IWC - Latest Insights from The EV Project and ChargePoint America PEV Infrastructure Demonstrations

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Idaho National Laboratory

IWC meeting
Houston, Texas
October 2014
INL was a primary partner in two national plug-in electric vehicle (PEV) charging infrastructure demonstrations

**EV Project**

- Purpose is to build mature EV charging infrastructure in 17 US regions. Study:
  - Infrastructure deployment process
  - Customer driving and charging behavior
  - Impact on electric grid
- 12,000+ AC level 2 charging units, 100+ DC fast chargers
- 8,000+ Electric drive vehicles
- INL data collection Jan 2011 – Dec 2013
- Project partners:

**ChargePoint America**

- Deploy 4,700+ residential and public AC level 2 charging units in 11 US regions
- Study customer usage of residential and public infrastructure
- INL data collection May 2011 – Dec 2013
Charging Units Reporting Data Nationally

- **107** DC Fast Charge
- **443** Private Nonresidential AC Level 2
- **3,555** Publicly Accessible AC Level 2
- **8,251** Residential AC Level 2
- **12,356** Total
Charging Units* Reporting Data Nationally

- 39 Not specified
- 264 Private Nonresidential
- 2,508 Publicly Accessible
- 1,836 Residential
- 4,647 Total

* All units are AC Level 2
Dual-port units count as 2 units
Measures of “Goodness”

There are numerous ways to assess how “good” public charging sites are:

- Charging frequency: number of charge events per day or week
- Charging time: hours connected
- Charging energy: kWh consumed / EV miles provided
- Parking time: time spent in parking space / in store
- Charging site host may want electric vehicle supply equipment (EVSE) for other reasons, such as image or cool factor
Public EVSE Usage Fees

Blink

- Public AC Level 2 fees started Jul – Aug 2012
  - Varies from $1.00 to $2.00 per hour connected
  - 16% of sites were still free as of Dec 31, 2013 (per local site host discretion)
- DC Fast Charger fees started Jul 2013
  - $5 for Blink member / $8 for non-member per session
  - There is at least one DCFC at a work location that is free

ChargePoint

- Vary by site (per local site host discretion)
- Many are free (rumored 70% free / 30% cost)

AeroVironment (States of Washington and Oregon)

- Free prior to Apr 1, 2014
- After Apr 1, 2014 – Monthly subscription fee of $19.99 for unlimited usage or “drive up” fee of $7.50 per session for DCFC and $4 per session for L2
Outline

• How has public AC level 2 EVSE and DC fast charger (DCFC) usage changed over time
  – What was the impact of implementing payment for use of DCFC
• Electric vehicle miles traveled (eVMT)
  – Leaf vs. Volt eVMT
  – Did Leaf eVMT change as public infrastructure usage changed
• Workplace charging
  – Charge triangle
  – Facebook case study
• Which public charging sites are used most frequently
  – By EVSE make and cost
  – By charging level and venue
• Determining hot spots using vehicle data
  – Bay Area examples
• I-5 Corridor EVSE usage preview
• Future work
How has public AC level 2 EVSE and DC fast charger (DCFC) usage changed over time?
Usage Frequency of Public Level 2 EVSE and DC Fast Chargers

Charging Frequency by EVSE Type

Charging Energy by EVSE Type
Roll-out of Blink DCFC usage fees during Q3. Also, Nissan DCFCs introduced; free use.
Usage Frequency of Public Level 2 EVSE and DC Fast Chargers by Region

Charging Frequency by EVSE Type and Region

- Blink DCFC
- ChargePoint Public L2
- Blink Public L2

Number of charging events per EVSE day

Year:
- Q4 2012
- Q1 2013
- Q2 2013
- Q3 2013
- Q4 2013
Total Energy Consumption at Blink Stations in San Francisco

![Graph showing energy consumption by month for Blink DCFC and Level 2 EVSE in San Francisco.](image)
Total Energy Consumption at Blink and ChargePoint Stations in San Francisco
Unintended Consequence of Per-session Fee

- Pricing model leads to an “all-you-can-eat” mentality?
- Tapering SOC increase vs. time gives diminishing returns for time invested

![Graph showing energy and time comparison before and after cost]

- 14% increase in energy transferred
- 20% increase in time connected
Infrastructure Usage by EV Project Leafs

- 4719 vehicles contributing data in vehicle months where home location is known

3 months before DCFC fees
(4/1/2013 – 7/1/2013)

- Home L1/L2: 83.6%
- Away L1/L2: 14.9%
- Away DCFC: 1.4%

3 months after DCFC fees
(9/1/2013 – 12/1/2013)

- Home L1/L2: 84.7%
- Away L1/L2: 14.3%
- Away DCFC: 1.0%
Electric Vehicle Miles Traveled
## Leaf vs. Volt Average Monthly eVMT

Oct 1, 2012 through Dec 31, 2013

<table>
<thead>
<tr>
<th></th>
<th>Nissan Leaf</th>
<th>Chevrolet Volt</th>
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<tbody>
<tr>
<td>Number of vehicles</td>
<td>4,039</td>
<td>1,867</td>
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<tr>
<td>Number of vehicle months</td>
<td>35,294</td>
<td>20,545</td>
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<tr>
<td>Total distance traveled (miles)</td>
<td>28,520,792</td>
<td>20,950,967</td>
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<tr>
<td>Distance traveled in EV mode (miles)</td>
<td>28,520,792</td>
<td>15,599,508</td>
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<tr>
<td>Percent of distance traveled in EV mode</td>
<td>100%</td>
<td>74.5%</td>
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<tr>
<td>Average monthly total VMT</td>
<td>808.1</td>
<td>1,019.8</td>
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<tr>
<td>Average monthly eVMT</td>
<td>808.1</td>
<td>759.3</td>
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</table>

Leafs only 6% more eVMT per month than Volts
Leaf vs. Volt Distribution of Monthly eVMT

Overlap of blue and green curves means many Volts averaged the same or more electric miles than Leafs.

Overlap of blue and red curves means many Leafs averaged the same or more total miles than Volts.

Distribution of vehicle average monthly eVMT and VMT, where each data point in the distributions represents a single vehicle’s average over the entire study period.
Aggregate eVMT does not appear to be tied to Blink DCFC usage…

… because most EV Project Leaf drivers did not charge away from home very much
Workplace Charging
Charging Location Preference – Nissan Leaf

707 Nissan Leafs with Access to Workplace Charging, 2012 – 2013

Overall Charging Frequency by Location (to scale)

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

Careful!
How important is this 3% to individual drivers’ mobility needs?

How does cost to use workplace charging influence this behavior?
Charging Location Preference – Chevy Volt

96 Chevrolet Volts with Access to Workplace Charging, 2013

Overall Charging Frequency by Location (to scale)

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

How does cost to use workplace charging influence this behavior?
Workplace Charging Case Study: Facebook

- Menlo Park, CA office campus
- May 1, 2013 to Aug 15, 2013
- 10 Blink Level 2 units (which were later replaced with ChargePoint units)
- 12 ChargePoint units with Level 2 cord and Level 1 outlet
- 1 Blink DC fast charger
- Publicly accessible
- Blink/CP L2 units free
- DCFC Blink network fees instituted Jul 2013
Charging Frequency at Facebook

Frequency distributions of number of charging events per cord or outlet per work day for different charge power levels.
Frequency distributions of time Level 1 outlets and Level 2 cords were connected to a vehicle per charging event.
Frequency distributions of time Level 1 outlets and Level 2 cords transferred power to a vehicle per charging event.
Energy Consumption at Facebook

Distribution of energy consumed per charging event by charge power level.
Facebook - ChargePoint Level 1 / Level 2 EVSE Usage

- Data were collected from 12 charging units that were capable of both AC Level 1 and AC Level 2 charging
- Drivers overwhelmingly preferred AC Level 2 cords over AC Level 1 outlets
  - When drivers arrived at these units and both Level 1 and Level 2 options were available, they chose to use the Level 2 cord 98% of time
- Drivers may have consciously chosen the faster charge rate or they may have been motivated simply by convenience
  - The Level 2 cord was available on the EVSE, but a driver needed to retrieve their own Level 1 cord to plug into the Level 1 outlet on the EVSE
Facebook - DC Fast Charger Usage

- The DC fast charger (DCFC) was typically used between 2 and 6 times per work day for 24 minutes or less per charging event
- 11% of the time when a DC fast charge event ended and another event began on the same work day, a vehicle was already connected to the second DC fast charger cord prior to the end of the first vehicle’s charging event
Facebook - Company Policies & Practices

- Facebook followed a few simple guidelines to encourage employees to self-manage electric vehicle supply equipment (EVSE) usage
  - Charging units were installed to allow access from multiple parking spaces
  - Drivers wanting a charge would park close to EVSE in use and leave their charge port door open
  - Drivers were encouraged to plug in neighboring vehicles after their vehicle completed charging
  - Employees were provided with an online message board – a Facebook page – allowing them to coordinate charging station usage
Facebook - Company Policies & Practices

• Data from the EVSE suggest that drivers leveraged these resources to minimize the time EVSE were not in use
  
  – 37% of the time when one charging event ended and the next began at the same AC Level 2 EVSE during the same work day, less than 30 seconds elapsed between the two charging events

  – 60% of the time, less than 3 minutes elapsed between consecutive charging events
Which public charging sites are used most frequently?
Usage of Publicly Accessible Level 2 Sites

Cumulative Distribution of Charging Frequency of Blink and ChargePoint Level 2 Publicly Accessible Sites

- 4% of public sites had greater than 20 events / week
- 8% of public sites had greater than 14 events / week
- 16% of public sites had greater than 7 events / week
- 28% of public sites had greater than our arbitrary minimum threshold (> 3 events / week)

9/1/2012 to 1/1/2014
Usage of Publicly Accessible Level 2 Sites

Cumulative Distribution of Charging Frequency of Blink and ChargePoint Level 2 Publicly Accessible Sites

Blink “for-cost” L2 sites used less than “free” L2 sites

9/1/2012 to 1/1/2014
Distribution of Usage Frequency of Blink & ChargePoint Level 2 EVSE Sites by Venue

- Median site usage frequency

Data from 9/1/2012 to 1/1/2014; includes all sites meeting minimum usage threshold
Distribution of Usage Frequency of Blink & ChargePoint Level 2 EVSE Sites by Venue
Blink & ChargePoint Level 2 Sites – Parking Lots and Garages

- 77.5 Downtown Palo Alto
- 73.4 Fifth & Mission Garage, San Francisco
- 70.6 Downtown Palo Alto
- 60.9 Downtown Redwood City
- 58.3 Parking Structure, Irvine CA
- 51.8 Parking Structure, Irvine CA
- 51.4 Parking garage, San Francisco CA
- 50.7 Sutter Stockton Garage, San Francisco CA
Blink & ChargePoint Level 2 Sites – Transportation Hubs

- 53.0 San Francisco Airport
- 39.3 Anaheim Canyon Metrolink
- 32.3 Oceanside Transit Center Metrolink train / light-rail/bus station park and ride
- 21.9 Oakland International Airport parking
- 17.0 San Francisco Airport
- 15.6 Expresso Airport Parking, San Leandro CA
- 15.2 San Francisco Airport
- 13.3 MBTA Alewife Station, Cambridge MA
- 10.9 Long Beach airport parking garage; all-electric vehicles can park free at Long Beach Airport.
Blink & ChargePoint Level 2 Sites – Public / Municipal

76.7 SCAQMD HQ building, Diamond Bar CA
52.8 City library, Dublin CA
50.0 City library, Redwood City CA
39.3 City hall, Huntington Beach CA
37.7 Civic center, Campbell CA
37.3 City hall, Hermosa Beach CA
35.1 SCAQMD HQ building, Diamond Bar CA
34.6 City hall, Orange CA
Blink & ChargePoint Level 2 Sites – Leisure

- 30.3 Rialto Sebastopol Cinemas, Sebastopol CA
- 25.7 La Cienega Tennis Center, Beverly Hills CA
- 23.9 Canal Park, Washington DC
- 20.8 Post Office Square Garage, Boston MA
- 18.2 Red Morton Community Center, Redwood City CA
- 14.4 San Diego Zoo
- 11.7 Balboa Park Air & Space Museum, Automotive Museum, gymnasium, Starlight theatre, etc.
<table>
<thead>
<tr>
<th>Location Description</th>
<th>Average No. of Charging Events per Site per Week</th>
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<tbody>
<tr>
<td>Retail-Small (Becker Surfboards), CA</td>
<td>50.1</td>
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<tr>
<td>Mall (Bella Terra Shopping Ctr), CA</td>
<td>49.9</td>
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<tr>
<td>Mall (Westfield Galleria Mall), CA</td>
<td>45.5</td>
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<td>Mall (The Grove), CA</td>
<td>40.7</td>
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<tr>
<td>Mall (The Americana at Brand), CA</td>
<td>40.3</td>
</tr>
<tr>
<td>Mall (Stanford Shopping Center), CA</td>
<td>32.1</td>
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<td>Mall, Beverly Hills CA</td>
<td>30.4</td>
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<tr>
<td>Mall (Fashion Valley Mall), CA</td>
<td>27.5</td>
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<tr>
<td>Retail-Small (Ralph’s grocery store), CA</td>
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<td>Retail-Small (Mollie Stone's Market grocery store), CA</td>
<td>23.4</td>
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<tr>
<td>Electric Lodge Performing Arts Center</td>
<td>22.8</td>
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<tr>
<td>(dance and fitness center), CA</td>
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</tr>
</tbody>
</table>
Distribution of Usage Frequency of Blink DCFC Sites by Venue

- Median site usage frequency

8/1/2013 to 1/1/2014 (after Blink network fees were instituted)
Distribution of Usage Frequency of Blink DCFC Sites by Venue

Average number of charging events per site per week

- Public Municipal
- Parking Lots/Garages
- Workplace
- Hotels
- Education
- Multi-Family
- Retail

[Graph showing the distribution of usage frequency by venue with specific frequencies indicated for each category.]
Distribution of Usage Frequency of Blink DCFC Sites by Venue
Distribution of Usage Frequency of Blink DCFC Sites by Venue
Blink DCFC Sites – Public / Municipal

- 22.0  City hall, Hayward CA
- 16.6  South Coast AQMD HQ, Diamond Bar CA
- 12.5  Petaluma Visitors Center near 101, Petaluma CA
Blink DCFC Sites – Parking Lots and Garages

Average number of charging events per site per week

42.3  Downtown Seattle WA
29.2  Downtown Seattle WA
16.0  Downtown Los Angeles CA
12.3  Public Library, park, shopping center, Santa Clara CA
  6.9  Public parking, Azusa CA
  5.9  Downtown San Francisco CA
  4.6  Business park, South San Francisco CA
Blink DCFC Sites – Retail

54.4  Tahoma Market on I5, Tacoma WA
35.0  Fred Meyer, Kirkland WA
30.4  Nissan dealership, Bellevue WA
23.1  Fred Meyer, Hillsboro OR
22.8  Fred Meyer, Seattle WA
22.6  Mall on I205, Happy Valley OR
20.9  Fred Meyer, Salem OR
19.1  Fred Meyer, Portland OR
16.5  Nissan dealership, Santa Rosa CA
16.4  Shopping center near I5, Wilsonville OR
16.0  United Markets (grocery store), San Rafael CA
12.7  Nissan dealership, Petaluma CA
Identifying Hot Spots Using Vehicle Data

- EV Project Leaf away-from-home parking location density in San Francisco Bay Area
- Cumulative through the end of 2013
Target, “everyday mall with some discount stores”

Trader Joe’s, Pier One, Yogurtland

REI, movie theater

Shopping center
Preview of Corridor EVSE Usage in Oregon and Washington
AeroVironment provided INL data from DCFCs and Level 2 units that were installed as part of the Washington & Oregon West Coast Electric Highway.

- Combined with Blink data from DCFCs and Level 2 charging stations.
- Combined with vehicle data using GPS and time stamps.
9/1/2012 to 1/1/2014
• Highest usage in metro areas
• Oregon’s Electric Byways appear to be attracting users off the I-5 corridor
• Analysis continues
Future Work
Tasks for FY15

Leaf and Volt travel studies

• Leaf and Volt away-from-home infrastructure usage vs. eVMT
  – Day-time vs. night-time; home vs. away from home; L1 vs. L2 vs. DCFC
  – Update Volt Aug and Sep 2013 papers

• Leaf driving range
  – How often do they drive beyond single charge range?
  – When they do, what infrastructure do they use? How far from home do they drive?
  – How important are DCFCs for range extension?
**Tasks for FY15 (cont.)**

**Workplace charging**

- Longitudinal driving and charging behavior of drivers with access to WP charging
  - How many WP charging users “need” it based on commuting patterns?
  - Are they off-setting home off-peak charging with WP on-peak charging?

- Vehicle charging frequency at small, medium, large companies with WP charging

- Additional case studies
Tasks for FY15 (cont.)

EVSE usage by venue
• Venue definitions paper
• Overall comparison of usage by venue
• Deep dives by venue (airports, retail, leisure, etc.)

EVSE usage and PEV travel on inter-city corridors
• OR/WA I5
• San Diego/LA
• Nashville/Knoxville (?)
• Chattanooga/Atlanta (?)
Tasks for FY15 (cont.)

Demand charge impact
• DCFCs
• Banks of Level 2 EVSE

Grid demand and vehicle states as inputs to models
• Use EV Project and ChargePoint America data to support Collaborative PEV Smart Grid Integration Requirements and Opportunities Study

EVSE installation costs vs. use ("bang for buck" analysis)
• ~60 Lessons learned topics identified
• INL recently obtaining EV Project costs documentation allows additional analysis
Upcoming EV Project White Papers

Infrastructure Issues
1. What makes an L2 commercial site highly utilized - correlation between utilization and three location based factors
2. What makes an L2 public site highly utilized - correlation between utilization and three location based factors
3. What makes a DCFC site highly utilized - correlation between utilization and three location based factors
4. What makes an L2 commercial site highly utilized - correlation between utilization and three host based factors
5. What makes an L2 public site highly utilized - correlation between utilization and three host based factors
6. What makes a DCFC site highly utilized - correlation between utilization and three host based factors

User Issues
7. What makes an L2 commercial site highly utilized - analyze correlation between utilization and three user based factors
8. What makes an L2 public site highly utilized - analyze correlation between utilization and three user based factors
Upcoming EV Project White Papers

User Issues – cont’d

9. What makes a DCFC site highly utilized - analyze correlation between utilization and three user based factors
10. Top mileage accumulators - characterize use patterns, demographics and geographic of top 50 highest mileage accumulators
11. Top residential charging users - characterize use patterns of top 50 users that never (or rarely) charge away from home
12. Top commercial/public charging users - characterize use patterns of top 50 users of commercial/public charging (by percent of their total charging)
13. Top DCFC users - characterize use patterns of top 50 users of DCFC (by percent of their total charging)

Cost Issues

14. What was the cost to add separate utility submeters at the time of EVSE installation
15. What is the impact of utility demand charges on a Level 2 host
16. What is the impact of utility demand charges on a DCFC host
17. What were the implementation challenges associated with workplace charging installation
18. What were the cost drivers for workplace charging installations
Upcoming EV Project White Papers

Cost Issues – cont’d

19. How do non-residential charging infrastructure installation costs vary by geographic location
20. What were the cost drivers for residential charging installations
21. How do residential charging infrastructure installation costs vary by geographic location
22. What were the cost drivers for DCFC installations
23. How do DCFC infrastructure installation costs vary by geographic location
24. What are the business models currently employed for commercial charging
25. What are the business models currently employed for workplace charging and what is the impact of free workplace charging
26. What are the business models currently employed for DCFC
27. How many Low Carbon Fuel Standard credits have been generated by the EV Project and how many gallons of gasoline have been saved in California
28. What are revenue streams and intangible benefits a charging site host can expect to gain from the installation of EVSE units

Grid Impact Issues

29. Characterize the demand and energy characteristics of L2 commercial EVSE
Upcoming EV Project White Papers

Grid Impact Issues – cont’d

30. Characterize the demand and energy characteristics of L2 public EVSE
31. Characterize the demand and energy characteristics of DCFC
32. Characterize the demand and energy characteristics of residential EVSE
33. Characterize clustering of L2 commercial EVSE
34. Characterize clustering of L2 public EVSE
35. Characterize clustering of DCFC
36. Characterize clustering of residential EVSE
37. Characterize global controllable demand from L2 commercial EVSE
38. Characterize global controllable demand from DCFC
39. Characterize global controllable demand from residential EVSE
40. Characterize energy storage required to reduce peak Level 2 commercial charging demand
41. Characterize energy storage required to reduce peak Level 2 public charging demand
42. Characterize energy storage required to reduce peak DCFC charging demand
43. Characterize energy storage required to reduce peak L2 public/commercial charging demand
Upcoming EV Project White Papers

Grid Impact Issues – cont’d

44. Characterize impact of 6.6kW residential charging
45. Characterize impact of 6.6kW Level 2 commercial charging
46. Characterize impact of 6.6kW Level 2 public charging
47. Characterize the capability of L1 residential charging to satisfy Volt charging needs
48. Characterize the capability of L1 residential charging to satisfy Leaf charging needs
49. SDG&E Project description and lessons learned - TOU rates
50. What was the impact of the car sharing on Publically Available charging infrastructure in San Diego
51. What were 'best practices' for residential infrastructure permitting
52. What were 'best practices' for public infrastructure permitting
53. What practices were used for non-residential charger locating (way-finding)
54. What were practices were used for workplace charging use allocation

Planning Issues

55. How does the location of public and commercial infrastructure actually deployed correlate with EV Project Micro-Climate planning locations
56. How does the use of public and commercial infrastructure actually deployed correlate with EV Project Micro-Climate planning locations
Upcoming EV Project White Papers

Planning Issues – cont’d

57. What percent of total charging energy is dispensed at Level 2 vs. DCFC
58. What percent of total charging energy is dispensed at residential vs. workplace vs. commercial vs. public venues
59. What practices were used for parking/charging enforcement issues
First FY-15 EV Project White Papers

• What were the cost drivers for workplace charging installations
• What were the cost drivers for publicly accessible charging installations
• What were the cost drivers for DCFC installations
• How do residential charging infrastructure installation costs vary by geographic location
• How do publicly accessible infrastructure installation costs vary by geographic location
• Characterize clustering of residential EVSE & grid impacts
• Characterize global controllable demand from residential EVSE “smart grid”
• How does the location of public and commercial infrastructure actually deployed correlate with EV Project Micro-Climate planning locations
First FY-15 EV Project White Papers: cont’d

• What percent of total charging energy is dispensed at residential vs. workplace vs. commercial vs. public venues vs. DCFC locations

• What makes a DCFC site highly utilized - correlation between utilization and three location based factors

• Top commercial/public charging users - characterize use patterns of top 50 users of commercial/public charging (by percent of their total charging)
For all EV Project and ChargePoint America publications, visit

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

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