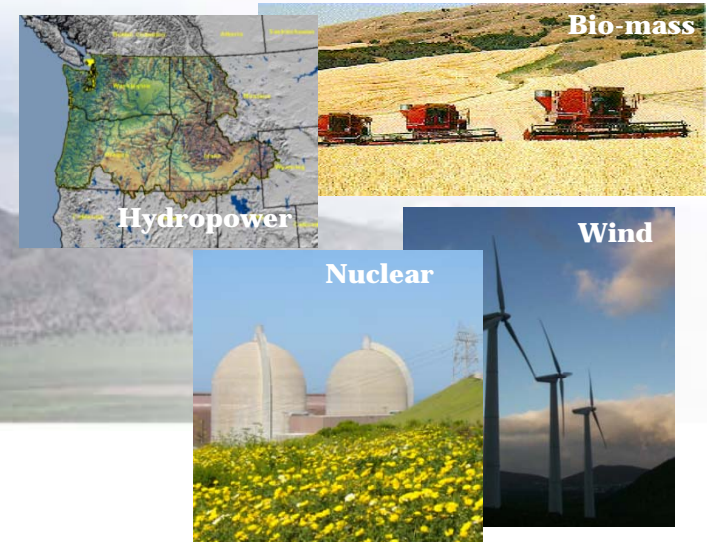


Advanced Vehicle Testing Activity – Plug-in Electric Vehicle Demonstration Results (Thus Far)

John Smart, Idaho National Laboratory
February 23, 2012

Outline

- ▶ Intro to INL and AVTA
- ▶ Plug-in Electric Vehicle Demonstrations
 - Chrysler Ram PHEV
 - Chevrolet Volt EREV
 - Ford Escape PHEV
- ▶ Charging Infrastructure Demonstrations
 - ChargePoint America
 - The EV Project



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 (AVATA)

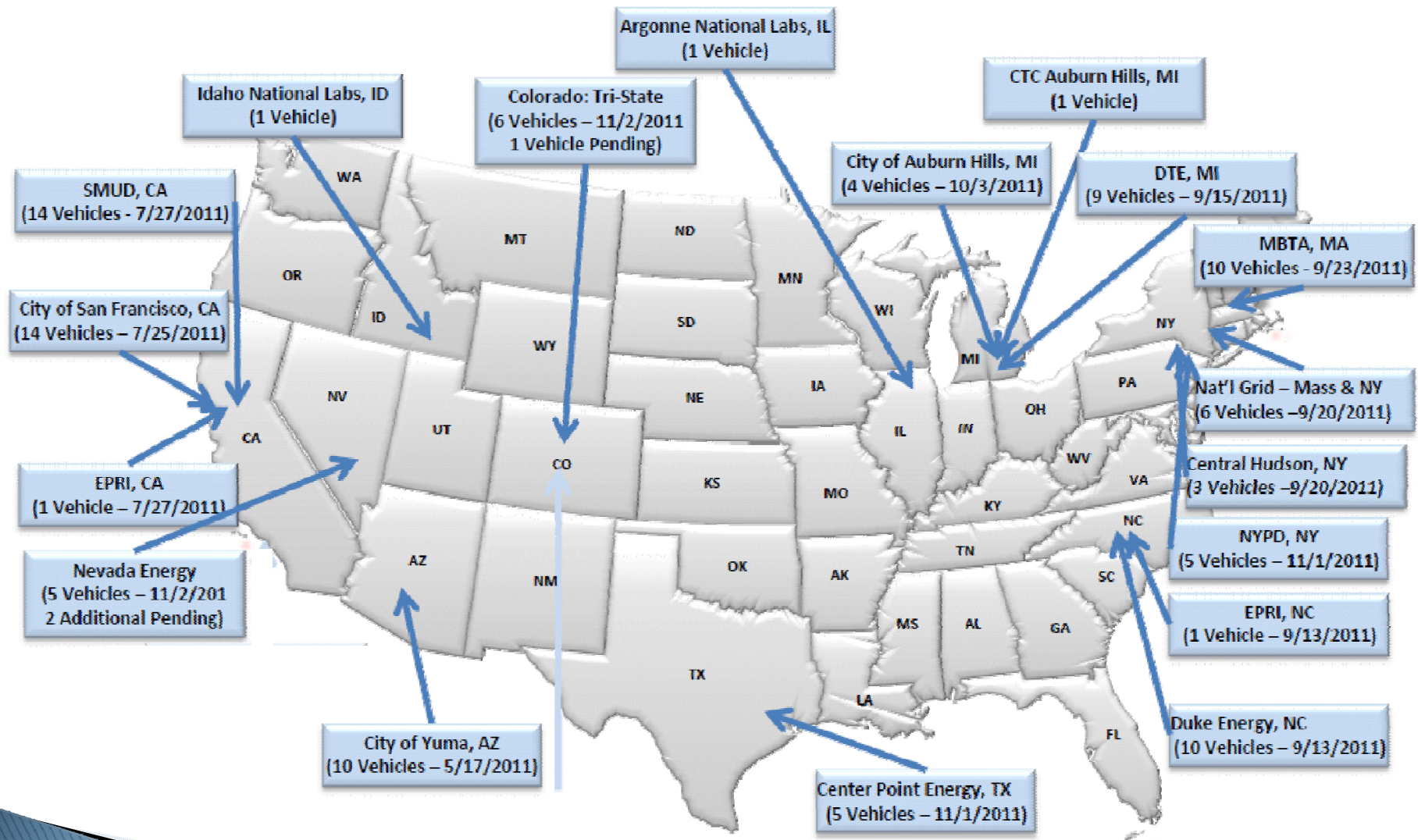
- ▶ Part of DOE's Vehicle Technologies Program
 - INL conducts the light-duty vehicle portion of the AVTA per DOE guidance
 - Many testing activities conducted with ECOtality North America
 - Support also provided to DOE Clean Cities
- ▶ The AVTA goal - Petroleum reduction and energy security
 - Conduct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

Plug-in Electric Vehicle Demonstrations

Chrysler Ram PHEV Demonstration

- ▶ Project partner: Chrysler Group LLC
- ▶ Project sponsor: DOE
- ▶ 140 trucks in commercial fleets
- ▶ INL data collection started mid-2011
 - onboard data loggers and cellular communications
- ▶ Objective is to demonstrate plug-in hybrid electric vehicle (PHEV) pickup trucks in diverse fleets to understand customer usage

Ram PHEV Fleet Locations



Ram PHEV Specs

- ▶ 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

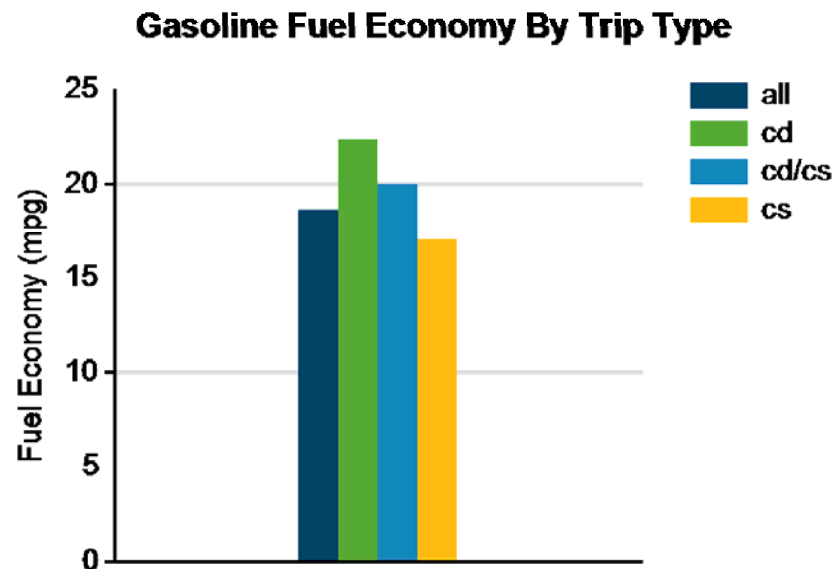
Ram PHEV 2011 Results

July 2011 through December 2011

- ▶ 100 trucks
- ▶ 27,800 trips, 218,900 miles
- ▶ 3,400 charges, 22 AC MWh

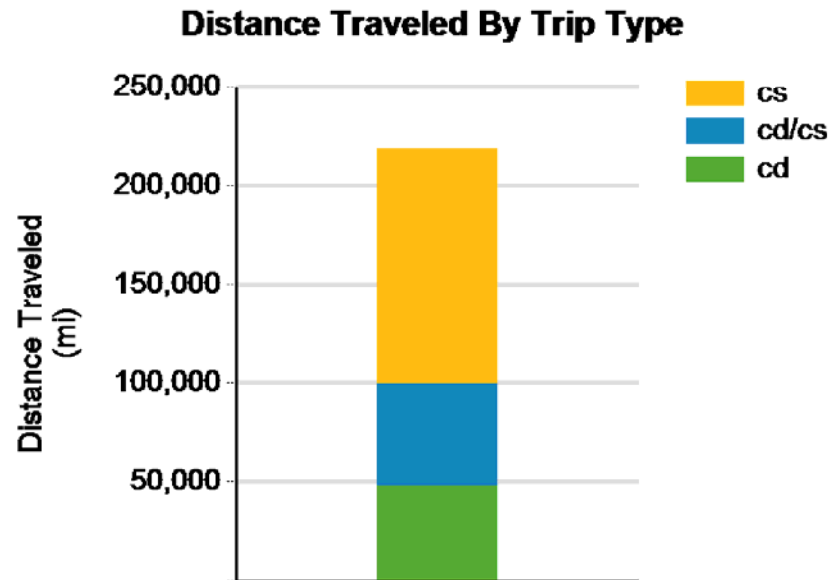
Ram PHEV 2011 Results

- ▶ 30% increase in MPG in charge depleting (CD) vs. charge sustaining (CS) operation



Ram PHEV 2011 Results

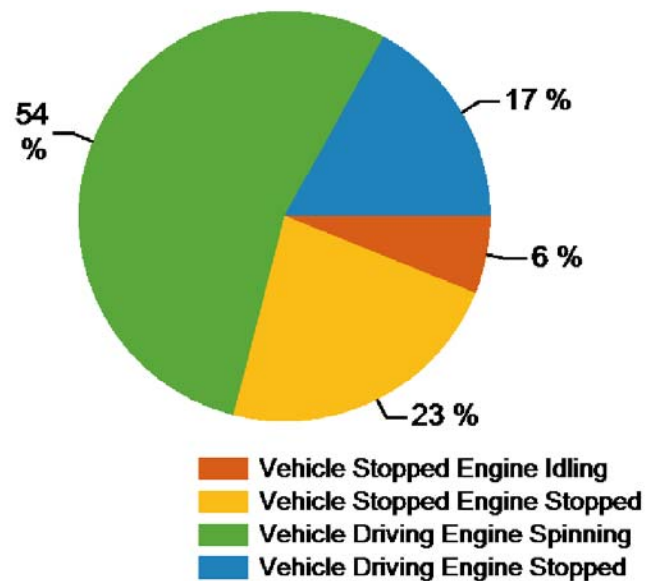
- ▶ 22% of all miles driven in charge depleting-only trips



Ram PHEV 2011 Results

- ▶ 24% of driving time in EV-only mode
- ▶ 79% of stopped time with engine off

Percent of Drive Time by Operating Mode



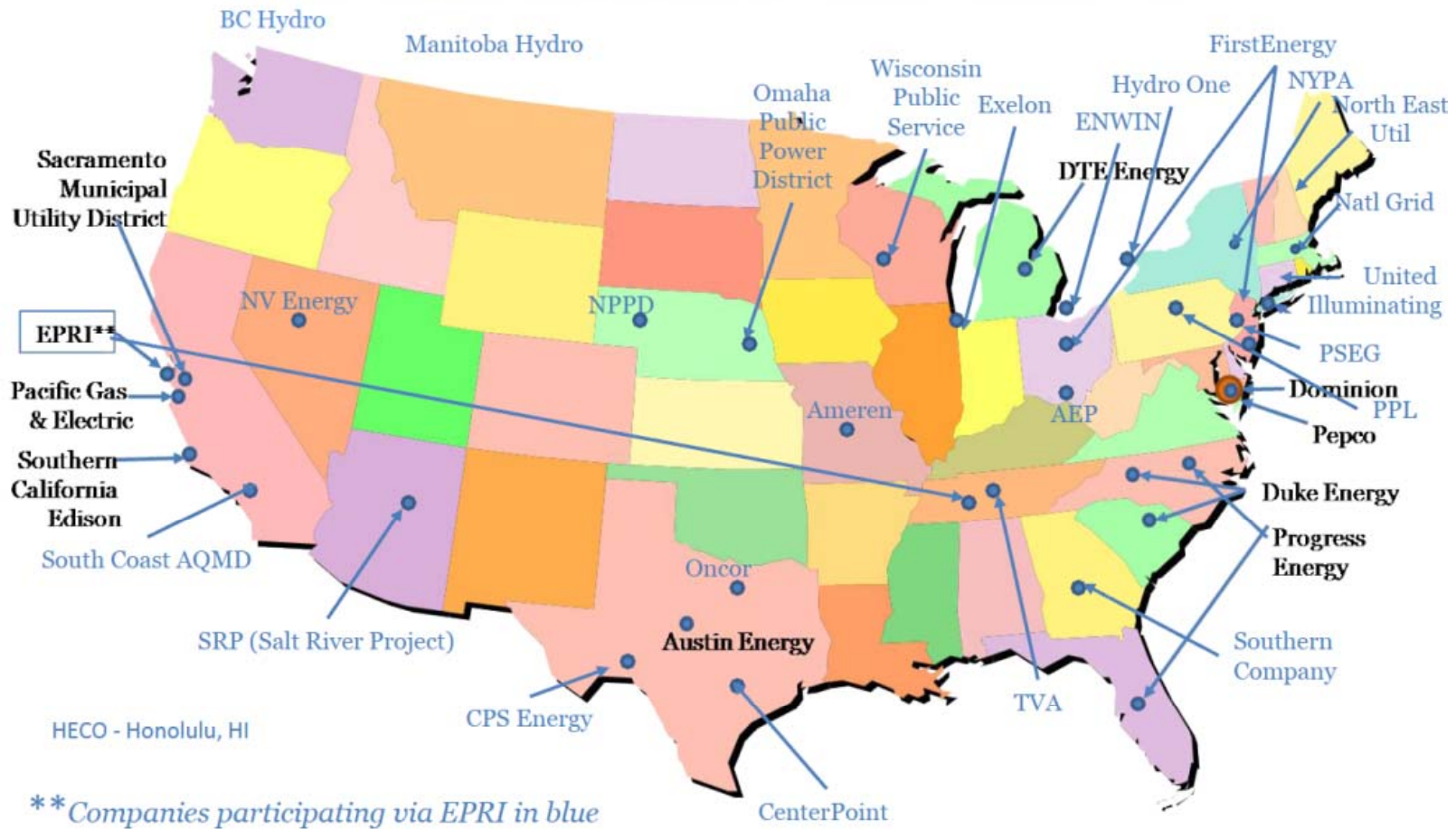
Ram PHEV 2011 Results

- ▶ 0.7 charging events per vehicle day driven
- ▶ 65 miles, 8.2 trips between charging events on average
- ▶ 75% of charging energy from L2 EVSE
- ▶ Most charging done during the day (typical for commercial fleets), with peak demand between 2:00 PM and 3:00 PM

Chevrolet Volt Vehicle Demonstration

- ▶ Project partner: General Motors LLC
- ▶ Project sponsor: DOE
- ▶ 145 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

Volt Demo Fleet Locations



http://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2011/veh_sys_sim/arravt071_vss_cesiel_2011_o.pdf

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



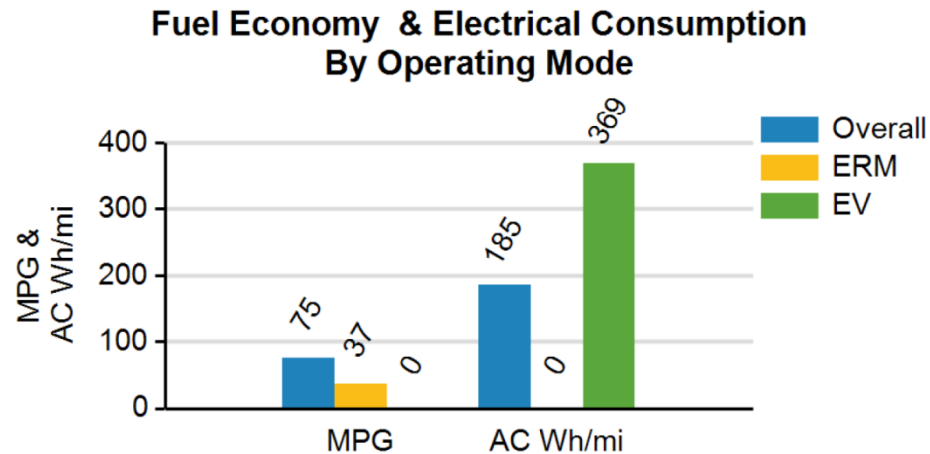
Volt Q3 2011 Results

July 2011 through September 2011

- ▶ 110 vehicles
- ▶ 208,165 miles, 38.6 AC MWh

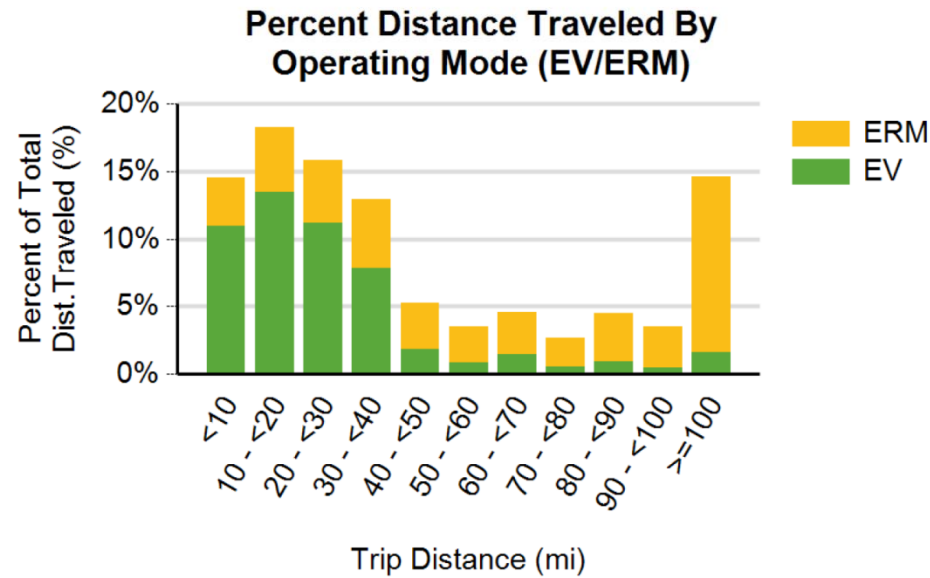
Volt Q3 2011 Results

- ▶ 369 AC Wh/mi in Electric-only (EV) Mode
- ▶ 37 MPG in Extended-range Mode (ERM)
- ▶ 75 MPG, 185 AC Wh/mi overall



Volt Q3 2011 Results

- ▶ 50% of miles driven in EV Mode vs. ERM



Volt Q3 2011 Results

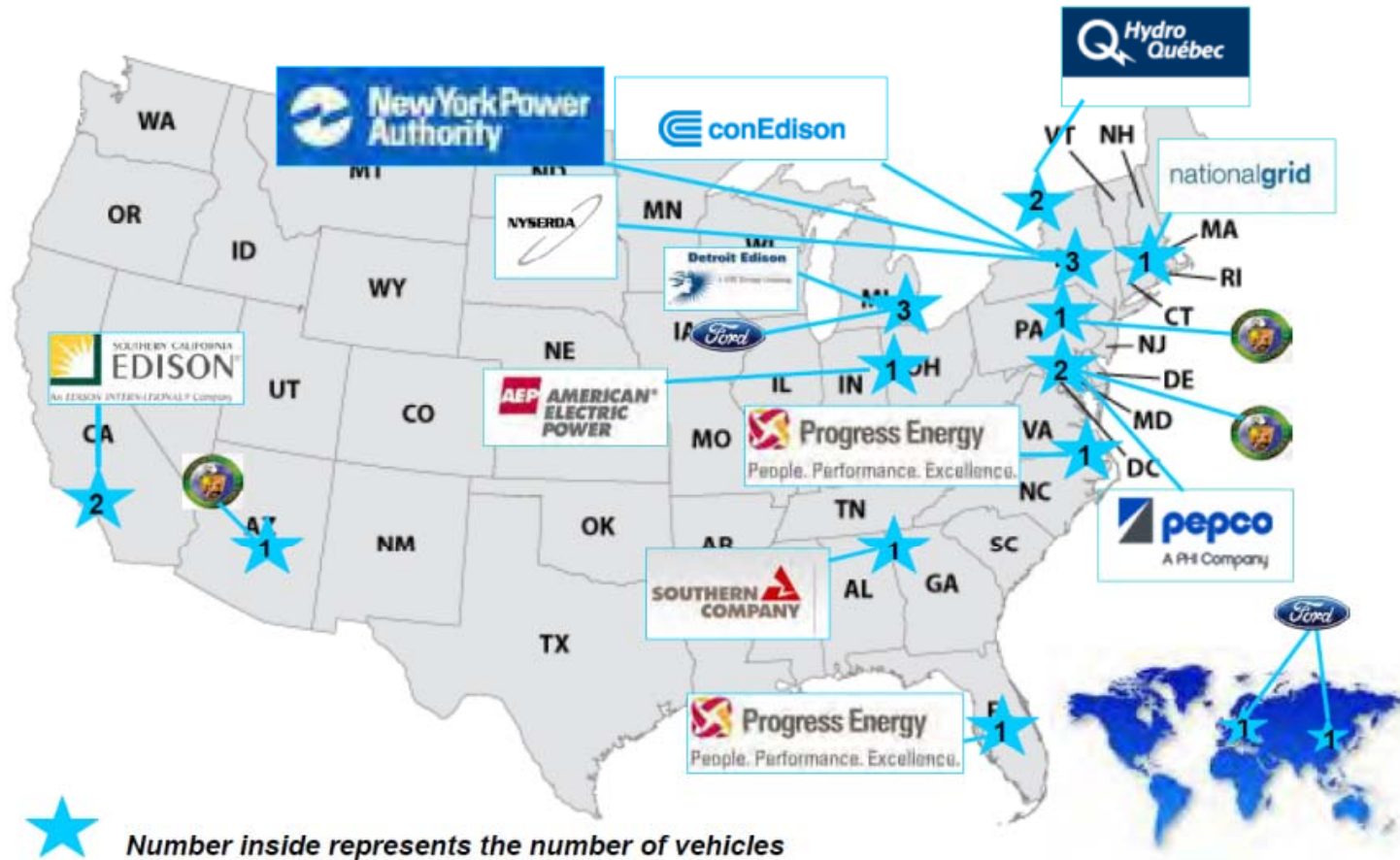
- ▶ Usually driven during the day and plugged in following the drive (typical for commercial fleets), with peak demand between 6:00 PM and 7:00 PM
- ▶ 1.3 charging events per vehicle day driven
- ▶ 44 miles, 3.3 trips between charging events
- ▶ 3.4 hrs drawing power per charging event
- ▶ 119 AC kWh consumed per vehicle month driven

Ford Escape PHEV

Advanced Research Fleet Demonstration

- ▶ Project partner: Ford Motor Company
- ▶ Project sponsor: DOE
- ▶ 21 Escape PHEVs operating in commercial fleets
- ▶ INL data collection started late 2009
 - onboard data loggers and cellular communications
- ▶ 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 Fleet Locations



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

Ford Escape PHEV Specs

- ▶ Blended-mode PHEV
- ▶ Escape Hybrid 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



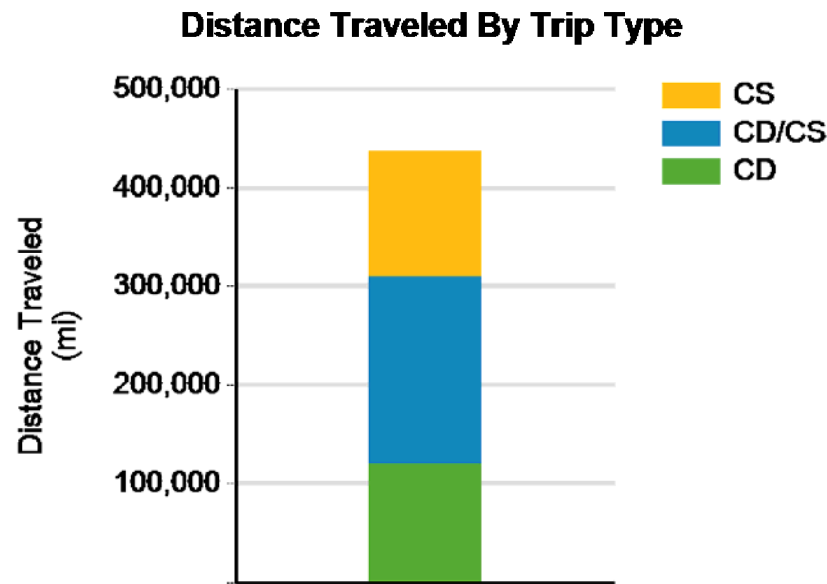
Escape PHEV Results to Date

November 2009 through January 2012

- ▶ 21 vehicles
- ▶ 437,972 miles, 43.3 AC MWh

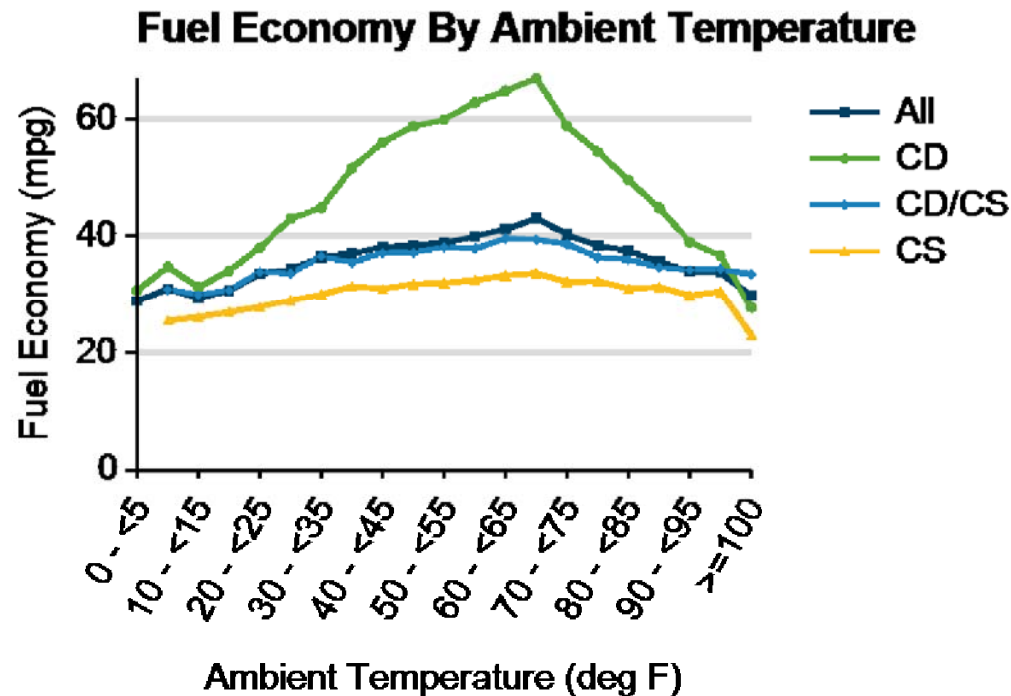
Escape PHEV Results to Date

- ▶ ~50% of all miles driven in CD mode
- ▶ 28% of all miles driven in CD-only trips



Escape PHEV Results to Date

- ▶ Dramatic variation in CD fuel economy as ambient temperature varies



Escape PHEV Results to Date

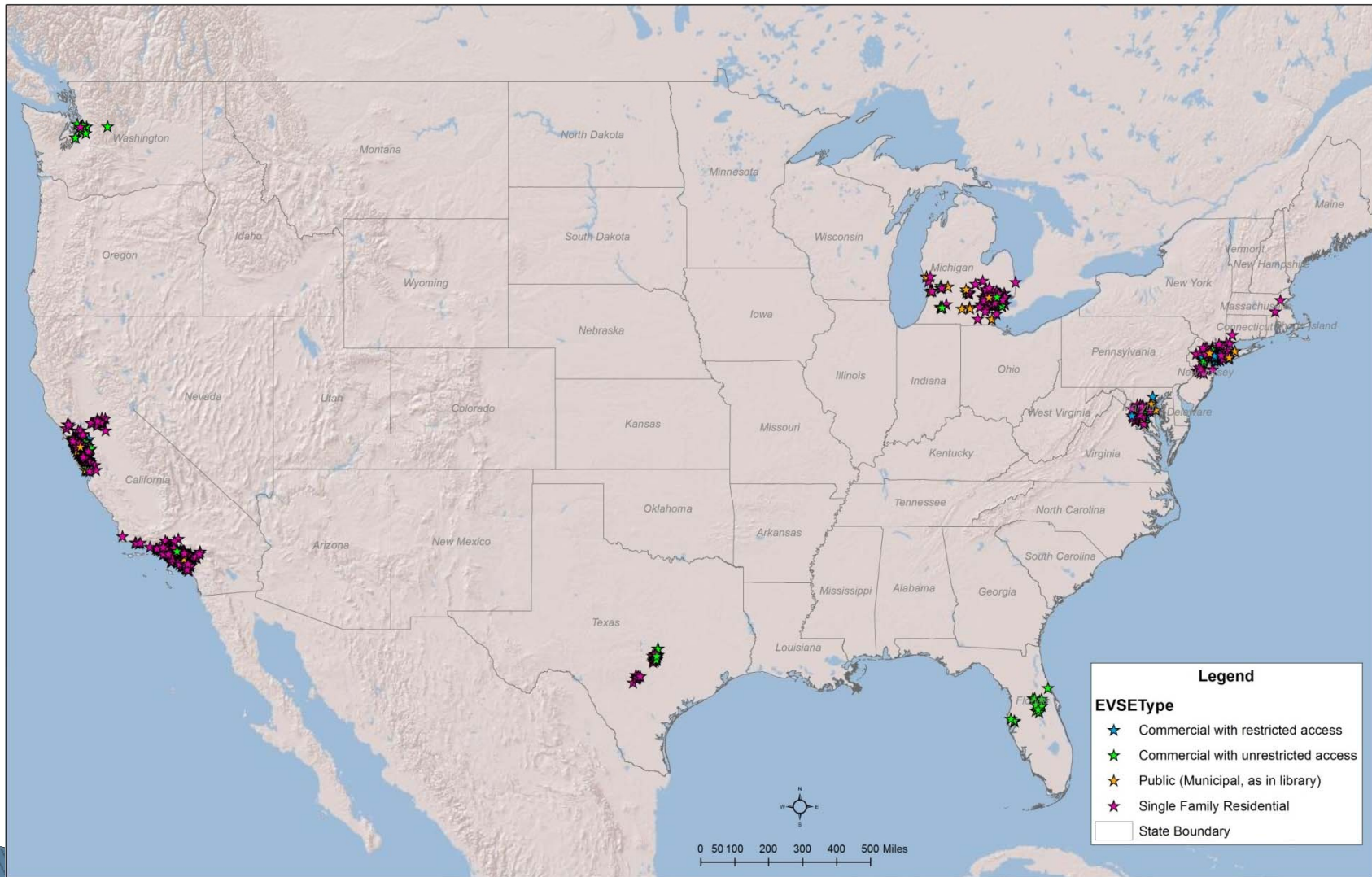
- ▶ Usually driven during the day and plugged in following the drive (typical for commercial fleets), with peak demand between 9:00 and 10:00 PM
- ▶ 1.8 charging events per vehicle day driven
- ▶ 31.5 miles, 2.6 trips between charging events
- ▶ 82 AC kWh consumed per vehicle month driven

Charging Infrastructure Demonstrations

ChargePoint Amercia Infrastructure Demo

- ▶ Project partner: Coulomb Technologies LLC
- ▶ Project sponsor: DOE
- ▶ 4,700 residential and public electric vehicle supply equipment (EVSE) units in 11 states and District of Columbia
- ▶ INL data collection started May 2011
- ▶ Objective is to understand customer usage of residential and public EVSE

ChargePoint America Locations



ChargePoint EVSE Specs

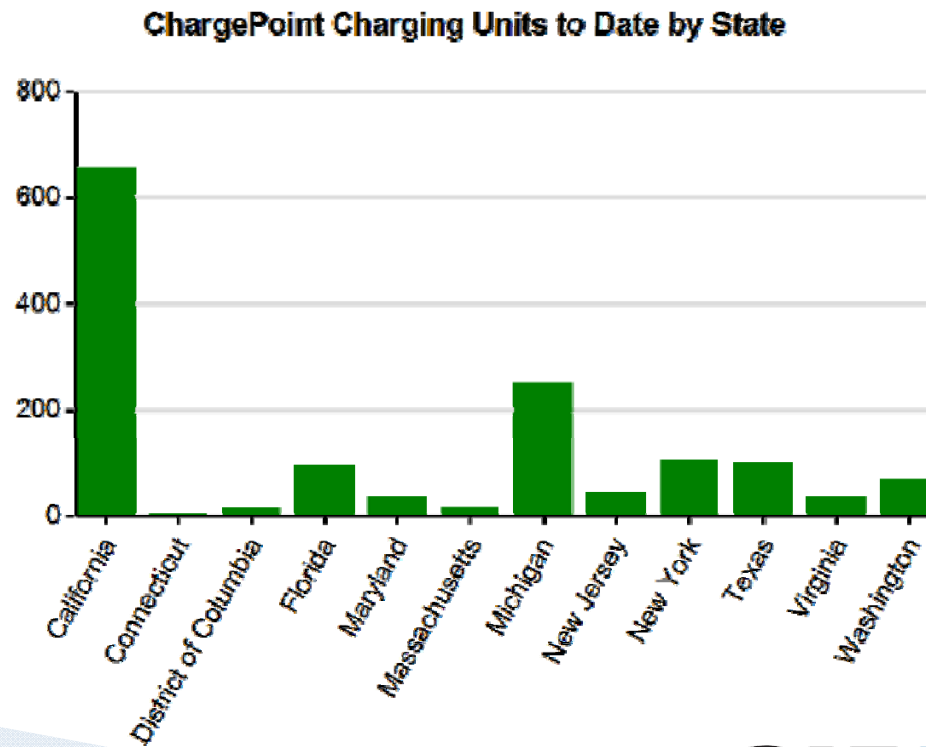
AC level 2 residential and commercial EVSE

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



ChargePoint America Results to Date

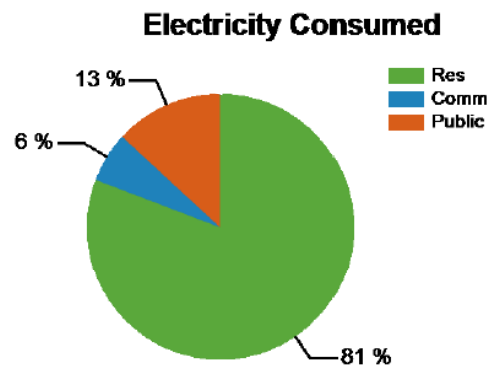
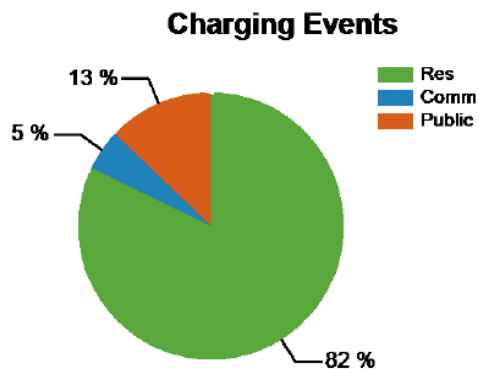
- ▶ May 2011 through December 2011
 - 1,432 EVSE units
 - 130,329 charging events, 870 AC MWh



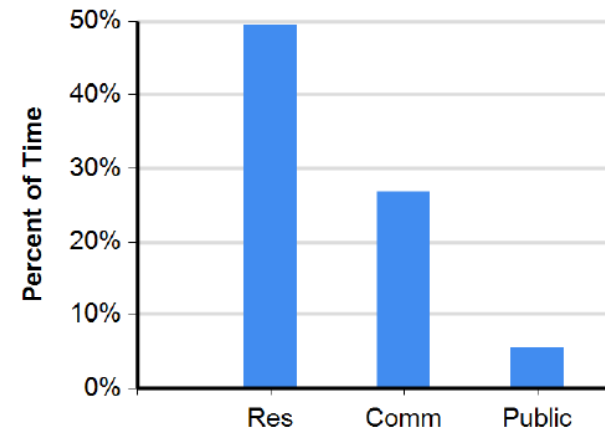
ChargePoint America Results to Date

Charging Unit Usage - By Type

	Residential	Private Commercial	Public
Charging units installed ¹	694	110	624
Charging events performed ²	107,600	6,200	16,381
Electricity consumed (AC MWh)	699.87	52.98	116.85
Percent of time with a vehicle connected	50%	27%	6%
Average electricity consumed per charging event (AC kWh)	6.5	8.5	7.1



Charging Unit Utilization



■ Percentage of Time with a vehicle connected

The EV Project Infrastructure Demo

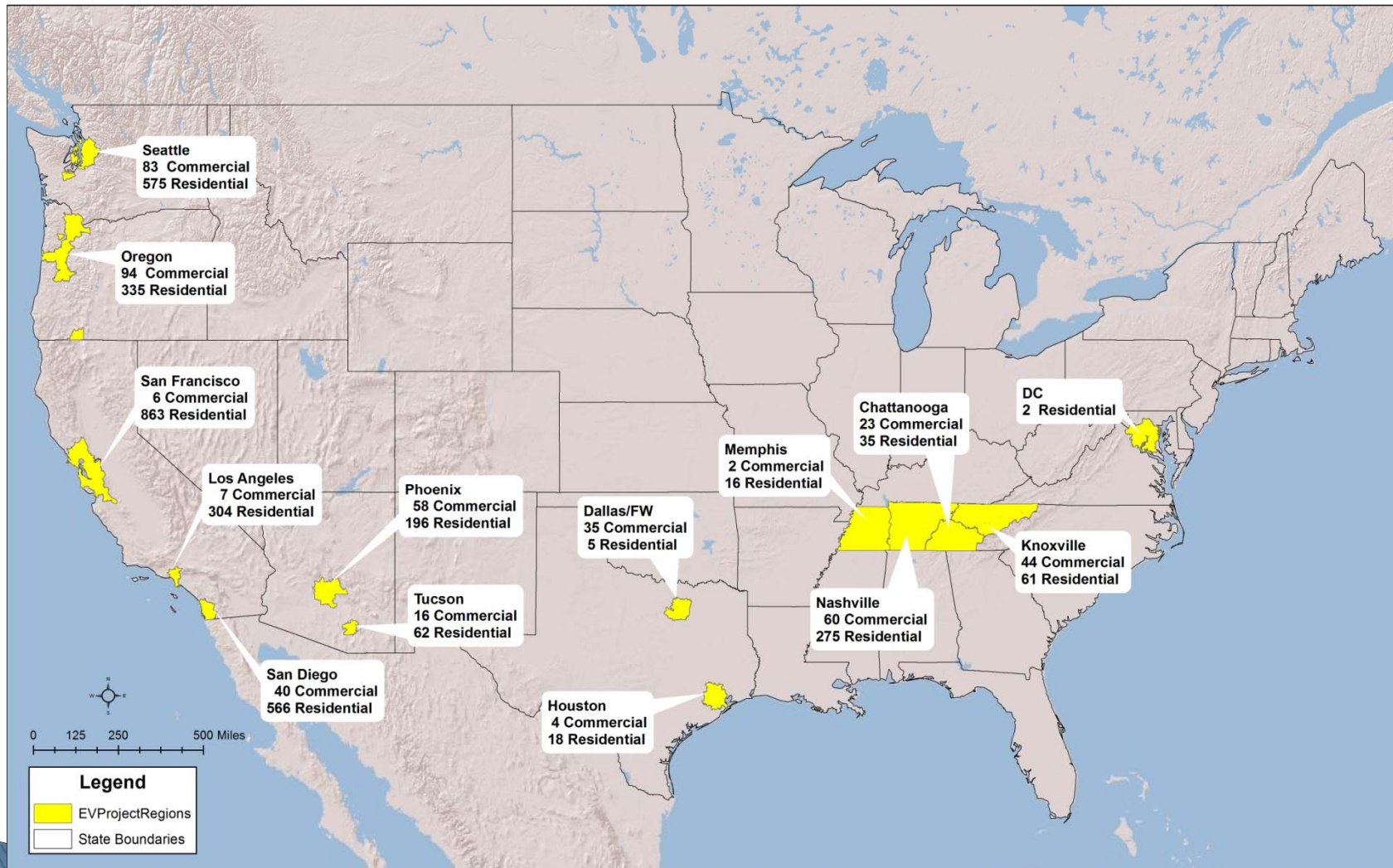
- ▶ Project partner: ECOtality North America
- ▶ Project sponsor: DOE
- ▶ >10,000 residential and public EVSE units
- ▶ >5,000 privately owned Nissan Leafs and Chevrolet Volts
- ▶ INL data collection started Jan 2011

The EV Project Infrastructure Demo

- ▶ Build mature EV charging infrastructure in 14 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

The EV Project Locations

Blink AC Level 2 EVSE Enrolled in The EV Project through December 2011



Nissan LEAF™ Specs

- ▶ Battery electric vehicle
- ▶ 80 kW motor
- ▶ 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
- ▶ Navigation screen interface and website for charge start/end scheduling
- ▶ Data acquisition via vehicle telematics



Blink EVSE Specs

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

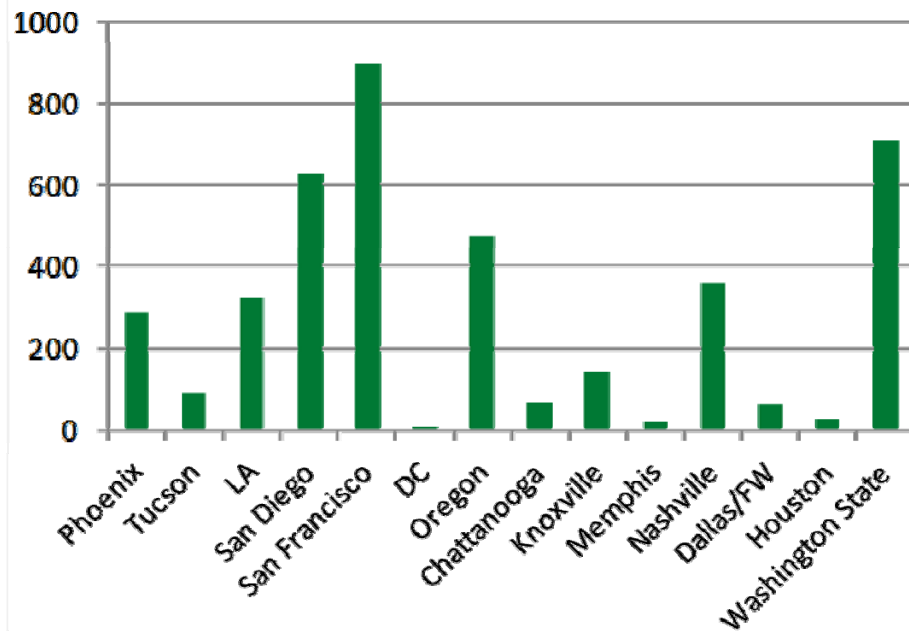
- ▶ 480 VAC 3 phase, 60 kW
- ▶ Two CHAdeMo connectors per charger
- ▶ Networked with data collection
- ▶ Touch screen user interface, RFID authentication



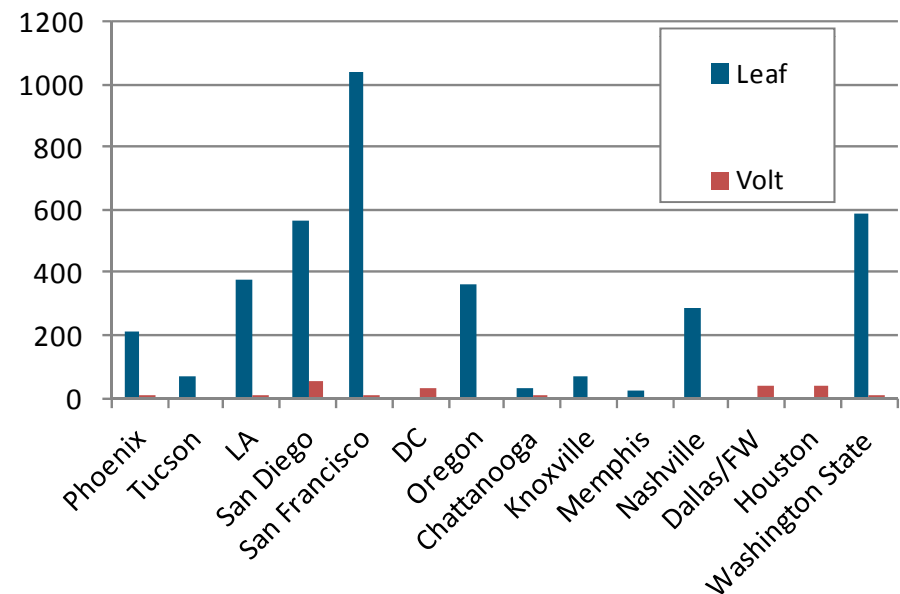
The EV Project 2011 Results

- ▶ 3,785 EVSE
- ▶ 3,629 LEAFs, 218 Volts

Number of EV Project EVSE Installed to Date*



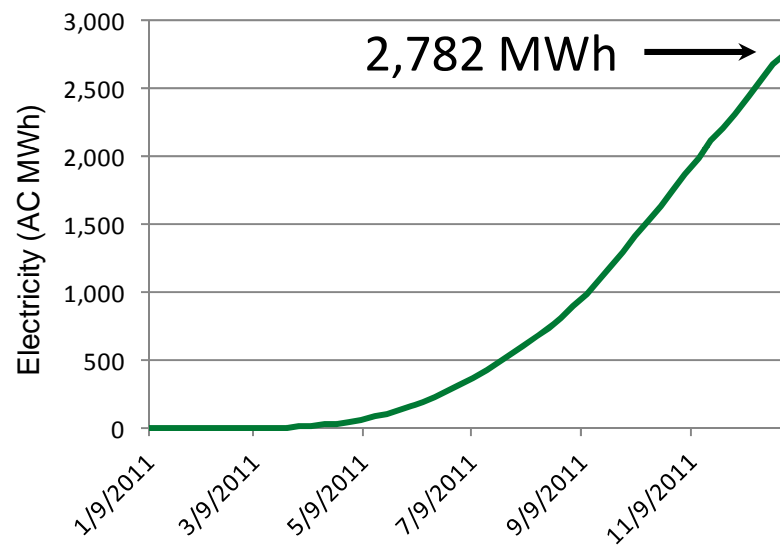
Number of EV Project Vehicles Enrolled to Date*



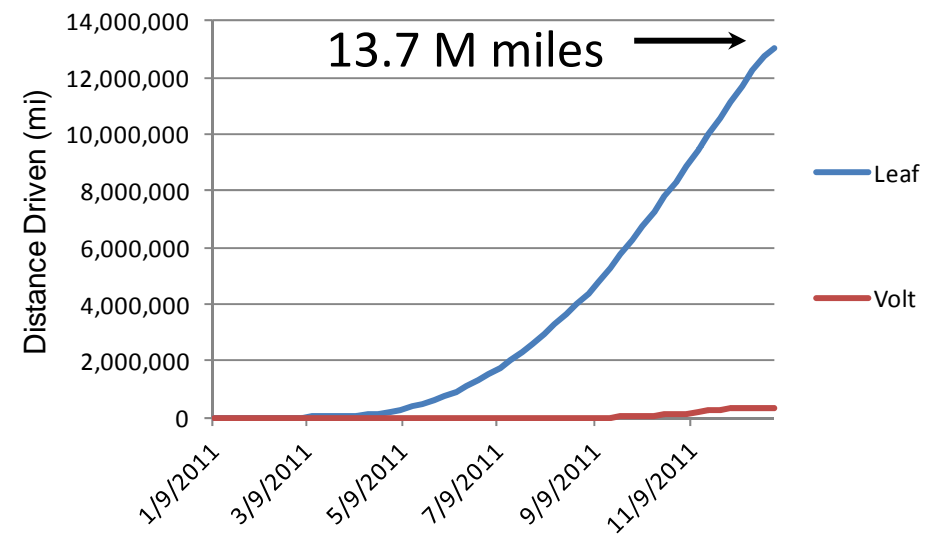
* Based on count of EVSE and vehicles from which INL has received usage data through Dec 2011

The EV Project 2011 Results

Electricity Consumed by
EV Project EVSE through 2011



Miles Accumulated by EV
Project Vehicles through 2011



The EV Project Q4 2011 Results

► Nissan LEAF Driving Statistics

Number of vehicles with matching residential EVSE	2,645
Number of trips	707,330
Total distance driven (mi)	4,878,735
Mean trip distance (mi)	6.9
Mean number of trips between charging events	4.0
Mean distance driven between charging events (mi)	30.0
Mean distance driven per vehicle day driven (mi)	27.7

The EV Project Q4 2011 Results

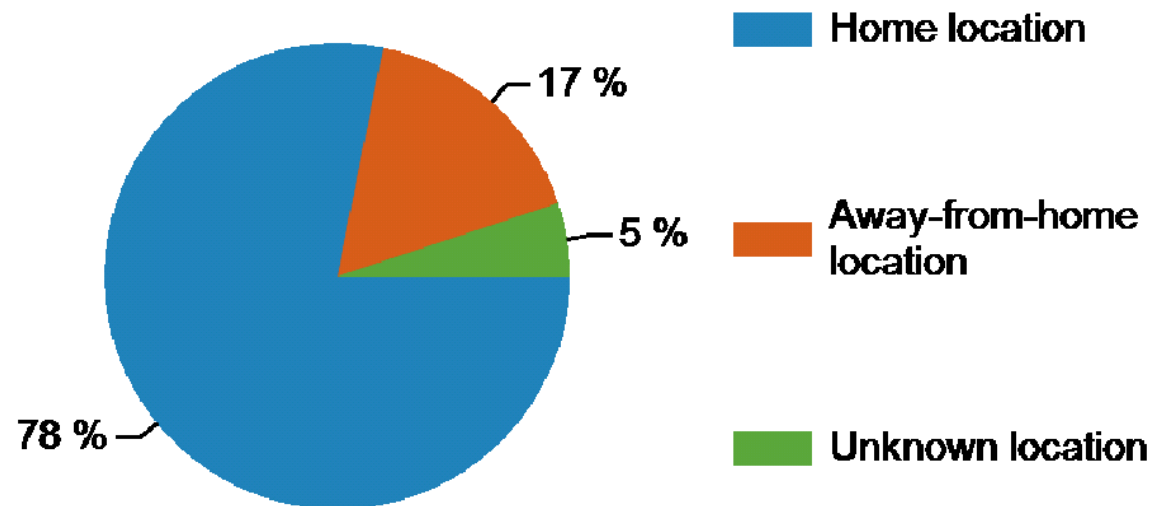
► Nissan LEAF Charging Statistics

Total number of charging events	176,362
Mean number of charging events per vehicle day driven	1.1

The EV Project Q4 2011 Results

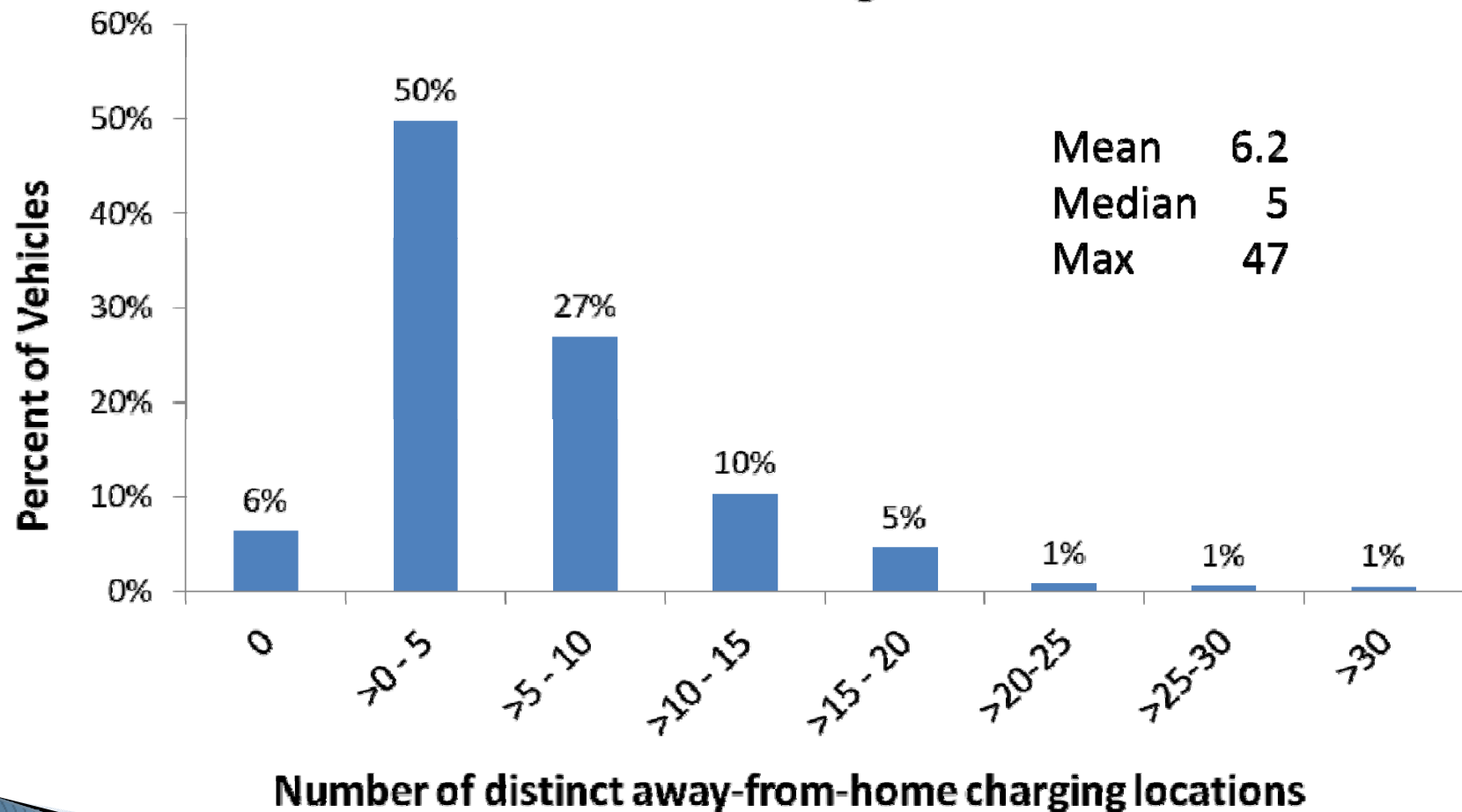
► Nissan LEAF Charging Statistics

**Frequency of Charging by
Charging Location**



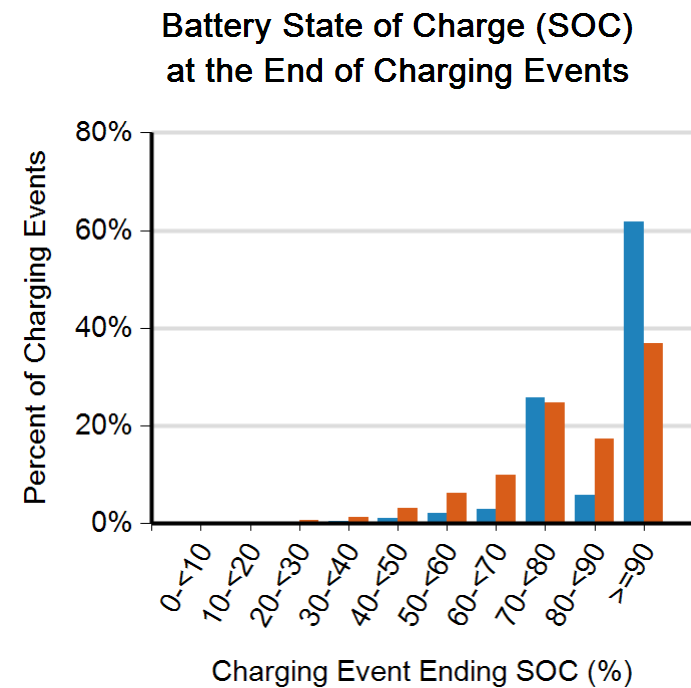
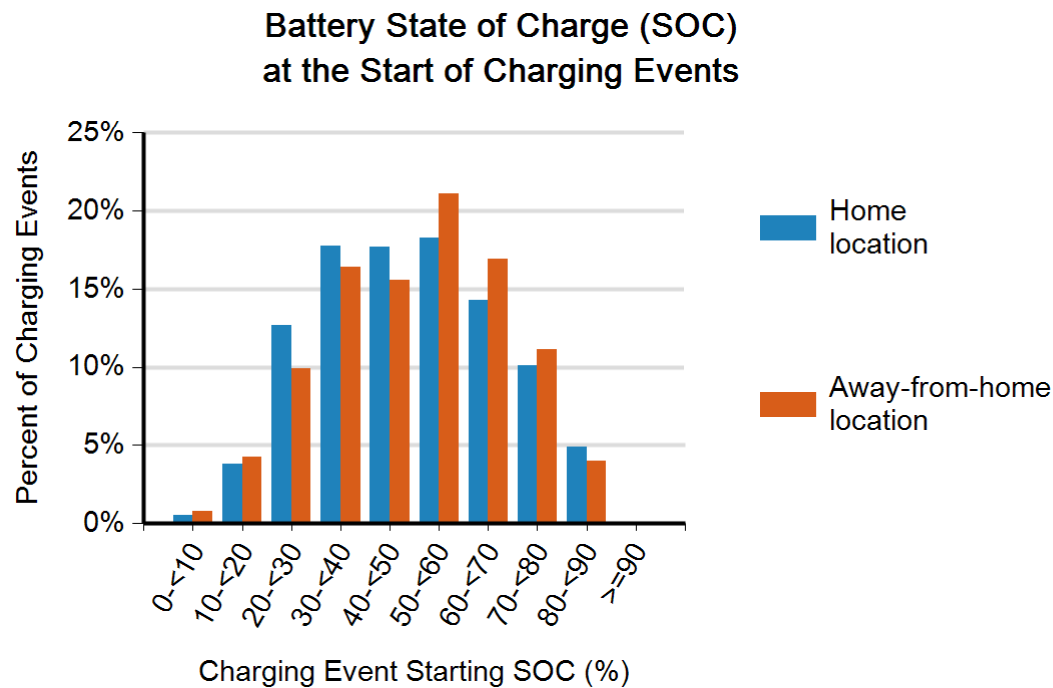
The EV Project Q4 2011 Results

**Distribution of Number of Away-from-home Charging Locations
Where Each Vehicle Has Charged at Least Once**



The EV Project Q4 2011 Results

► Nissan LEAF Charging Completeness



The EV Project Q4 2011 Results

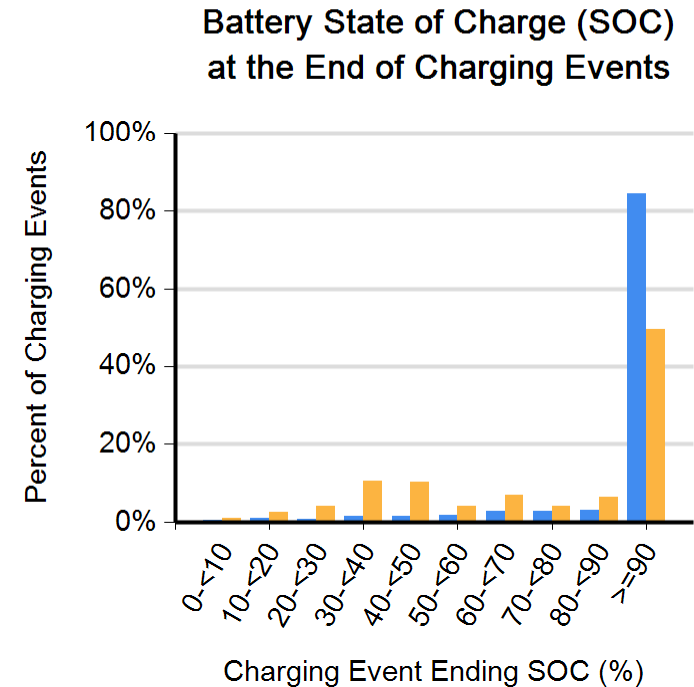
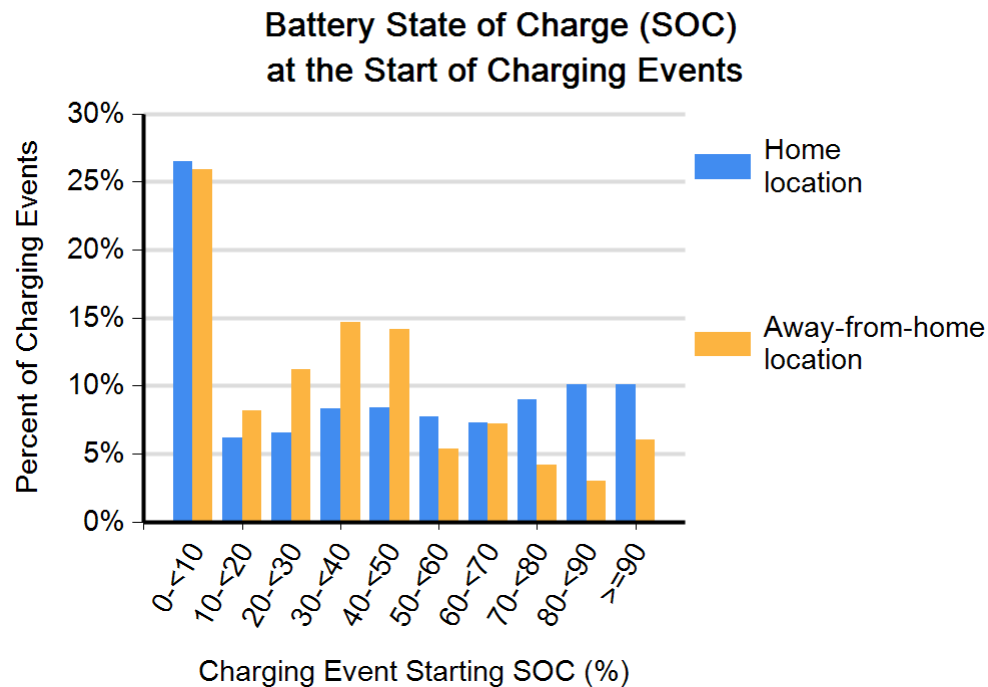
▶ Chevrolet Volt Driving and Charging Statistics

Number of vehicles with matching residential EVSE	45
Overall fuel economy (mpg)	131
Overall electrical energy consumption (AC Wh/mi)	271
Number of trips	13,819
Total distance driven (mi)	108,115
Mean trip distance (mi)	7.8
Mean number of trips between charging events	3.5
Mean distance driven between charging events (mi)	27.1
Mean distance driven per vehicle day driven (mi)	38.0

Total number of charging events	3,994
Mean number of charging events per vehicle day driven	1.4

The EV Project Q4 2011 Results

▶ Chevrolet Volt Charging Completeness

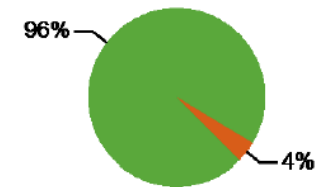


Blink EVSE Usage Q4 2011

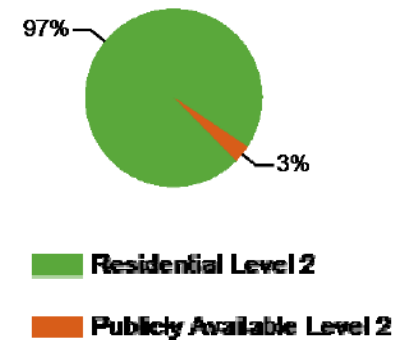
Charging Unit Usage

	Residential Level 2	Publicly Available Level 2
Number of charging units ¹	2,704	438
Number of charging events ²	159,225	6,372
Electricity consumed (AC MWh)	1,253.63	41.42
Percent of time with a vehicle connected to charging unit	32%	6%
Percent of time with a vehicle drawing power from charging unit	6%	2%

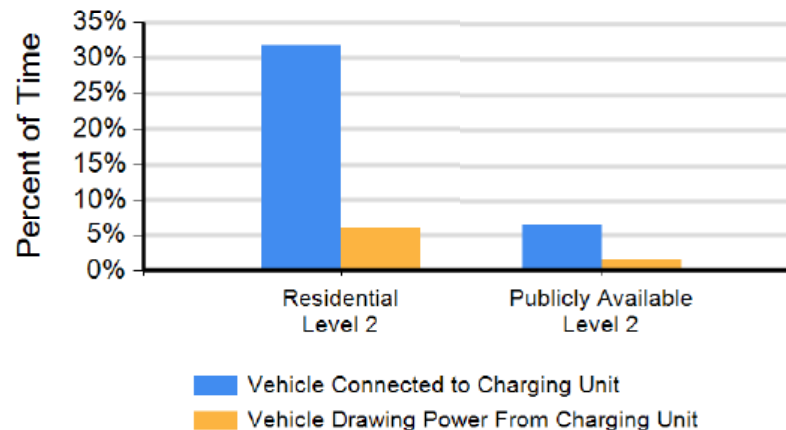
Number of Charge Events



Electricity Consumed



Charging Unit Utilization



Blink EVSE Usage Q4 2011

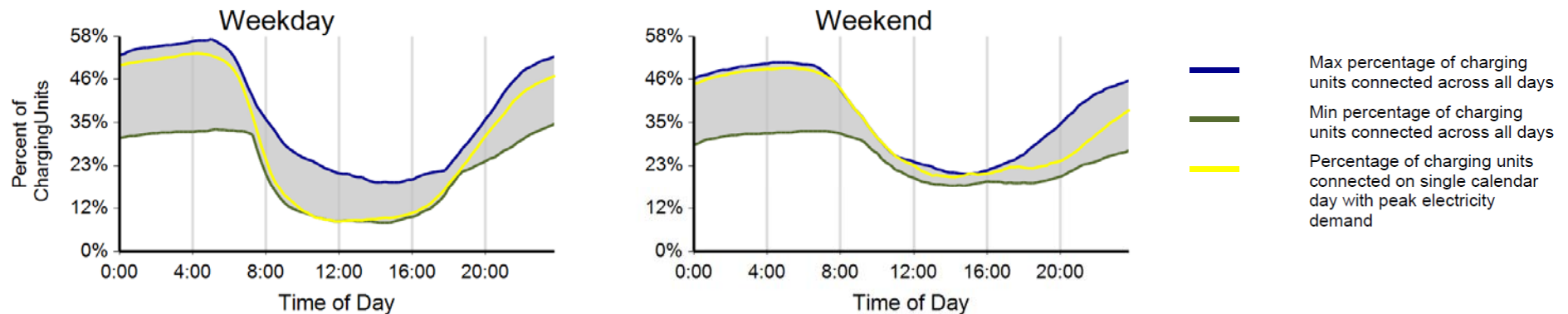
Individual charging event statistics

	Residential AC Level 2			Publicly Available AC Level 2		
	Weekday	Weekend	Overall	Weekday	Weekend	Overall
Average length of time with vehicle connected per charging event (hr)	11.6	11.4	11.5	7.7	4.9	7.2
Average length of time with vehicle drawing power per charging event (hr)	2.3	1.9	2.2	1.9	1.5	1.8
Average electricity consumed per charging event (AC kWh)	8.3	6.9	7.9	6.7	5.3	6.5

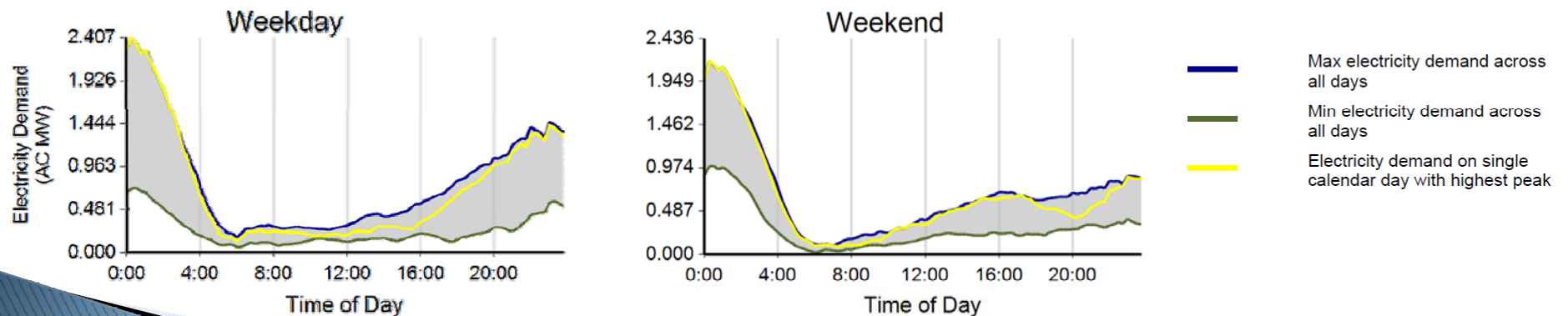
Blink Time of Day Usage Q4 2011

All Residential EVSE

Range of Percent of Charging Units with a Vehicle Connected versus Time of Day



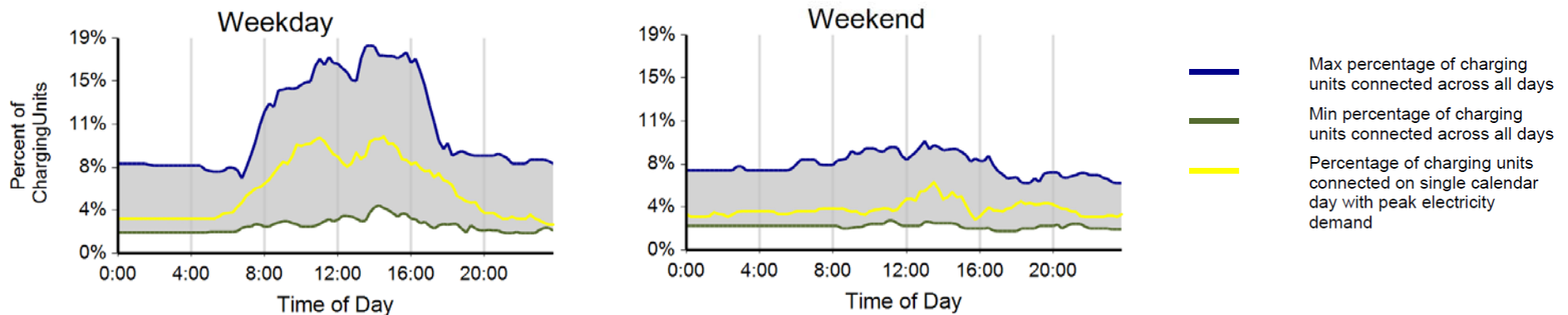
Range of Aggregate Electricity Demand versus Time of Day



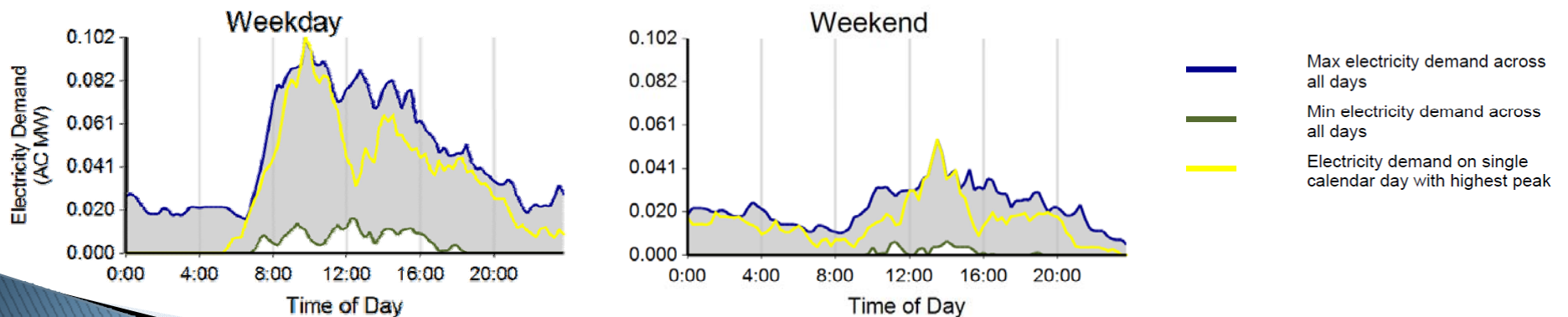
Blink Time of Day Usage Q4 2011

All Commercial EVSE

Range of Percent of Charging Units with a Vehicle Connected versus Time of Day



Range of Aggregate Electricity Demand versus Time of Day



Summary

Vehicles

- ▶ 27 – 65 miles on average between charging events
- ▶ 0.7 – 1.8 charging events per day

EVSE

- ▶ Avg time connected to vehicle per charging event
 - 11 hrs residential
 - 5 – 8 hrs public
- ▶ Avg time with vehicle drawing power per charging event
 - 2 – 2.5 hrs residential
 - 1.5 – 2 hrs public
- ▶ Avg energy consumed per charging event
 - 6.5 – 8 kWh residential
 - 5 – 7 kWh public

Summary

EV Project

- ▶ Time-of-use rates in some areas are influencing drivers to schedule charging off peak
- ▶ Sharp spike at beginning of off-peak period brings a different set of challenges

EV Project Conclusions

Too early to draw conclusions!

- ▶ Slow economy has affected deployment rate
- ▶ Vehicle owners are early in ownership experience
- ▶ Public EVSE roll-out is in early stages
 - Only 1/5 of installations completed
 - Public charging has been free; in the future it won't be

Additional Information

Quarterly and project-to-date reports and other information available at AVTA website:

<http://avt.inl.gov>

Acknowledgements

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

INL/CON-11-24279