PEVs in North America and Charging Infrastructure Use

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• 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
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.

<table>
<thead>
<tr>
<th>BEVs</th>
<th>PHEVs/EREVs</th>
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<tbody>
<tr>
<td>Tesla Model s</td>
<td>BMW 330e</td>
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<td>BMW X5 xDrive 50e</td>
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<td>Tesla Model X</td>
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<td>Mitsubishi i-MiEV</td>
<td>BMW i3</td>
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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://www.afdc.energy.gov/data/10314
- 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

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

[Links to INL and EVSE information]
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 home

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

- Volt:
  - Home: 57%
  - Work: 39%
  - Other: 4%

- Leaf:
  - Home: 65%
  - Work: 32%
  - Other: 3%

• EV Project data
Workday and Non-Workday Charging Behavior

707 Leafs Charging on Workdays

96 Volts Charging on Workdays

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
For publications and general PEV and charging infrastructure information, visit http://avt.inl.gov