PEVs in North America and Charging Infrastructure Use

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Idaho National Laboratory

Idaho National Laboratory

- U.S. Department of Energy (DOE) 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

Vehicle / Infrastructure Testing Experience

- **Since 1994, INL has benchmarked PEVs and electric vehicle supply equipment (EVSE) with telematics systems in the field, and on closed test tracks and dynamometers**
  - **250 million test miles of data from 27,000 electric drive vehicles and 16,600 charging units**
  - **EV Project: 8,228 Leafs, Volts and Smarts, 12,363 EVSE and DCFC**
    - **4.2 million charge events, 124 million test miles. At one point, 1 million test miles every 5 days**

- **PEVs include both electric (EV) and plug-in hybrid electric (PHEV) vehicles**

Plug-in Electric Vehicles and Charging Infrastructure in North America

Charging Nomenclature

- **EVSE (electric vehicle supply equipment)**
  - **AC Level 1: 120V AC (up to 16 Amps, 1.92 kW Max)**
  - **AC Level 2: 240V AC (up to 80 Amps, 19.2 kW Max)**
- **DCFC: (DC fast chargers) 440V. Three DCFC technologies**
  - **Japanese CHAdeMO protocol connector**
  - **SAE standard connector (SSC)**
  - **Tesla DCFC**
  - **The three are mostly not compatible**
- **Most PEVs have onboard chargers that operate at 3.3 or 6.6 kW, one PEV charges at 10 kW**

SAE Combo Connector for DCFC

SAE J1772. Levels 1 & 2 connector

AC Levels 1 and 2 EVSE Description

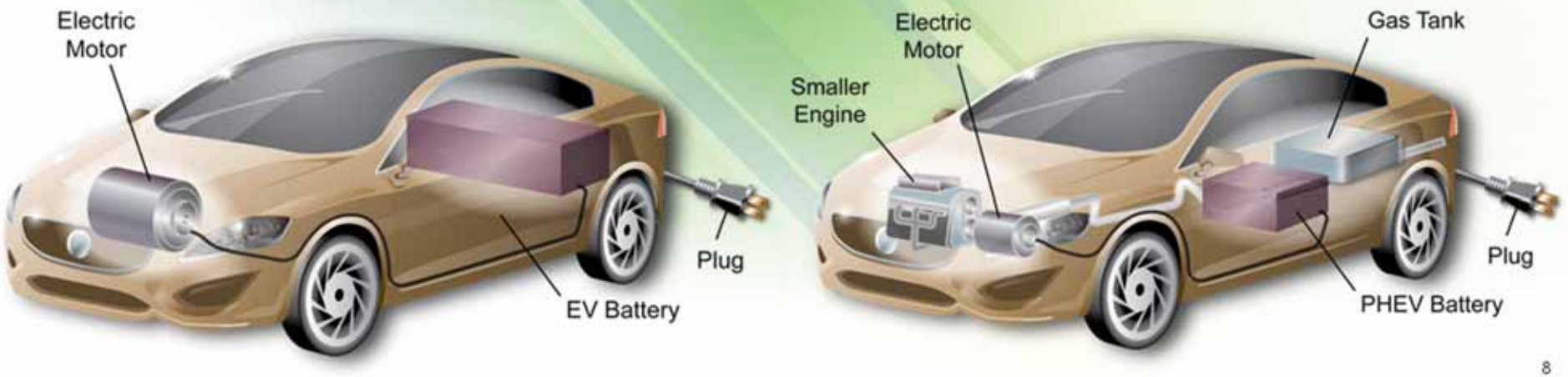
- **EVSE is a piece of equipment that allows a PEV to be safely connected to the grid via a SAE J1772 connector**
- **EVSE are not chargers**
- **Bridges the PEV and electric grid gap**
- **Provides electricity to the PEV's on-board power electronics and on-board charger**
- **Suited for fleets, public access and residential locations**

DC Fast Charger (DCFC) Description

- It is a charger that sits off-board the vehicle
- Converts AC grid energy to DC vehicle energy
- Larger and more expansive than AC Level 1 and 2 EVSE, but it charges a PEV much faster
- Today's DCFC charge up to 50 or 120 kW
- Provides electricity directly to the vehicle's battery
- Requires sophisticated DCFC-to-PEV communication
- Suited for fleets and public access

Vehicle Nomenclature

- **PEV: plug-in electric vehicle that connects to the grid to recharge the traction battery pack**
  - **BEVs: battery electric vehicle, all electric**
  - **PHEVs: plug-in hybrid electric vehicle, blended electric and internal combustion engine operations schemes**
  - **EREVs: extended range electric vehicle, operates as a BEV first, and when electric range has been exceeded, operates like a normal PHEV**



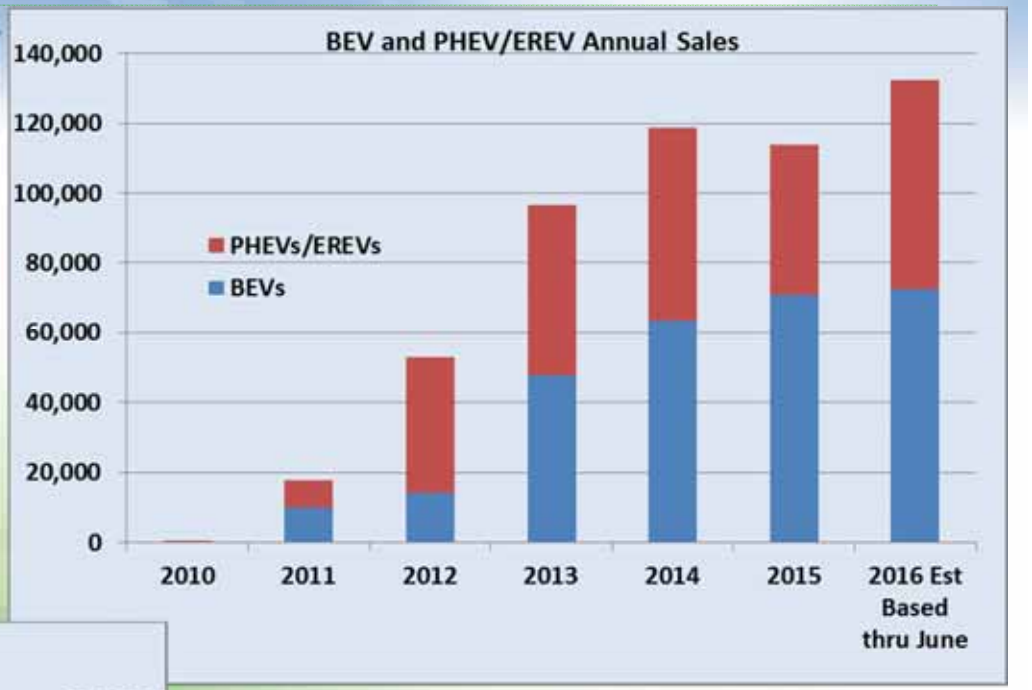
2016 U.S. BEVs and PHEVs/EREVs

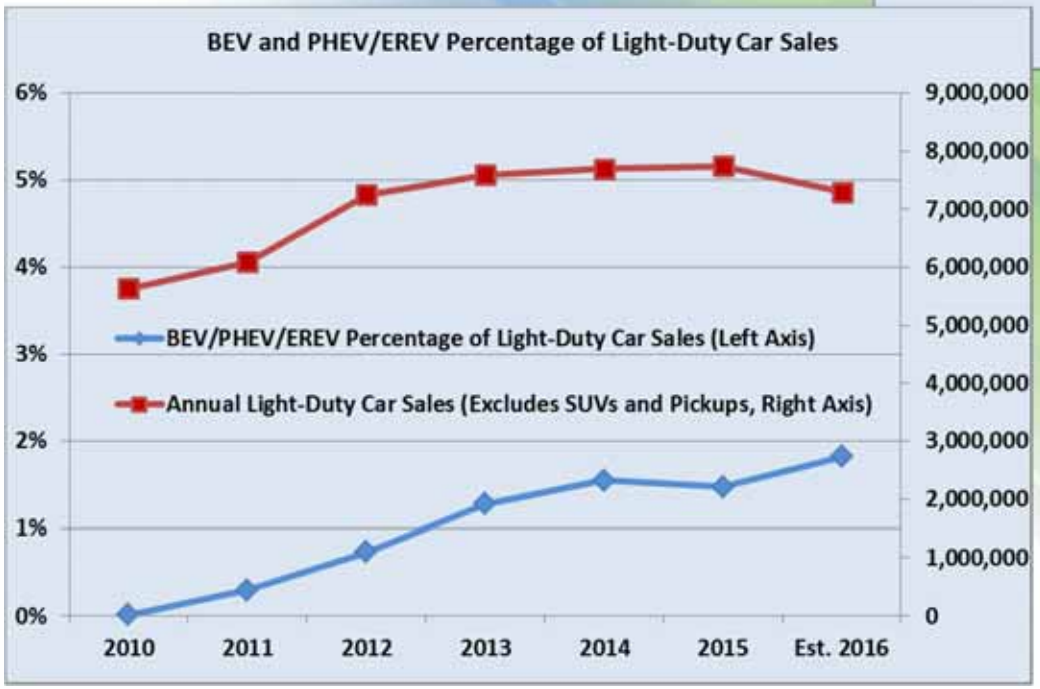
- **27 PEV models sold during 2016 in the U.S.**

BEVs	PHEVs/EREVs	
Tesla Model s	BMW 330e	BMW X5 xDrive 50e
Tesla Model X	Mercedes S550H PHEV	Audi A3 Sprtbk e-tron
Nissan Leaf	Toyota Prius PHEV	Hyundai Sonata PHEV
Fiat 500e	Mercedes GLE 550e	Porsche Cayene S-E
Chevrolet Spark EV	BMW i8	Volvo XC90
VW e-Golf	Cadillac ELR	
Kia Soul EV	Porsche Panamera S-E	
Ford Focus Electric	Chevrolet Volt	
Smart ED	Ford Fusion Energi	
Mercedes B250e	Ford C-Max Energi	
Mitsubishi i-MiEV	BMW i3	

PEV U.S. Annual Sales

- PEV cumulative sales of 533,000 (June 2016)
- 114,000 PEVs were sold in 2015, 4% decrease over 2014

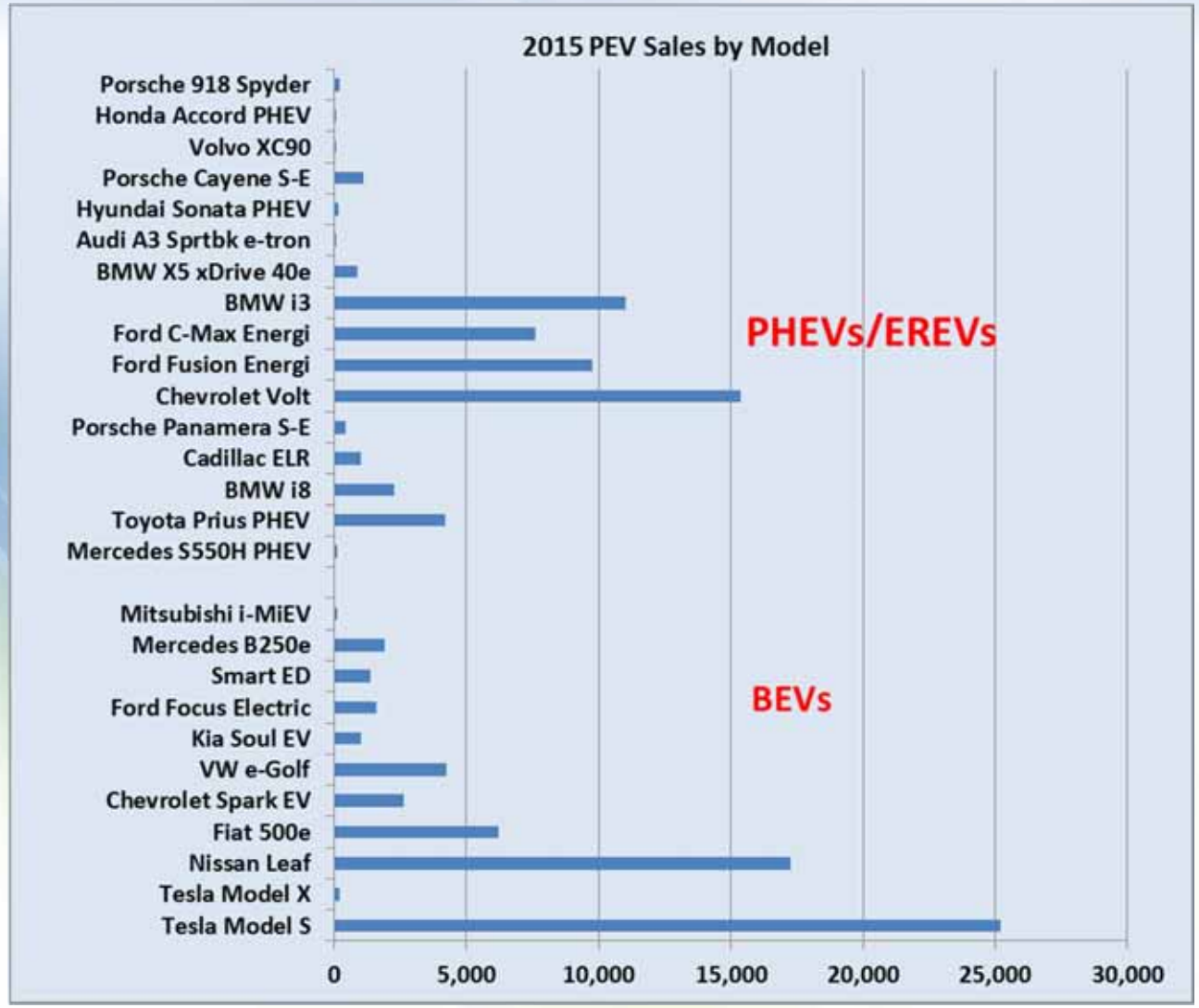




Sources:
http://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952
http://www.afdc.energy.gov/data/10314
http://online.wsj.com/mdc/public/page/2_3022-autosales.html
http://www.detroitnews.com/story/business/autos/2016/01/05/auto-sales/78295542/

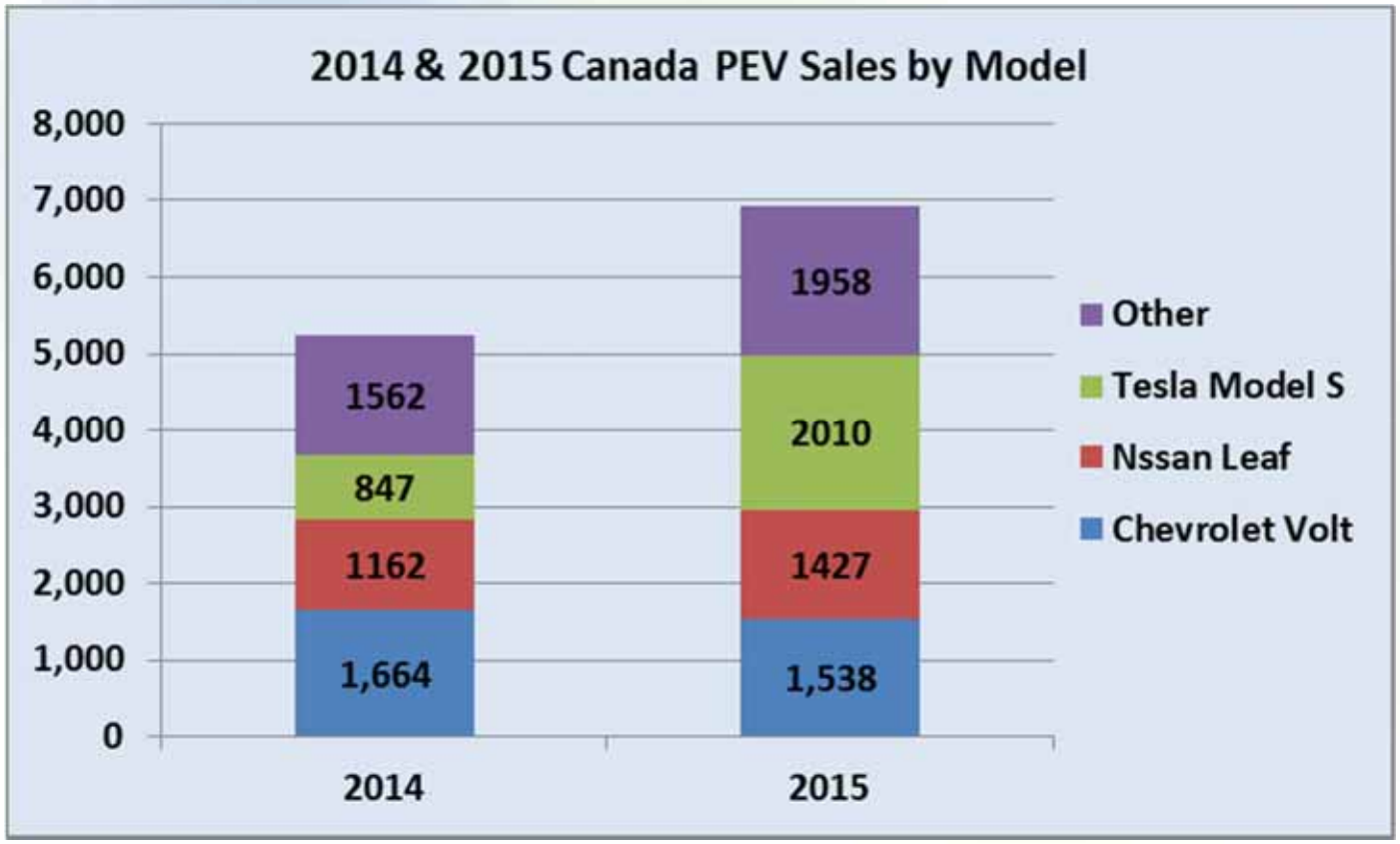
2015 U.S. PEVs Sales by Model

- 27 PEV models sold during 2015
- About 114,000 total PEVs were sold
- Note some are different than the 27 models on sale during 2016



PEV Canada Annual Sales

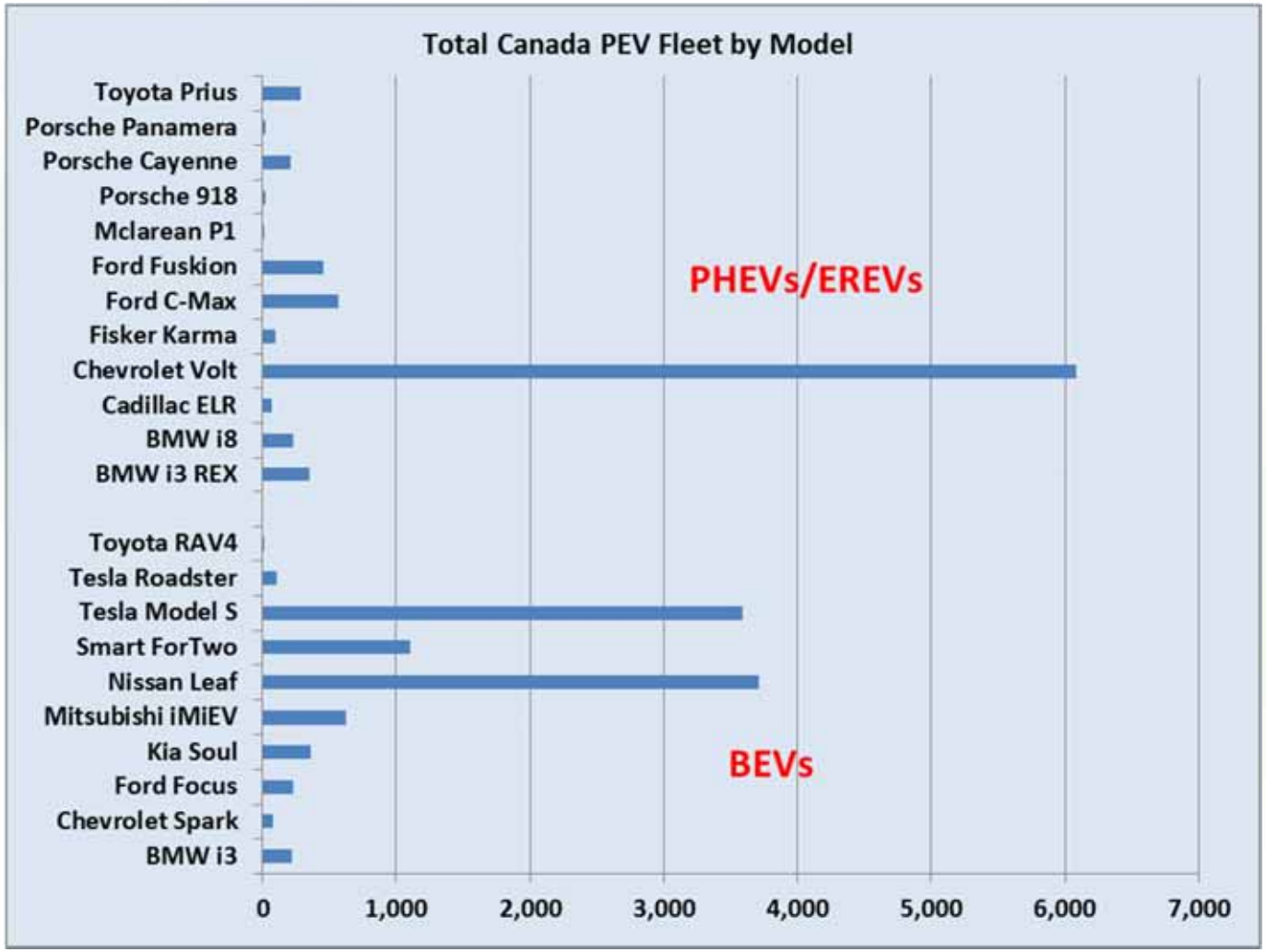
- 12,168 total PEV sales in 2014 and 2015
- 32% increase in 2015 over 2014
- Tesla Model S 2015 sales up 137% over 2014



Source: http://www.fleetcarma.com/ev-sales-canada-2015/

Total Canadian Fleet by PEV Model (Dec. 2015)

- **18,431 Total PEVs in Canada**
- **10,034 BEVs and 8,417 PHEVs**

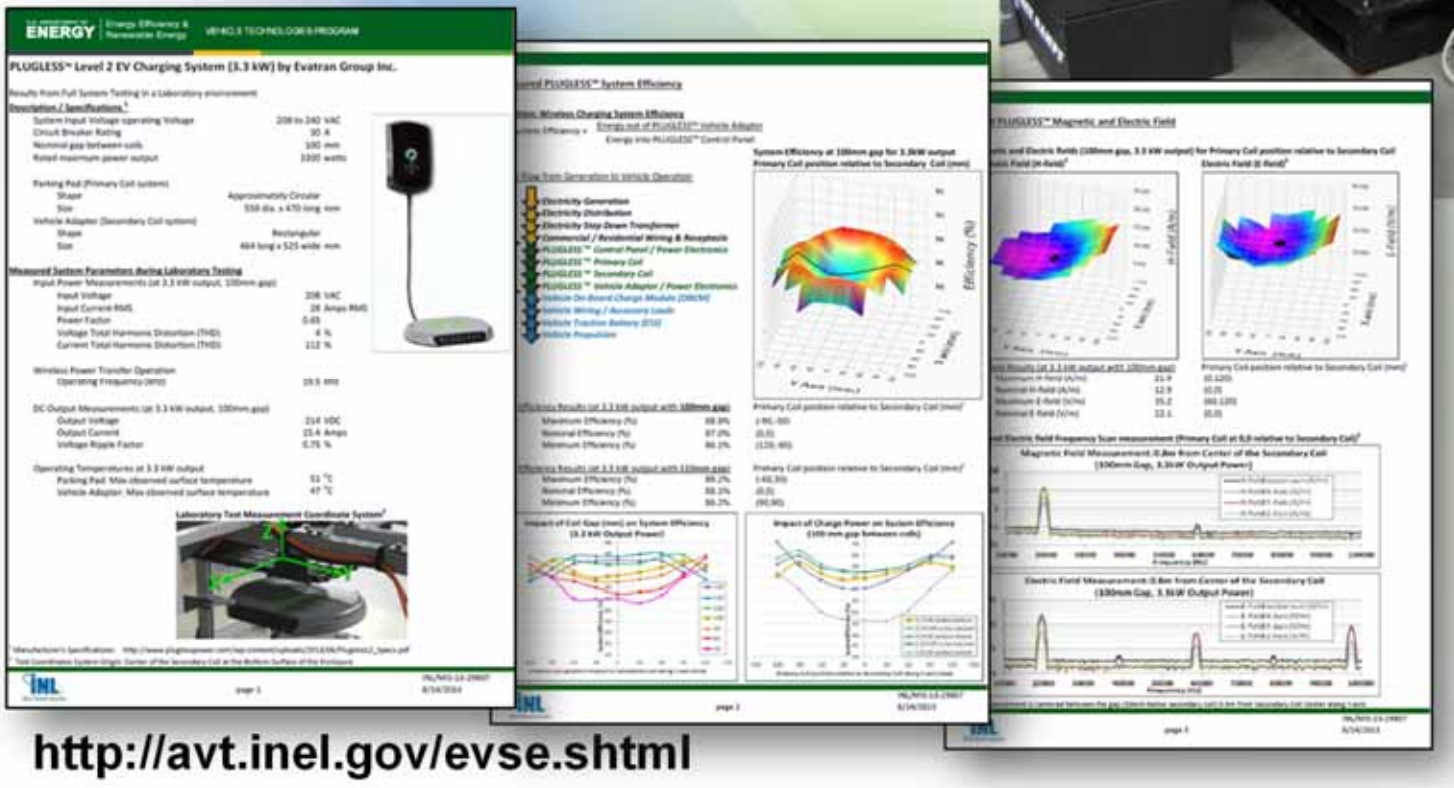


DCFC Capable Vehicles

- DCFC Capable (all BEVs)
  - BMW i3 – CCS (SAE Combo Connector Standard)
  - Chevrolet Spark – CCS
  - Mitsubishi i-MiEV – CHAdeMO
  - Nissan Leaf – CHAdeMO
  - Kia Soul – CHAdeMO
  - Tesla Model S - Tesla
  - Other OEMs may offer
- EVSE Level 2 Capable
  - All PEVs
- EVSE Level 1 Capable
  - All PEVs

Wireless Power Transfer Brief Discussion

- **INL has tested seven wireless charging systems**
- **Efficiency, compatibility and safety issues need additional attention**

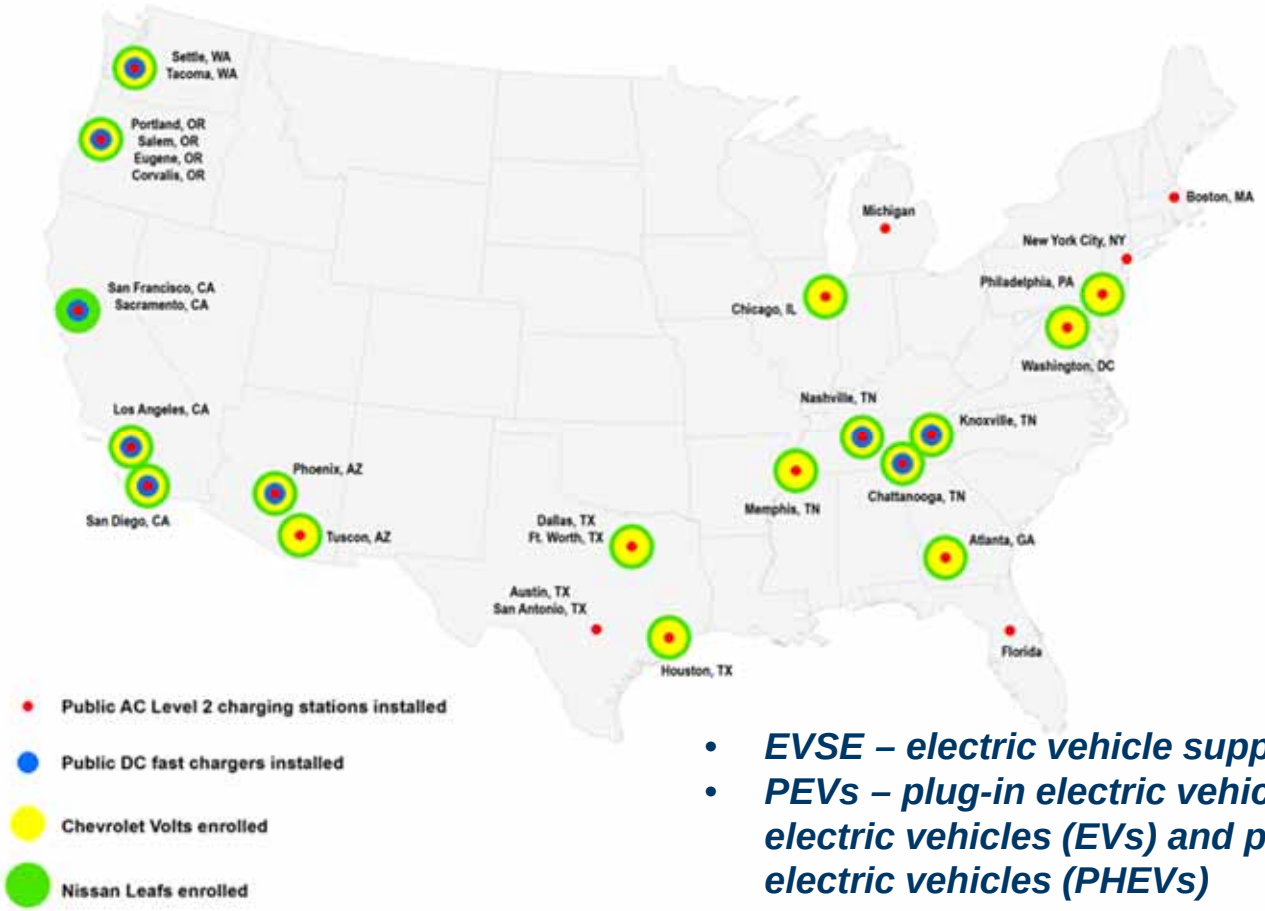


http://avt.inel.gov/evse.shtml

Charging Infrastructure Use and Electric Vehicle Miles Traveled

PEV and EVSE Locations – EV Project and ChargePoint America

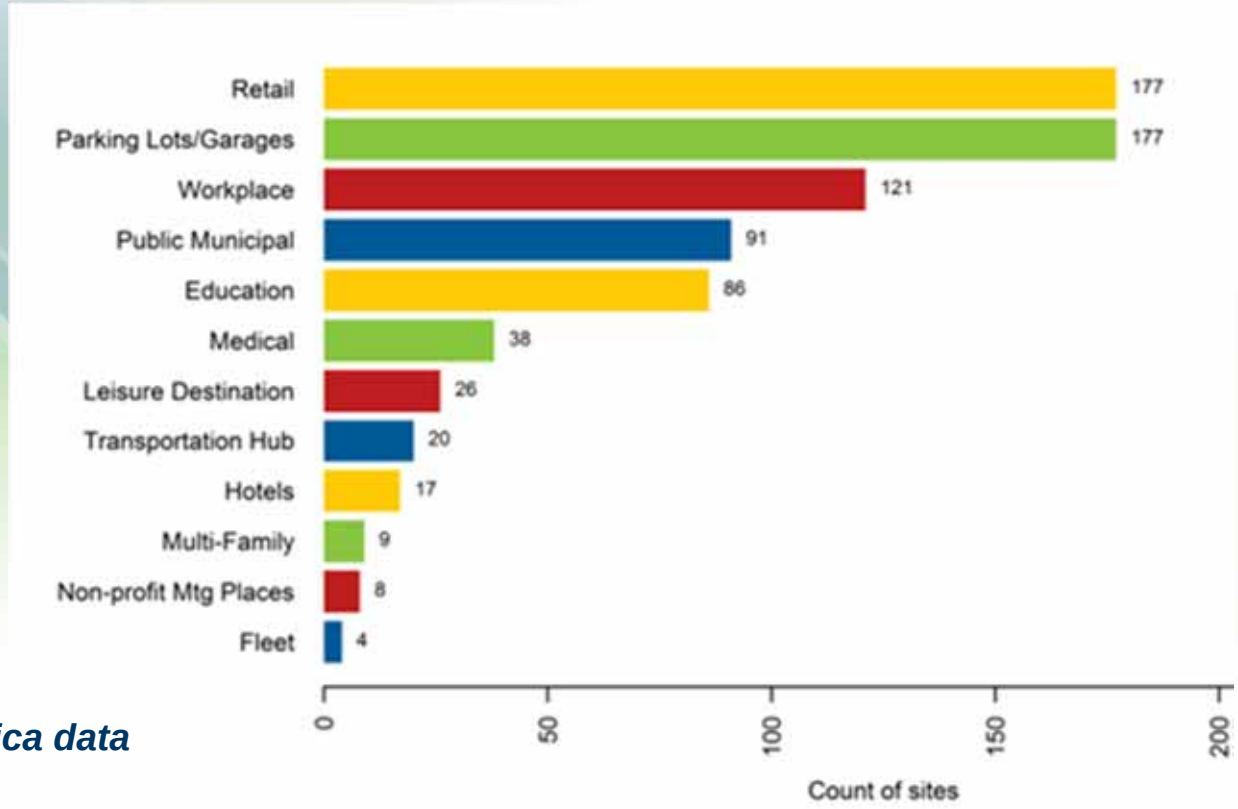
- **17,000 AC Level 2 EVSE and DCFC and 8,300 PEVs provided charging and vehicle operations data via telematics systems**



- ***EVSE – electric vehicle supply equipment***
- ***PEVs – plug-in electric vehicles. Includes electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs)***
- ***DCFC – DC fast charger***

Public AC Level 2 EVSE Charging Venues

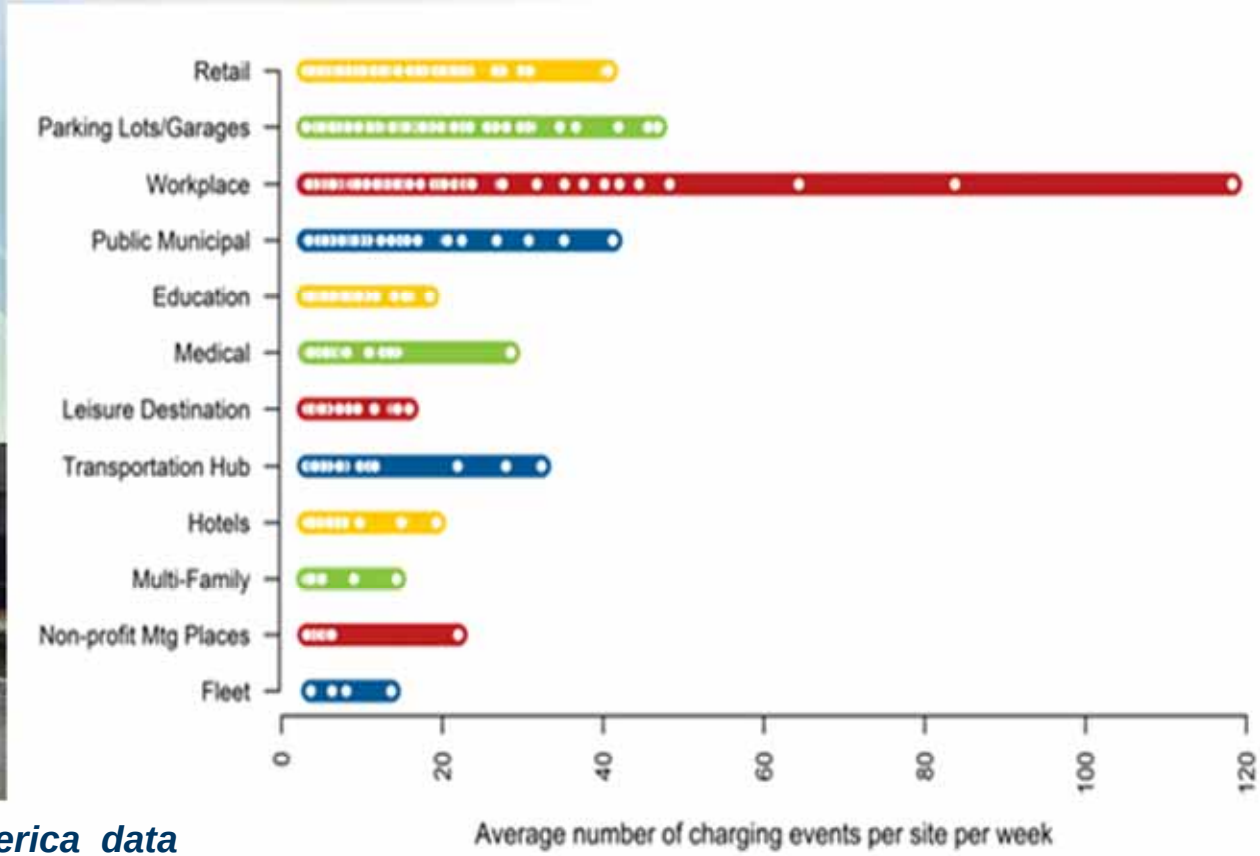
- **774 public Level 2 (240V) sites in primary venues**
- **Retail and parking lot/garage venues contained over 45% of all public sites**
- **Workplace was 16% of all public sites**



- *EV Project & ChargePoint America data*

Frequency of Public AC Level 2 EVSE Charge Events by Venue

- **The top 7 workplace sites averaged over 40 charging events per week**

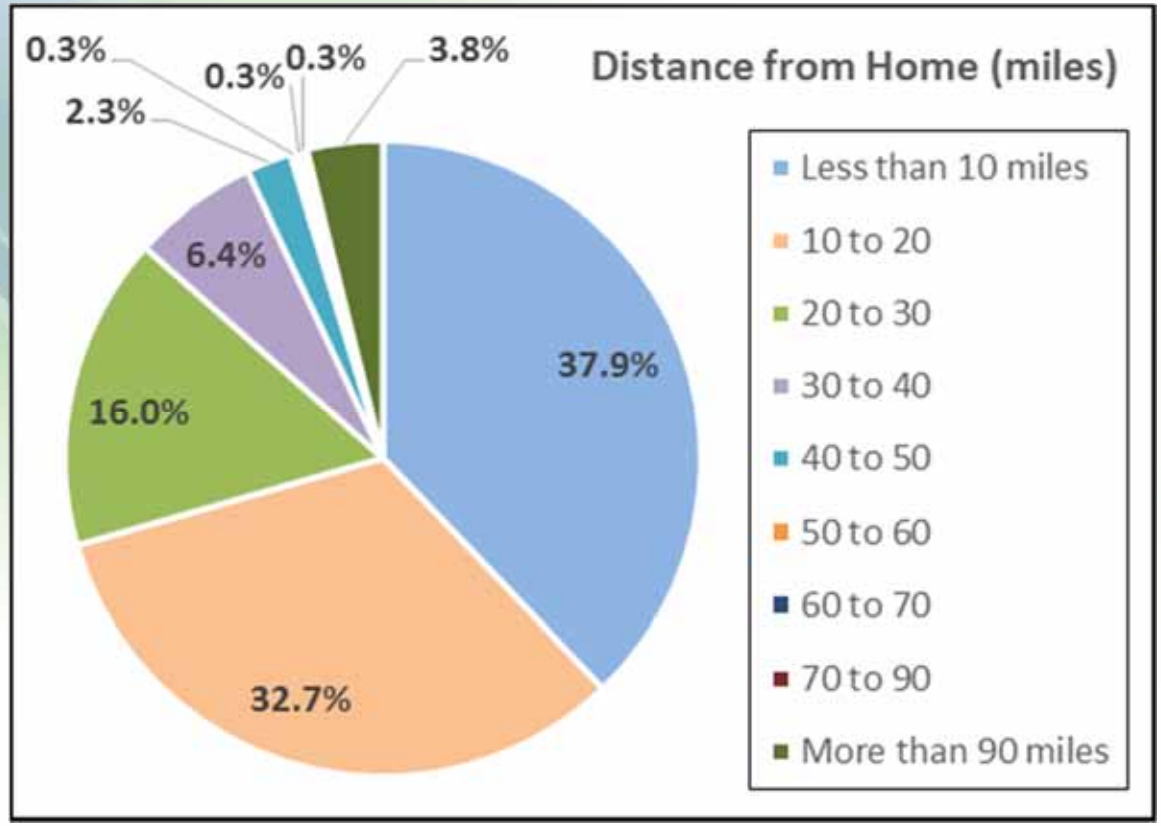


- *EV Project & ChargePoint America data*

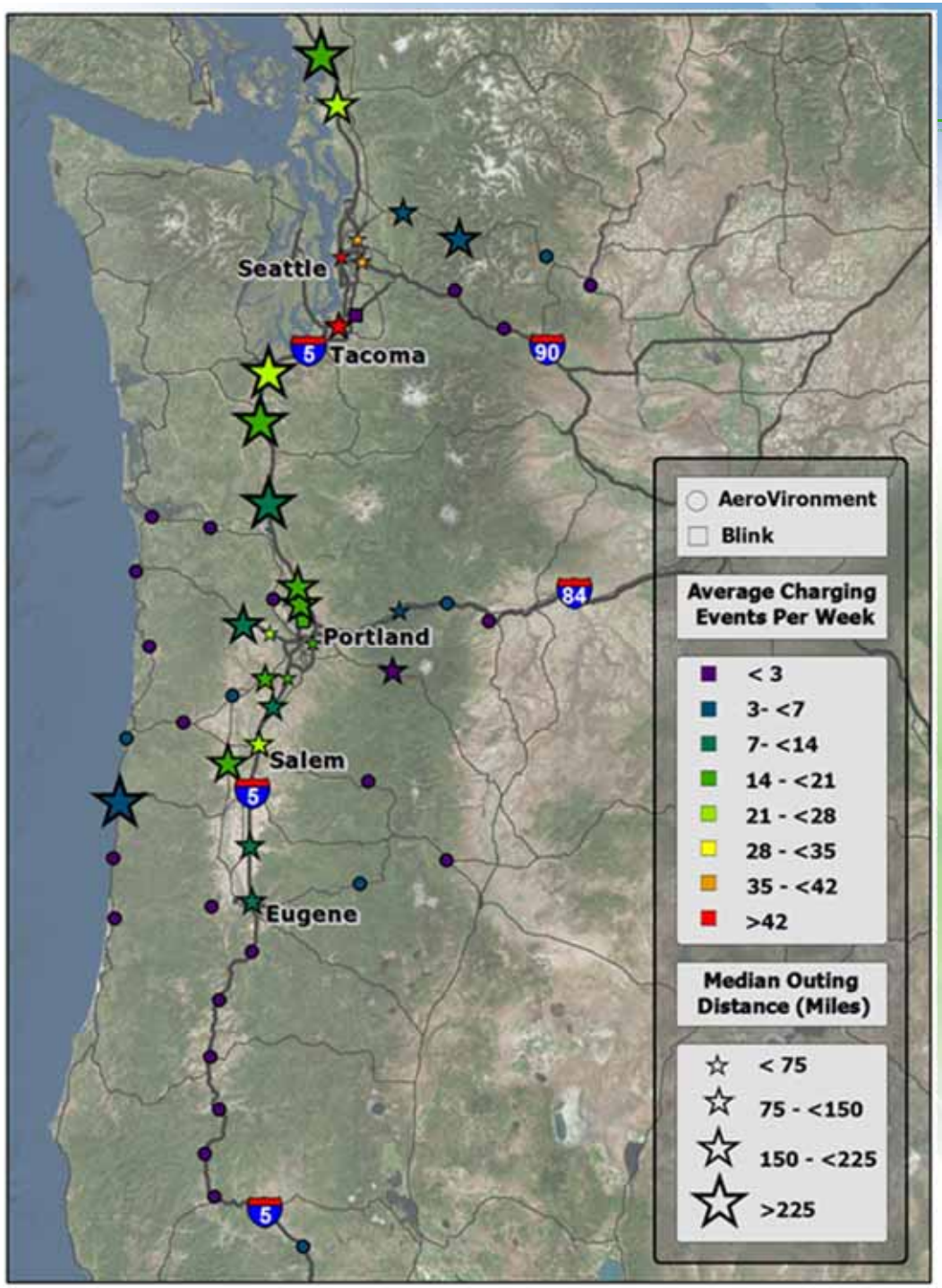
Use Patterns at Highly Utilized DCFC

- 20 highest utilized DCFC used an average of 21 to 66 times per week
- EV Project Leafs charged an average of 17 miles from home and the average state of charge was 35% at charge initiation
- 71% charge events occurred 20 miles or less from

Leafs distance from home when fast charging (last 6 months of the EV Project)



- *EV Project data*

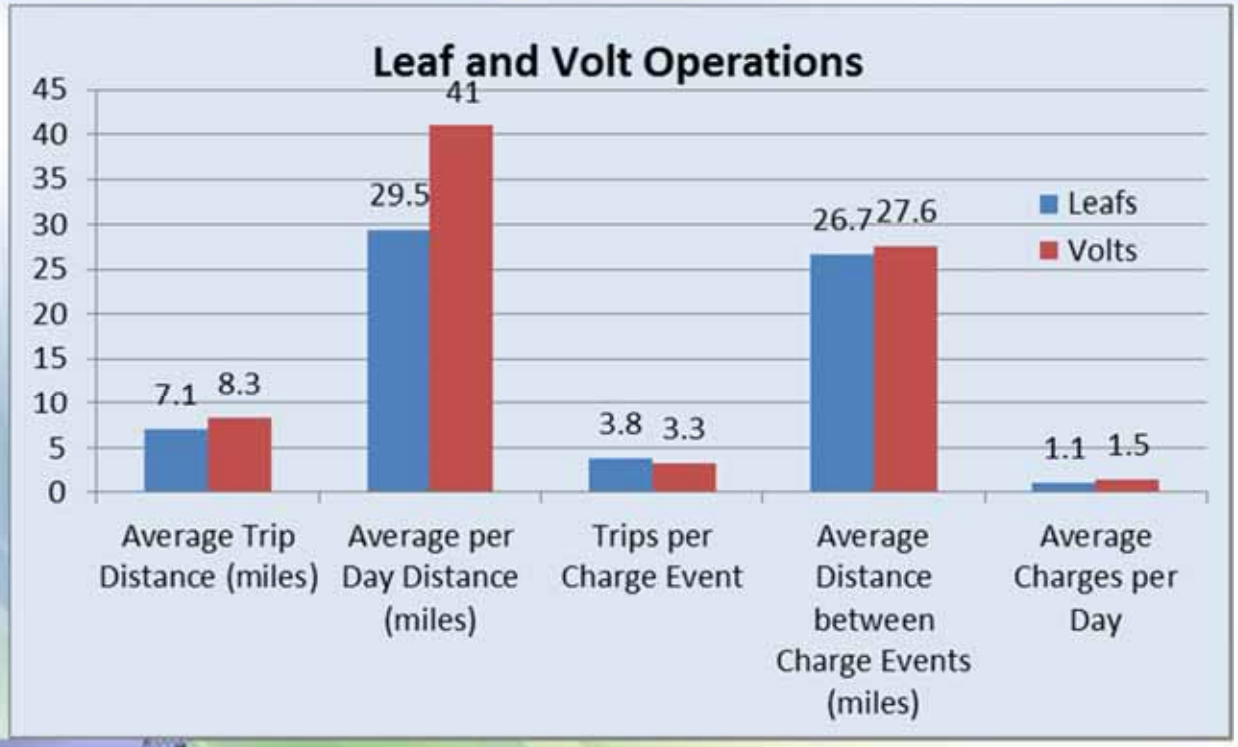


I-5 Corridor – 45 AeroVironment and 12 Blink DCFC

- **36,846 charge events by 2,515 distinct BEVs**
- **19 outings greater than 500 miles**
- **One Leaf driver drove 770 miles during one outing, by fast charging 16 times at 9 different DCFC**

- ***INL received data for 45 AeroVironment and 12 Blink DCFC***

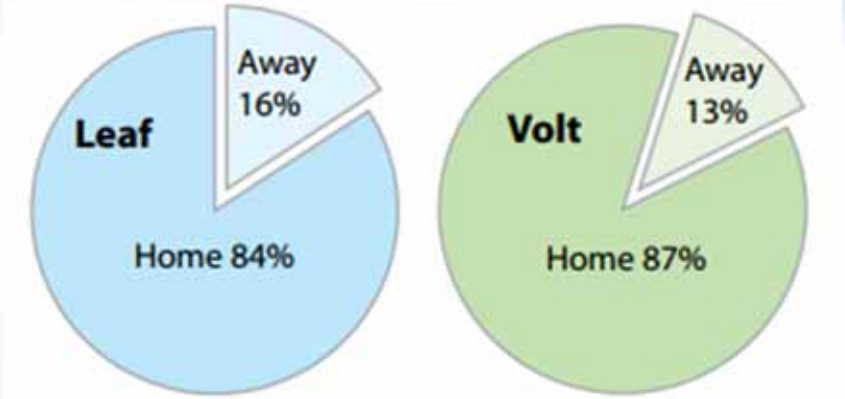
Leaf and Volt Operations Profile

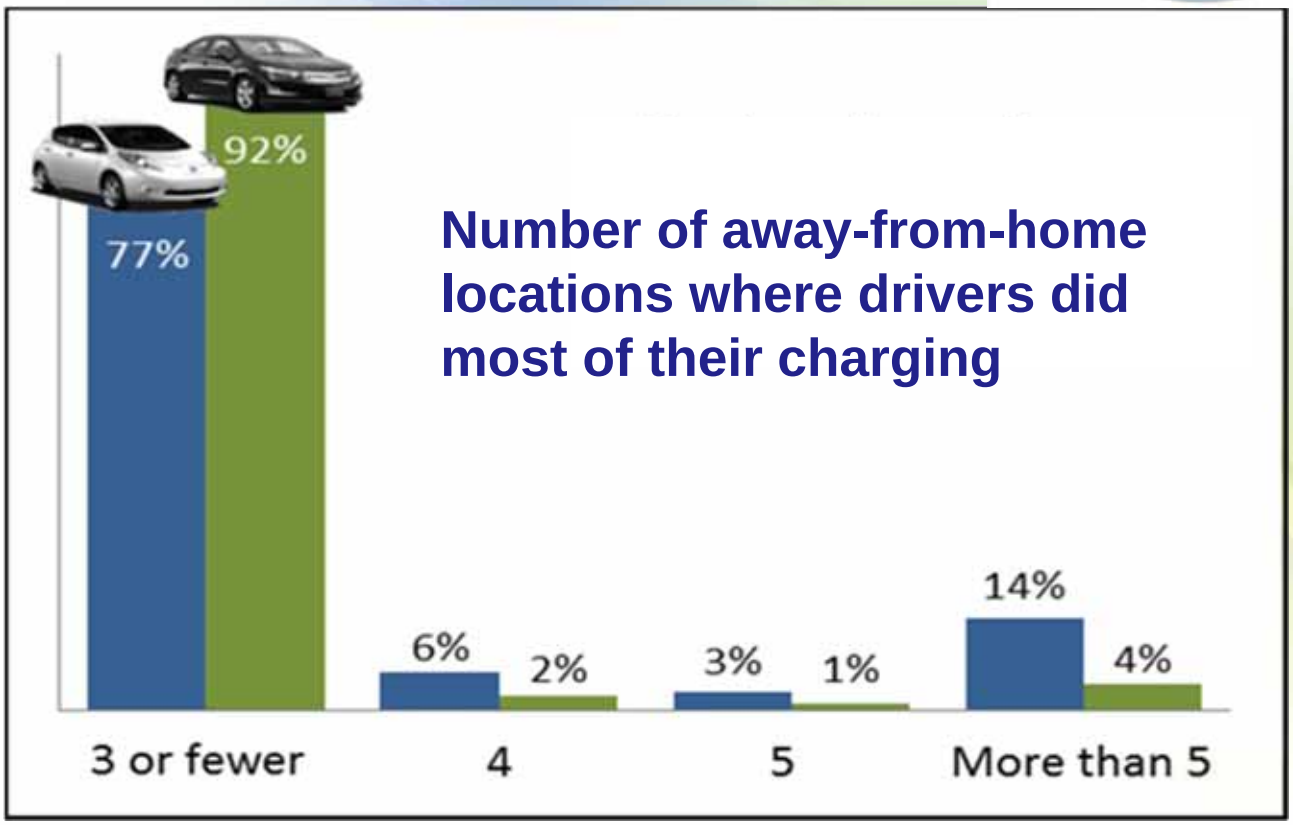


- ***EV Project data***

Number of Charging Locations & Power Levels

- **Most Leaf and Volt drivers performed their charging at home**



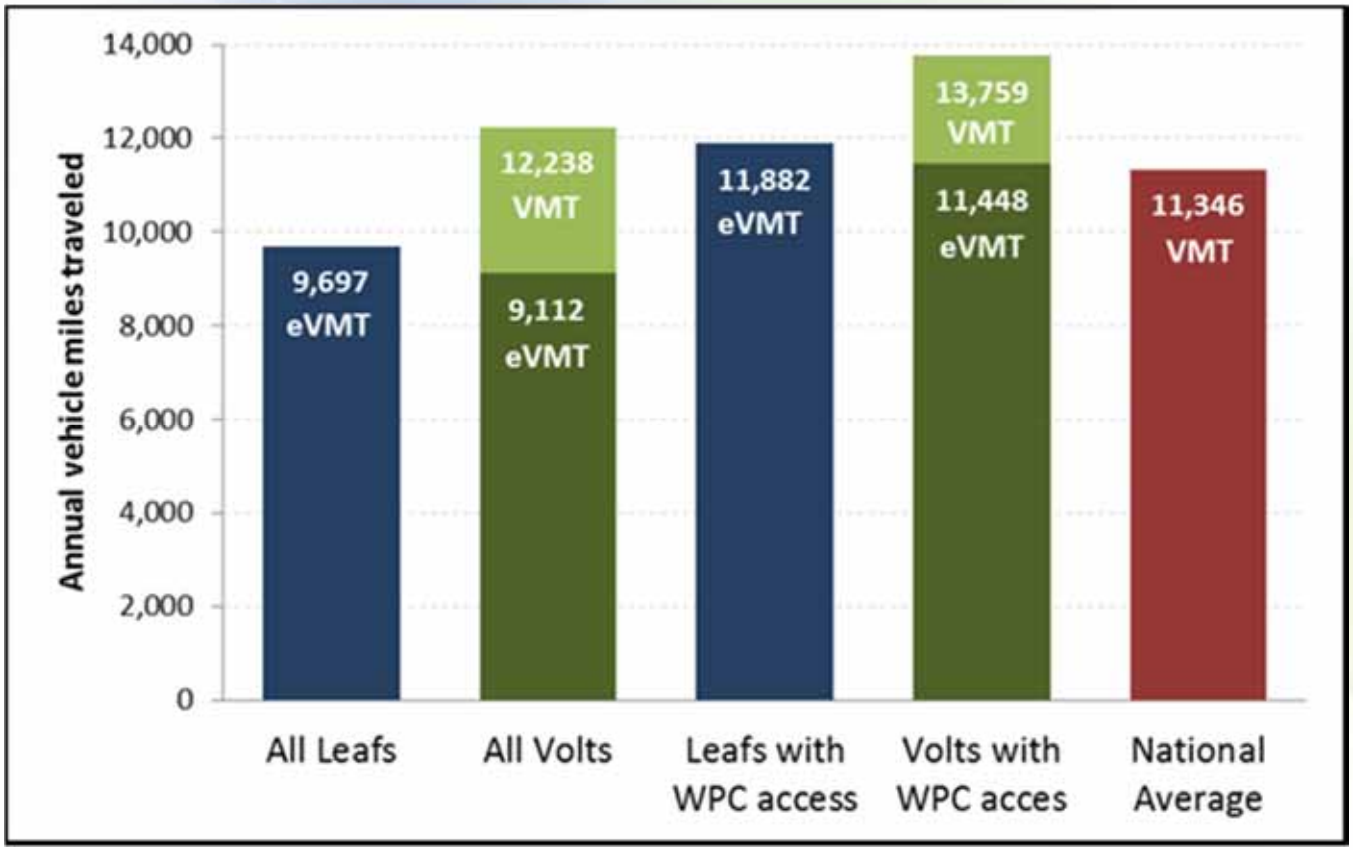


Number of away-from-home locations where drivers did most of their charging

- ***EV Project data***

Work Place Charging and eVMT Impact

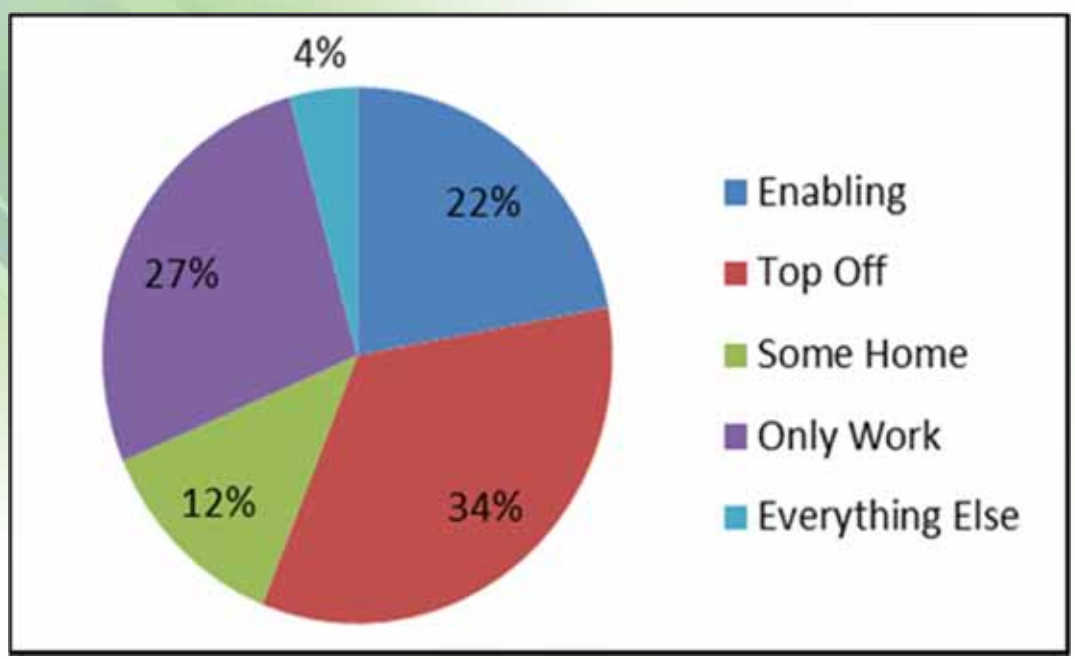
- electric Vehicle Miles Traveled (eVMT) are extended when drivers have access to work place charging (WPC)
  - Nissan Leafs: 23% more annual eVMT with WPC
  - Chevrolet Volts: 26% more annual eVMT with WPC



- *EV Project data*

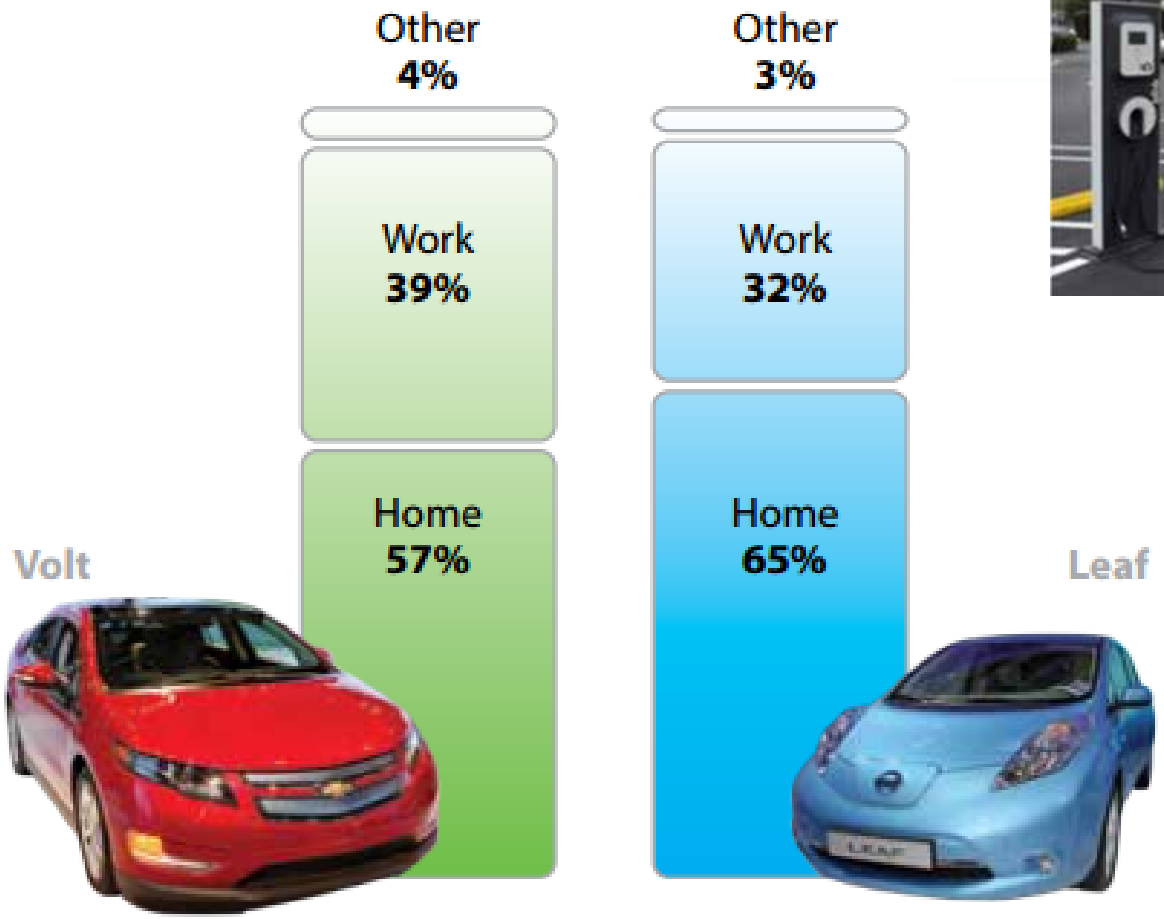
Leaf Workplace Charging Behavior

- For drivers with residential and work place charging:
  - 22% of daily driving required home and workplace charging in order to complete that day's driving (exceeded the battery range)
  - 27% of the days at work, drivers only charged at work and not at their residences (free electricity)
- Conventional thinking says most Leafs would charge at home every night and workplace charge only when needed. However, this behavior only includes 56% of days (top off and enabling)



- *EV Project data*

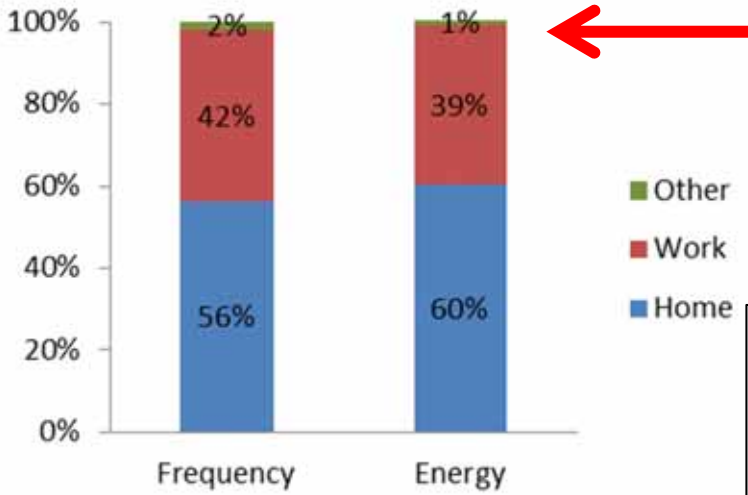
Leaf & Volt Drivers With Access to Home & Work Charging Preferences



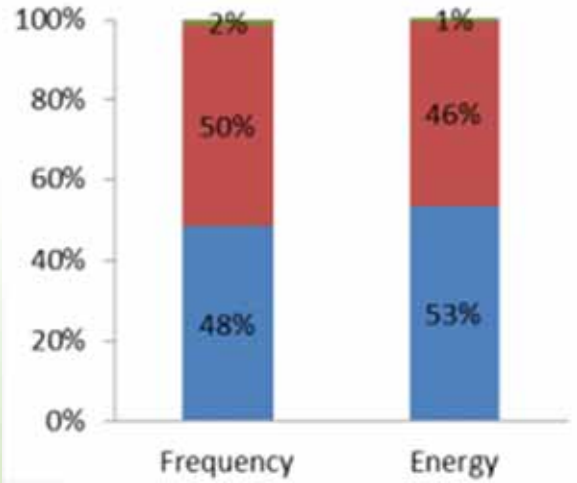
- ***EV Project data***

Workday and Non-Workday Charging Behavior

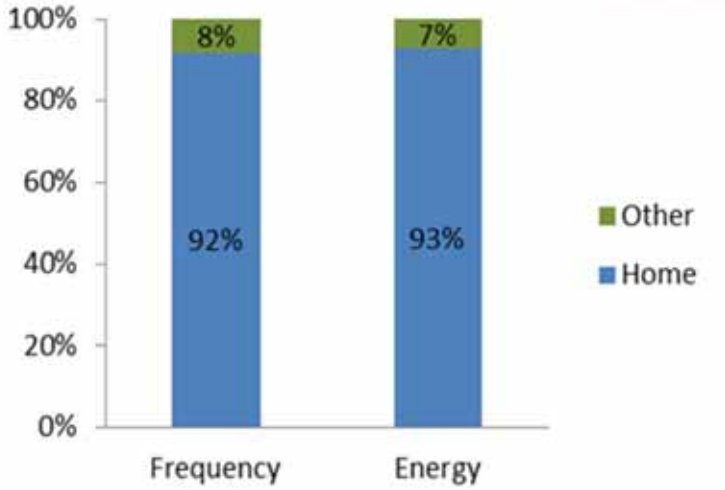
707 Leafs Charging on Workdays



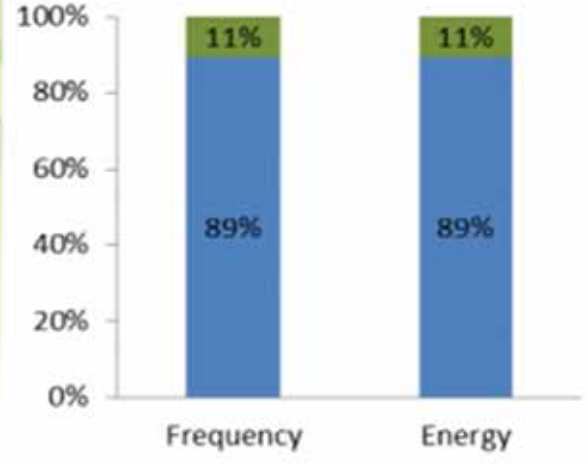
96 Volts Charging on Workdays



Same Leafs on non-work days



Same Volts on non-work days



In aggregate, workplace vehicle drivers had little use for public infrastructure on days when they went to work

- ***EV Project data***

PEV Infrastructure Charging Summary

- Encourage AC Level 1 or 2 EVSE Residential Charging
  - It is popular and occurs off-peak grid demand

- Encourage AC Level 1 or 2 Workplace Charging
  - Increases eVMT, often beyond the range of a single charge and it is popular

- DCFC should first be sited along major commuter routes within major metropolitan areas
  - Supports both intra- and inter-city travel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For publications and general PEV and charging infrastructure information, visit http://avt.inl.gov