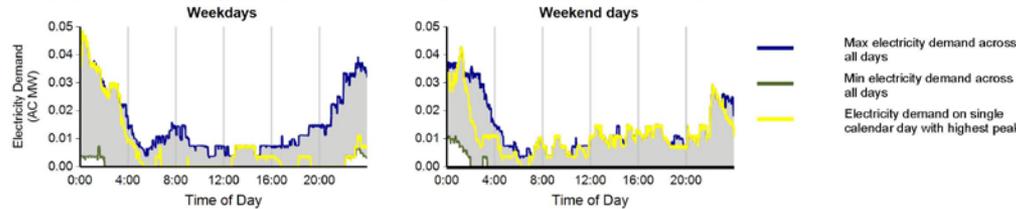
Charging Unit Utilization



## Charging Availability: Range of Percent of Charging Units with a Vehicle Connected versus Time of Day<sup>3</sup>



## Charging Demand: Range of Aggregate Electricity Demand versus Time of Day<sup>4</sup>



<sup>1</sup> Includes all charging units that were in use by the end of the reporting period

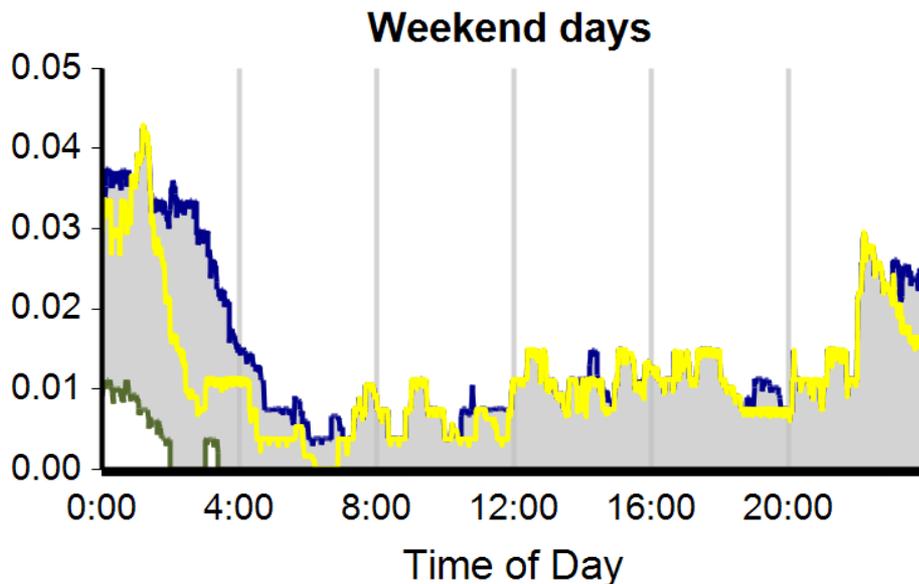
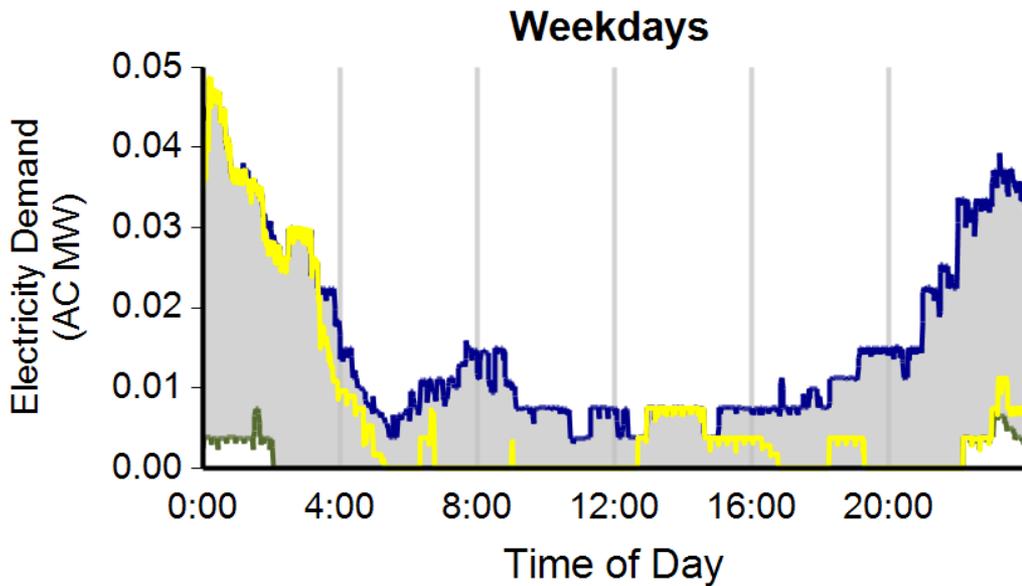
<sup>2</sup> A charging event is defined as the period when a vehicle is connected to a charging unit, during which period some power is transferred

<sup>3</sup> Considers the connection status of all charging units every minute

<sup>4</sup> Based on 15 minute rolling average power output from all charging units

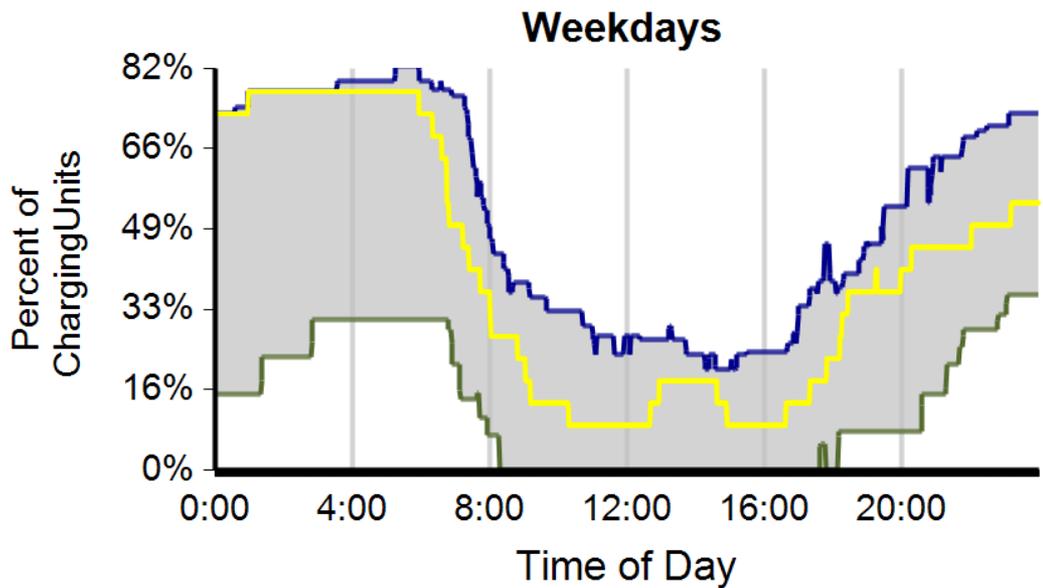
# EV Project – EV Charging Infrastructure Summary Report

- Charging unit usage
- Percent charging units with a vehicle connected by time of day
- Range of aggregate electricity demand versus time of day
- See next 2 slides



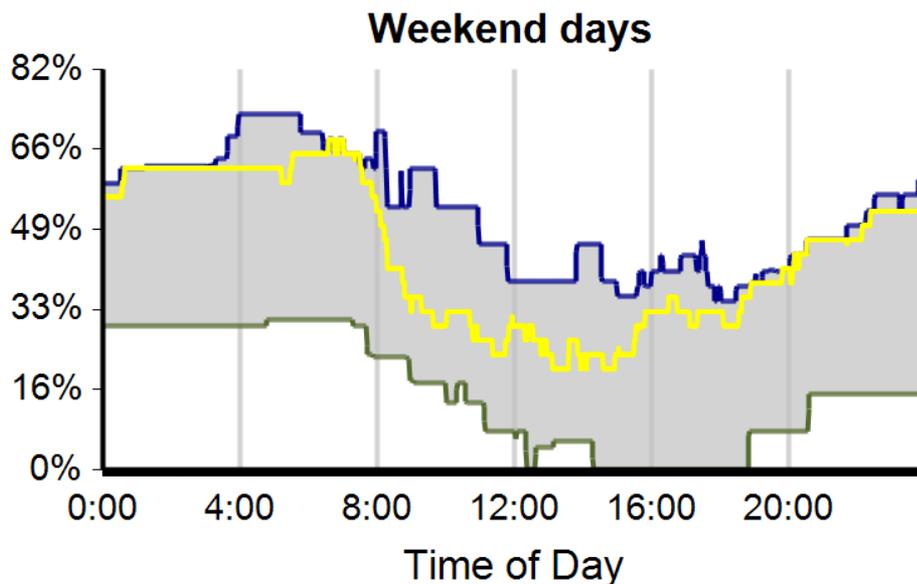
# EV Project – EV Charging Infrastructure Summary Report – cont'd

- Power demand range for any time during reporting quarter
- Yellow line is daily profile for the day with quarterly peak demand
- Both graphs in AC MW
- Based on 15 minute rolling average MW demand



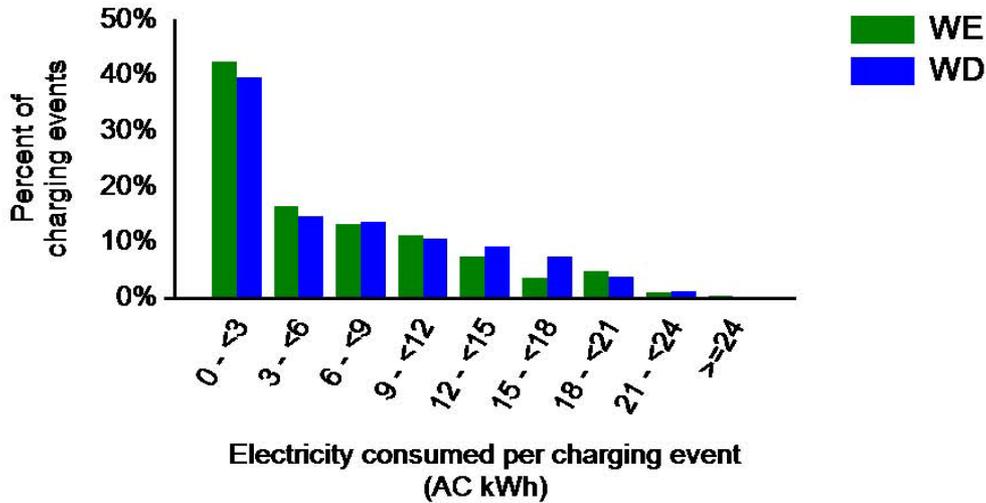
# EV Project – EV Charging Infrastructure Summary Report – cont'd

- Range of charging units with a vehicle connected
- Yellow line is for day with peak power demand
- Both graphs percent of charging units

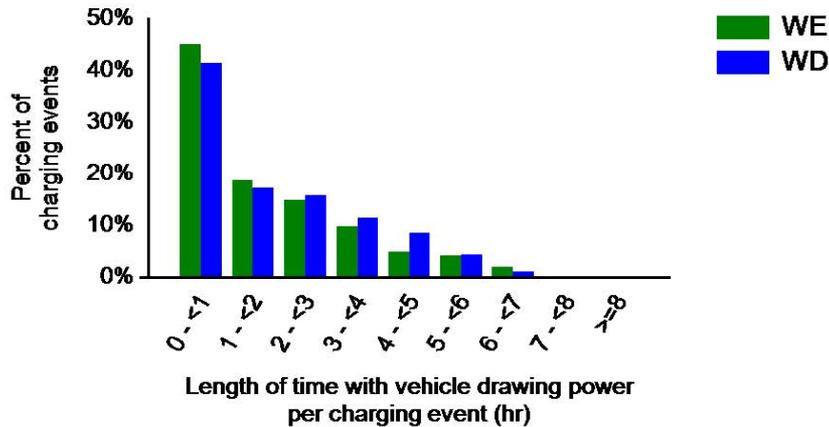


# EV Project – EV Charging Infrastructure Summary Report – cont'd

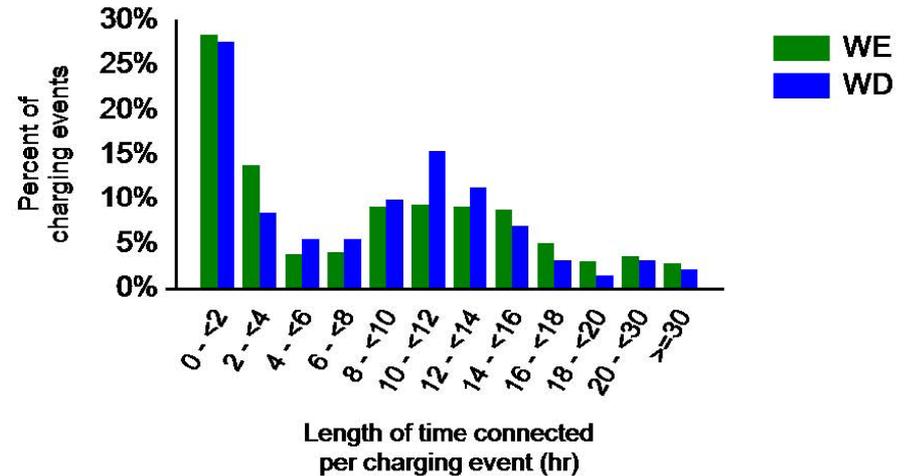
## Distribution of Electricity Consumed per Charging Event



## Distribution of Length of Time with a Vehicle Drawing Power per Charging Event



## Distribution of Length of Time with a Vehicle Connected per Charging Event



# EV Project – Updated Number of Units

## 1<sup>st</sup> Quarter 2011 Report Leaf and EVSE Units with Data

<b>Number of Leafs</b>	<b>50</b>
<b>Number of Blink EVSE</b>	<b>107</b>
<b>Total number of units providing data</b>	<b>157</b>

## July 25, 2011 Leaf and EVSE Units with Data

<b>Number of Leafs</b>	<b>1,697</b>
<b>Number of Blink EVSE residential</b>	<b>1,752</b>
<b>Number of Blink EVSE commercial</b>	<b>122</b>
<b>Total number of units providing data</b>	<b>3,571</b>

# Ford Escape PHEV vehicle demo

- Ford produced 21 Ford Escape PHEVs prototype vehicles with 12 kWh battery pack
- Blended mode operation (engine comes on during charge depleting mode to meet power demand)
- Part of DOE's Technology Acceleration and Deployment Activity



Ford Escape Advanced Research Fleet

Number of vehicles: 21 Date range of data received: 11/01/2009 to 04/30/2011  
 Reporting period: Nov 09 - Apr 11 Number of vehicle days driven: 5,425

All Trips Combined

Overall gasoline fuel economy (mpg)	38
Overall AC electrical energy consumption (AC Wh/mi) <sup>1</sup>	101
Overall DC electrical energy consumption (DC Wh/mi) <sup>2</sup>	66
Total number of trips	23,548
Total distance traveled (mi)	299,960

Trips in Charge Depleting (CD) mode<sup>3</sup>

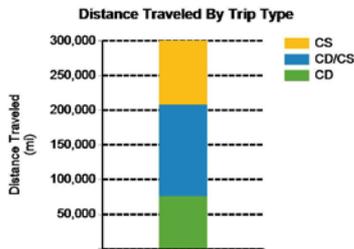
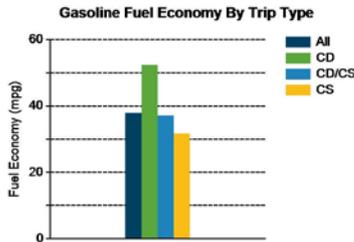
Gasoline fuel economy (mpg)	52
DC electrical energy consumption (DC Wh/mi) <sup>4</sup>	170
Number of trips	13,205
Percent of trips city   highway	84%   16%
Distance traveled (mi)	75,997
Percent of total distance traveled	25%

Trips in both Charge Depleting & Charge Sustaining (CD/CS) modes<sup>5</sup>

Gasoline fuel economy (mpg)	37
DC electrical energy consumption (DC Wh/mi) <sup>6</sup>	55
Number of trips	4,506
Percent of trips city   highway	38%   62%
Distance traveled (mi)	131,484
Percent of total distance traveled	44%

Trips in Charge Sustaining (CS) mode<sup>7</sup>

Gasoline fuel economy (mpg)	32
Number of trips	5,831
Percent of trips city   highway	65%   35%
Distance traveled (mi)	92,478
Percent of total distance traveled	31%



Notes: 1 - 7. Please see <http://avt.inl.gov/pdf/phev/fordreportnotes.pdf> for an explanation of all PHEV Fleet Testing Report notes. Since these vehicles are flex-fuel capable, some driving events are conducted with E-85, which may decrease fuel economy results

\*The Ford Escape Advanced Research Fleet was designed as a demonstration of customer duty cycles related to plug-in electric vehicles. The vehicles used in this demonstration have not been optimized to provide the maximum potential fuel economy.\*

# Ford Escape PHEV 3-Page Report

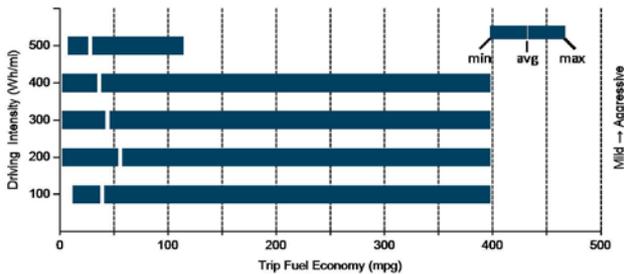
- 300,000 test miles and 24,000 trips
- All trips, 38 mpg, 101 AC Wh/mi & 66 DC Wh/mi
- Charge Depleting (CD), 52 mpg & 170 DC Wh/mi
- Charge Sustaining (CS), 32 mpg
- Plugging in = 63% increase in overall MPG when comparing CD to CS trips
- 56% of miles in CD trips
- 25% of miles in CS trips

Trips in Charge Depleting (CD) mode	City	Highway
Gasoline fuel economy (mpg)	48	57
DC electrical energy consumption (DC Wh/mi)	171	169
Percent of miles with internal combustion engine off	37%	13%
Average trip driving intensity (Wh/mi)	265	305
Average trip distance (mi)	3	17

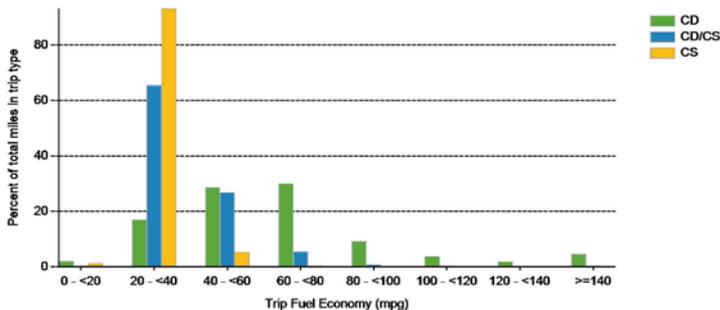
Trips in Charge Depleting and Charge Sustaining (CD/CS) mode	City	Highway
Gasoline fuel economy (mpg)	43	36
DC electrical energy consumption (DC Wh/mi)	79	52
Percent of miles with internal combustion engine off	30%	5%
Average trip driving intensity (Wh/mi)	277	325
Average trip distance (mi)	9	41

Trips in Charge Sustaining (CS) mode	City	Highway
Gasoline fuel economy (mpg)	30	32
Percent of miles with internal combustion engine off	23%	4%
Average trip driving intensity (Wh/mi)	266	321
Average trip distance (mi)	4	38

Effect Of Driving Intensity (Wheel Energy) on Fuel Economy This Month



Trip Fuel Economy Distribution By Trip Type



# Ford Escape PHEV 3-Page Report

- Highway and city cycle impacts
- CD city, 48 mpg, 171 DC Wh/mi
- CD highway, 57 mpg, 169 DC Wh/mi
- CS city, 30 mpg
- CS highway, 32 mpg
- Plugging in = 60% increase in city MPG and 78% increase in highway MPG (compare CD to CS)
- During CD trips 50% miles with engine off
- During CS trips 27% miles with engine off

# Other INL Data Collection Projects – cont'd

- 140 Ram PHEV pickups – same report format as Ford Escape PHEVs (August reporting)
- 150 Chevy Volts data collection (August reporting)
- 20 Lithium PHEV Escape Quantum conversions (SCAQMD) – same format as Ford (August reporting)
- Development of vehicle-based battery test-bed mule for testing emerging battery technologies
- Developing other EVSE data collection activities that support Clean Cities-funded demonstrations with:
  - Aerovironment
  - Eaton
  - Shorepower



# Acknowledgement

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

**Argonne and Oak Ridge National Laboratories provide dynamometer and other testing support**

## More Information

<http://avt.inl.gov>

INL/MIS-11-22496