Electric Vehicle Mile Traveled (eVMT): On-road Results and Analysis

PI: Barney Carlson
Idaho National Laboratory
Energy Storage & Transportation Systems
Advanced Vehicle Testing Activity (AVTA)

June 9, 2015

Project ID VSS171

2015 DOE Vehicle Technologies Program Annual Merit Review
INL/MIS-15-34807

This presentation does not contain any proprietary, confidential, or otherwise restricted information.
Overview

Timeline
FY15:
• Arrange NDAs
• Obtain driving and charging data from multiple OEMs
• Conduct analysis
• Report on results

Barriers
• Lack of availability of real world data from electric drive vehicles
  • Need to quantify Electric vehicle miles traveled for plug-in hybrid electric as well as all-electric vehicles
• Lack of concise analysis method to determine eVMT of blended PHEV operation

Budget
• FY15: $ 120k

Partners
• Honda North America
• Ford Motor Company
• Toyota Motor Engineering & Manufacturing NA
• General Motors
Objective / Relevance

• Analyze real world data from eight vehicle models to determine the
  – Electric Vehicle Miles Traveled (eVMT)

• Present the findings to:
  – Automotive manufacturers
  – U.S. DOE
  – California Air Resources Board
  – Universities / Academia

• Analysis results used by California Air Resources Board for consideration of amendments to the Zero Emissions Vehicles (ZEV) credit regulations for the mid-term review in 2016
Milestones

Completed:

- Non disclosure agreements (NDA) signed with multiple automotive OEMs
  - necessary for data sharing of privately owned vehicles
- Data transfer from multiple OEMs
- Data was organized and loaded into SQL database
- Quality Analysis of the data was conducted
  - trip by trip data validity
  - monthly data completeness
- eVMT was calculated for BEVs and PHEVs / EREVs
  - PHEVs / EREVs: three calculation methods were compared
  - BEVs: one calculation method was used
- eVMT results were presented to California Air Resources Board
Approach:

- Data is from real customer, on-road vehicle operation
  - 158,468,000 miles from 21,600 vehicles
  - From across the U.S. (i.e. widely varying regions and climates)
- Calculated electric vehicle miles traveled (eVMT) for:
  - Ford Fusion Energi
  - Ford C-Max Energi
  - Honda Accord PHEV
  - Toyota Prius PHEV
  - Chevrolet Volt
  - Ford Focus Electric
  - Honda Fit EV
  - Nissan Leaf
Data completeness was calculated on monthly basis
- Ensure minimal missing data
  - data logger error, telematics disruption, etc.
  - eVMT analysis conducted only for months with acceptable data completeness

To align results from the differing data formats, three calculation methods were evaluated to determine eVMT from blended trips
- eVMT calculation methods only differed by <2.5% for the 3 methods

Final results are from two of the methods
- based on EPA Label Fuel Economy and Elec. Energy Consumption
- based on vehicle average Charge Sustaining fuel consumption

Note: for All-Electric Vehicles, by definition, eVMT = total VMT
Approach: eVMT Calculation based on Label Fuel Economy

- Every trip is classified as one of the following:
  - All-Electric (EV), Blended, or Charge Sustaining mode of operation
- From the EPA Label Fuel Economy and Elec. Energy Consumption:
  - The slope is determined from EV to CS (i.e. “A” to “C”)
    - \( \frac{\Delta \text{gal/mi}}{\Delta \text{Wh/mi}} \)
- For EV trips: \( eVMT_{EV} = \text{TripLength} \) (mi)
- For each Blended trip
  - Fuel Displaced by Electrical Energy is determined
    - \( \text{Disp}_\text{Gal} = \text{Trip Wh consumed} \times \left( \frac{\Delta \text{gal/mi}}{\Delta \text{Wh/mi}} \right) \)
  - Calculated Trip eVMT\text{Blended}
    - \( eVMT_{\text{Blended}} = \frac{\text{TripLength} \times \text{Disp}_\text{Gal}}{\text{Trip}_\text{Gal} + \text{Disp}_\text{Gal}} \)
- For Charge Sustaining: \( eVMT_{\text{ChrgSustain}} = 0 \)

\[ eVMT = \text{sum}(eVMT_{EV}) + \text{sum}(eVMT_{\text{Blended}}) \]
Approach:

eVMT Calculation based on Vehicle Average Charge Sustaining Fuel Consumption

• Every trip is classified as All-Electric (EV), Blended, or Charge Sustaining mode of operation

• For EV trips: $eVMT_{EV} = \text{TripLength (mi)}$

• For Blended trips: $\text{Dist}_{Electrified}$ is calculated using the following:

\[ \text{Dist}_{Electrified} = \text{Dist}_{CD} - \frac{\text{Gasoline}_{CD}}{FC_{CS}} \]

\[ \text{Dist}_{Electrified} = \text{Dist}_{Total} - \frac{\text{Gasoline}_{Total}}{FC_{CS}} \]

  – For the amount of fuel consumed during the trip, $\text{Dist}_{Electrified}$ is the distance driven in excess of what could have been driven in CS mode, as enabled mainly by grid energy

  – Using a calculated average Fuel Consumption data (FCcs) for each vehicle, the $\text{Dist}_{Electrified}$ (EV Equivalent) was calculated for every Blended trip.

• For Charge Sustaining: $eVMT_{ChrgSustain} = 0$

• $eVMT = \text{sum}(eVMT_{EV}) + \text{sum}(\text{Dist}_{Electrified})$
## Accomplishment:

<table>
<thead>
<tr>
<th></th>
<th>Nissan LEAF *</th>
<th>Chevrolet Volt *</th>
<th>Ford Focus Electric</th>
<th>Ford C-Max Energi</th>
<th>Ford Fusion Energi</th>
<th>Honda Fit EV</th>
<th>Honda Accord PHEV</th>
<th>Toyota Prius PHEV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Vehicles</strong></td>
<td>4,039</td>
<td>1,867</td>
<td>2,193</td>
<td>5,368</td>
<td>5,803</td>
<td>645</td>
<td>189</td>
<td>1,523</td>
</tr>
<tr>
<td><strong>Number of Vehicle Months</strong></td>
<td>35,294</td>
<td>20,545</td>
<td>12,622</td>
<td>38,096</td>
<td>32,022</td>
<td>6,090</td>
<td>1,437</td>
<td>15,676</td>
</tr>
<tr>
<td><strong>Total Vehicle Miles Traveled VMT (miles)</strong></td>
<td>28,520,792</td>
<td>20,950,967</td>
<td>10,043,000</td>
<td>39,376,000</td>
<td>33,098,000</td>
<td>4,912,920</td>
<td>1,794,494</td>
<td>19,772,530</td>
</tr>
<tr>
<td><strong>Total Calculated Electric Vehicle Miles Traveled eVMT (miles)</strong></td>
<td>28,520,792</td>
<td>15,599,508</td>
<td>10,043,000</td>
<td>12,918,000</td>
<td>11,572,000</td>
<td>4,912,920</td>
<td>399,412</td>
<td>3,224,981</td>
</tr>
<tr>
<td><strong>Avg. Monthly VMT</strong></td>
<td>808.1</td>
<td>1,019.8</td>
<td>795.7</td>
<td>1,033.6</td>
<td>1,033.6</td>
<td>806.7</td>
<td>1,248.8</td>
<td>1,261.3</td>
</tr>
<tr>
<td><strong>Avg. Monthly eVMT</strong></td>
<td>808.1</td>
<td>759.3</td>
<td>795.7</td>
<td>339.1</td>
<td>361.4</td>
<td>806.7</td>
<td>278</td>
<td>207.0</td>
</tr>
<tr>
<td><strong>Est. Annual VMT</strong></td>
<td>9,697</td>
<td>12,238</td>
<td>9,548</td>
<td>12,403</td>
<td>12,403</td>
<td>9,680</td>
<td>14,986</td>
<td>15,136</td>
</tr>
<tr>
<td><strong>Est. Annual eVMT</strong></td>
<td><strong>9,697</strong></td>
<td><strong>9,112</strong></td>
<td><strong>9,548</strong></td>
<td><strong>4,069</strong></td>
<td><strong>4,337</strong></td>
<td><strong>9,680</strong></td>
<td><strong>3,336</strong></td>
<td><strong>2,484</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Format Description</th>
<th>Key-On / Key-Off</th>
<th>Key-On / Key-Off</th>
<th>Enhanced Key-On / Key-Off</th>
<th>Trip Summary</th>
<th>Trip Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic Characterization</td>
<td>CA, OR, WA, AZ, TX, TN, GA, D.C., PA, IL</td>
<td>CA, OR, WA, AZ, TX, TN, GA, D.C., PA, IL</td>
<td>Nationwide</td>
<td>CA, OR, NJ, MD, CT, MA, RI, NY</td>
<td>CA, NY</td>
</tr>
</tbody>
</table>


Minimally Charged Vehicles are Not Excluded from analysis. These data include 14% of Accord PHEVs that achieve between 0-50 monthly eVMT.
Accomplishment: eVMT and VMT

Vehicle Average Monthly eVMT and VMT

Distance Bins: =0, >0 to 100, >100 to 200, >300 to 400, >400 to 500, etc.
Accomplishment: eVMT (monthly electric vehicle miles traveled)

Vehicle Average Monthly eVMT

Distance Bins: =0, >0 to 100, >100 to 200, >300 to 400, >400 to 500, etc.
Accomplishment:
VMT (total monthly vehicle miles traveled)

Vehicle Average Monthly VMT

Distance Bins: =0, >0 to 100, >100 to 200, >300 to 400, >400 to 500, etc.
Accomplishment:
**Nissan Leafs & Chevy Volts Regional Distribution**

Nissan Leafs and Chevrolet Volts Reporting Data in The EV Project through December 2013

Legend:
- **Nissan Leafs**
- **Chevy Volts**
- **Smart Electric Drive**
Accomplishment: Ford C-Max Energi, Fusion Energi, and Focus Electric Regional Distribution

<table>
<thead>
<tr>
<th># of distinct Vehicles ever Driven in the Region</th>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
<th>Region 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford C-Max Energi</td>
<td>2500</td>
<td>2024</td>
<td>1890</td>
<td>1556</td>
</tr>
<tr>
<td>Ford Fusion Energi</td>
<td>2885</td>
<td>1571</td>
<td>2189</td>
<td>1393</td>
</tr>
<tr>
<td>Ford Focus Electric</td>
<td>1337</td>
<td>289</td>
<td>313</td>
<td>328</td>
</tr>
</tbody>
</table>
Response to Previous Year Reviewer Comments

- This project is New for this year
Future Work

• Analyze impact to eVMT of the following:
  – Seasonal variation (ambient temperature)
  – Regional variation
    • especially CA and New England ZEV states
  – Impact of workplace charging
    • How much does this extend or enable ZEV driving?
  – Electric vehicle miles traveled (eVMT)
    • Per charge event
    • Pre calendar day
  – Understanding of household vehicle utilization
    • i.e. when is second vehicle used in the same household
      – for trips greater than EV range?
      – other functions
Summary

- On-road data from privately owned vehicles was analyzed
  - 158,468,000 miles from 21,600 vehicles
  - eVMT analysis
    - Annual eVMT ranged from
      - BEV: 9,548 to 9,697 mi
      - PHEV / E-REV: 2,484 to 9,112 mi
- Data from all vehicle models were from varying regions and climates
- Three eVMT calculation methods for blended operation were compared
  - eVMT calculation methods differed by < 2.5%  
- For PHEVs / EREVs a correlation can be observed between eVMT and battery capacity
- Results were presented to California Air Resources Board at Oct 2014 board meeting with respect to Zero Emissions Vehicles (ZEV) credit regulations prior to the mid-term review
Acknowledgement

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

More Information
http://avt.inl.gov