Battery Electric Vehicle Driving and Charging Behavior Observed Early in The EV Project

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Outline

- Overview of the EV Project
  - Project objectives
  - Product specs
  - Current status
- Purpose of the paper
- Results: Nissan LEAF driving and charging behavior in 2011
The EV Project

World’s largest EV infrastructure deployment project

- Build mature EV charging infrastructure in 14 US regions
- 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

- Deploy >13,000 residential and public EVSE units
- Enroll >8,000 privately owned Nissan LEAF battery electric vehicles and Chevrolet Volt extended range electric vehicles
- Deployment from Oct 2010 – Dec 2013
- INL data collection phase from Jan 2011 – Dec 2013
Project Partners

Sponsor

U.S. Department of Energy

Primary Partners

ECOtality North America
Nissan North America
Chevrolet
Idaho National Laboratory
The EV Project Locations

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

Legend
- Yellow: EV Project Regions
- Grey: State Boundaries

- Seattle: 83 Commercial, 576 Residential
- Oregon: 94 Commercial, 335 Residential
- San Francisco: 6 Commercial, 863 Residential
- Los Angeles: 7 Commercial, 304 Residential
- Phoenix: 58 Commercial, 196 Residential
- Tucson: 16 Commercial, 62 Residential
- San Diego: 40 Commercial, 566 Residential
- Dallas/FW: 35 Commercial, 6 Residential
- Memphis: 2 Commercial, 16 Residential
- Chattanooga: 23 Commercial, 35 Residential
- Knoxville: 44 Commercial, 61 Residential
- Nashville: 60 Commercial, 275 Residential
- DC: 2 Residential

0 125 250 500 Miles

2012-01-0199
Nissan LEAF™ Specs

- Battery electric vehicle
- 24 kWh 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
Chevrolet Volt Specs

- All-electric capable EREV
- 16 kWh 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
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
Deployment at End of 2011

- 3,785 EVSE (467 publically available)*
- 3,629 LEAFs, 218 Volts*

Number of EV Project EVSE Installed to Date*

Number of EV Project Vehicles Enrolled to Date*

* Varies from manuscript due to refinement of reporting criteria
Purpose of Paper

- Paper describes early **driving and charging behavior** of EV Project Nissan LEAF drivers.
- Serves as baseline for comparison to behavior observed later in the project as driver habits and charging infrastructure mature.
- Future works will evaluate of charging infrastructure placement and impact of vehicle charging on the electric grid.
Influences on Behavior

- Early adopters, early market
- Limited public charging opportunities
- Drivers new to Nissan LEAF, new to electric vehicles

90% of vehicles had driven 7,000 miles or less by end of 2011

Median: 3,472 mi
Max: 23,298
**The EV Project 2011 Results**

**Nissan LEAF Driving Statistics**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicles with matching residential EVSE</td>
<td>2,903</td>
</tr>
<tr>
<td>Number of trips</td>
<td>1,454,220</td>
</tr>
<tr>
<td>Total distance driven (mi)</td>
<td>10,000,316</td>
</tr>
<tr>
<td>Mean / median trip distance (mi)</td>
<td>6.9 / 4.0</td>
</tr>
<tr>
<td>Mean / median distance driven per vehicle day driven (mi)</td>
<td>30.3 / 26.8</td>
</tr>
<tr>
<td>Mean / median number of trips between charging events</td>
<td>4.2 / 3.0</td>
</tr>
<tr>
<td>Mean / distance driven between charging events (mi)</td>
<td>28.8 / 27.1</td>
</tr>
</tbody>
</table>
Trip Distance

Distribution of Trip Distance

Mean: 6.9
Median: 4.0
Max: 100.6
Driving between charging events

Distribution of Distance Driven Between Consecutive Charging Events

- Mean: 28.8
- Median: 27.1
- Max: 101.0

Distance driven between charging events (mi)

Frequency of occurrence
Distance driven per day

Distribution of Distance Driven Per Day

- **Frequency of Occurrence**
- **Distance driven per vehicle day driven (mi)**

Mean: 30.3
Median: 26.8
Max: 227.7
The EV Project Q4 2011 Results

- **Nissan LEAF Charging Statistics**

<table>
<thead>
<tr>
<th>Total number of charging events</th>
<th>347,222</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean / median number of charging events per vehicle day driven</td>
<td>1.05 / 0.99</td>
</tr>
</tbody>
</table>
Charging Events per Day

Distribution of Vehicle Average Number of Charging Events per Day Driven

- Mean: 1.05
- Median: 0.99
- Max: 3.22

Number of Charge Events per Vehicle Day Driven

Frequency of Occurrence

0% 5% 10% 15% 20% 25% 30% 35%

0.0 < 0.2 0.2 < 0.4 0.4 < 0.6 0.6 < 0.8 0.8 < 1 1.0 < 1.2 1.2 < 1.4 1.4 < 1.6 1.6 < 1.8 1.8 < 2 2.0 < 2.2 2.2 < 2.4 2.4 < 2.6 ≥ 2.6
The EV Project 2011 Results

- Nissan LEAF Charging Location

Frequency of Charging by Charging Location

- Home location: 82%
- Away-from-home location: 18%
The EV Project 2011 Results

- >70% of vehicles charged at least once away from home
- Most of those vehicles charged at 5 or more distinct locations, such as:
  - Shopping centers
  - Health clubs and spas
  - Bars and restaurants
  - Office buildings
  - Other homes
- Small number of vehicles charged exclusively away from home
- Mix of locations was similar for vehicle with high and low charging frequency
The EV Project 2011 Results

- Nissan LEAF Charging Completeness

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

- On average, LEAFs charged frequently with respect to time and range
  - ~1 charge per day
  - ~30 miles between charging events
  - charging started with 20 – 80% SOC in pack
- Most charging done at home but away-from-home charging was explored
- Averages are not enough -- distributions show wide variety of charging and driving behavior from vehicle to vehicle

Remember...
- Vehicle drivers were early in ownership experience
- Limited public charging opportunities in 2011
Additional Information

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

http://avt.inl.gov/evproject.shtml

Acknowledgements

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