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- Laboratory Overview
- EVI-Pro, National Infrastructure Analysis
- EVI-Pro Lite
- Market Analysis
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US Department of Energy National Lab System
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- **EVI-Pro, National Infrastructure Analysis**
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PEV Charging Analysis – NREL Objective

Inform regional/national stakeholders on plug-in electric vehicle (PEV) charging infrastructure, focusing on non-residential applications to:

- Reduce range anxiety as a barrier to increased PEV sales
- Enhance charging options to maximize eVMT and enable greater PEV adoption
- Ensure effective use of private/public infrastructure investments

Some key questions related to investment in PEV charging stations...

Recent Studies

- California (2014)
- Seattle, WA (2015)
- Massachusetts (2017)
- Colorado (2017)
- Columbus, OH (2017)
- National PEV Infrastructure Analysis (2017)
- Maryland (2018)
- Columbus Yellow Cab (2019)

How many?

What kind?

Where?
NREL analysis was published in September 2017 as a Department of Energy EERE Report. This study was supported by the U.S. Department of Energy’s Vehicle Technologies Office. Report projects charging infrastructure necessary to support a fleet of vehicles at the national level.

https://www.nrel.gov/docs/fy17osti/69031.pdf
Electric Vehicle Infrastructure Projection Tool (EVI-Pro)

![Diagram of EVI-Pro tool components]

- **Vehicle Attributes**
- **Infrastructure Attributes**
- **Travel Data**
- **PEV Sales Projections**

**Driving/Charging Simulations** (Estimated individual charging behavior)
- Participation rates
- Charging load profiles
- Consumer eVVTI benefits
- Individual charging sessions

**Spatial/Temporal Post Processing** (Estimate potential for shared use of EVSE)
- EVSE density
- EVSE utilization
- EVSE counts

**Weight and scale**
- EVSE density

**EVSE**: Electric Vehicle Supply Equipment
Electric Vehicle Infrastructure Projection Tool (EVI-Pro)

- PHEVs & BEVs Attributes
- Home/Work/Public, L1/L2/DCFC
- Real-world GPS data
- Future PEV Stock

- Vehicle Attributes
- Infrastructure Attributes
- Travel Data
- PEV Sales Projections

Driving/Charging Simulations
(Quantify individual charging behavior)

- Participation rates
- Charging load profiles
- Consumer eVVTI benefits
- Individual charging sessions

Spatial/Temporal Post Processing
(Estimate potential for shared use of EVSE)

- EVSE density
- EVSE utilization

Weight and scale

EVSE counts

EVSE: Electric Vehicle Supply Equipment

Spatial Dimensionality
Electric Vehicle Infrastructure Projection Tool (EVI-Pro)

Foundational assumptions:
- Future PEVs will be driven in a manner consistent with today’s gasoline vehicles
- Consumers prefer to perform the majority of charging at their home location
- Charging at non-residential stations will be used to maximize eVMT
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Electric Vehicle Infrastructure Projection Tool (EVI-Pro)

Foundational assumptions:
- Future PEVs will be driven in a manner consistent with today’s gasoline vehicles
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- Charging at non-residential stations will be used to maximize eVMT

Developed in collaboration with California Energy Commission!
National Modeling Approach
National Modeling Approach

Geospatial Travel Data
- California
- Columbus
- Massachusetts

EVI-Pro Model

Nominal EVSE/PEV Ratios by PEV type and EVSE type

Adjustments for:
- Population Density
- PEV Concentration
- Ambient Temperature

Spatial Disaggregation
- X Million PEVs nationally
- (based on existing registrations)

PEV counts by type for:
- 486 Urban Areas
- 3,087 Urban Clusters
- 50 Rural Areas

Apply locally adjusted EVSE/PEV ratios to all 3,623 regions

Localized EVSE estimates for all 3,623 regions
While most travels can be completed on a single-charge, access to an extensive and convenient network of DCFC stations along corridors that enable reliable long-distance intercity travel is required to support long-distance travel.
### Results – Central Scenario & Sensitivity Analysis

#### Central Scenario

<table>
<thead>
<tr>
<th></th>
<th>Cities</th>
<th>Towns</th>
<th>Rural Areas</th>
<th>Interstate Corridors</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEVs</td>
<td>12,411,000</td>
<td>1,848,000</td>
<td>642,000</td>
<td>---</td>
</tr>
<tr>
<td>DCFC Stations</td>
<td>4,900</td>
<td>3,200</td>
<td>---</td>
<td>400</td>
</tr>
<tr>
<td>DCFC Plugs (to meet demand)</td>
<td>19,000</td>
<td>4,000</td>
<td>2,000</td>
<td>2,500</td>
</tr>
<tr>
<td>DCFC Plugs per station</td>
<td>3.9</td>
<td>1.3</td>
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<td>6.3</td>
</tr>
<tr>
<td>DCFC Plugs per 1,000 PEVs</td>
<td>1.5</td>
<td>2.2</td>
<td>3.1</td>
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</tr>
<tr>
<td>Non-Res L2 Plugs</td>
<td>451,000</td>
<td>99,000</td>
<td>51,000</td>
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<tr>
<td>Non-Res L2 Plugs per 1,000 PEVs</td>
<td>36</td>
<td>54</td>
<td>79</td>
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Estimated requirements for PEV charging infrastructure are heavily dependent on:

1) evolution of the PEV market, 2) consumer preferences, and 3) technology development.
**Results – Central Scenario & Sensitivity Analysis**

**Central Scenario**

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Estimated requirements for PEV charging infrastructure are heavily dependent on: 1) evolution of the PEV market, 2) consumer preferences, and 3) technology development.

**Sensitivity Analysis**
Florida Results, Central Scenario
National Analysis Insights and Conclusions

- **Communities** are expected to have significantly larger charging infrastructure requirements (coverage) than **interstate corridors**
  - Analysis also produced 550,000 community-based L2 plugs in baseline scenario

- Demand for non-residential plugs for a **15-million PEV market**:
  - 25,000 DCFC plugs in communities (approximately 3.4 plugs per 1,000 BEVs)
  - 600,000 L2 plugs (approximately 40 plugs per 1,000 PEVs)

- Sensitivity analysis indicates a **strong relationship between the evolution of the PEV and EVSE markets**

Understanding **driving patterns**, **PEV characteristics** (range, charging power), and **charging behavior** and then prioritizing corridors and setting station spacing accordingly could help **optimize the utility and economics of charging stations**
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NREL created a free, web-based tool allowing users to leverage the variable relationships employed in the study.
EVI-Pro Lite, cont.

https://afdc.energy.gov/evi-pro-lite
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Plug-In Electric Vehicle Sales Trends

Monthly PEV shares (of all LDVs)

- Reduction in Tesla’s tax credit
- Tesla Model 3 Entry
Sales Frequency by Price, 2016

Sales Frequency by Price, 2016


Georgia Electric Car Sales Drop ~90% In ~6 Months

Impact of phase-out of $7,500 tax credit

Largely untapped market by new EV’s
Major Takeaways

• Many factors influence necessary EV infrastructure
  – Fleet characteristics, **presence of home charging**
• DCFC is more than just interstates and highways
• Workplace charging often overlooked. Workplace plugs represent 2/3 of projected L2 infrastructure in analysis
• EV’s must be planned for, but they are not imminent!
  – Incentives and infrastructure access continue to influence sales. If there’s a tipping point, we’re not there yet!
Thanks! Questions?

This work was funded by the US Department of Energy Vehicle Technologies Office.
EVI-Pro Modeling Approach
### Simulated charging behavior for a BEV100 under an example travel day

<table>
<thead>
<tr>
<th>Destination</th>
<th>Departure</th>
<th>Arrival</th>
<th>Drive Miles</th>
<th>Dwell Hours</th>
<th>Simulated Charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>8:20 AM</td>
<td>9:00 AM</td>
<td>32.8</td>
<td>5.00</td>
<td>L2</td>
</tr>
<tr>
<td>Non-Res</td>
<td>2:00 PM</td>
<td>3:30 PM</td>
<td>68.9</td>
<td>0.25</td>
<td>---</td>
</tr>
<tr>
<td>Non-Res</td>
<td>3:45 PM</td>
<td>4:00 PM</td>
<td>6.3</td>
<td>0.25</td>
<td>---</td>
</tr>
<tr>
<td>Non-Res</td>
<td>4:15 PM</td>
<td>4:20 PM</td>
<td>0.9</td>
<td>0.67</td>
<td>DCFC</td>
</tr>
<tr>
<td>Non-Res</td>
<td>5:00 PM</td>
<td>5:30 PM</td>
<td>9.2</td>
<td>0.25</td>
<td>---</td>
</tr>
<tr>
<td>Non-Res</td>
<td>5:45 PM</td>
<td>6:00 PM</td>
<td>5.0</td>
<td>0.50</td>
<td>---</td>
</tr>
<tr>
<td>Home</td>
<td>6:30 PM</td>
<td>7:30 PM</td>
<td>46.8</td>
<td>12.83</td>
<td>L1</td>
</tr>
</tbody>
</table>

**Driving/Charging Simulations**

Bottom-up simulations based on travel behavior are used to produce a variety of charging scenarios.

**Optimal charging behavior** is assumed to investigate spatial and temporal charging demand and to estimate:
- non-residential infrastructure requirements
- aggregate load profiles
### Central Scenario and Sensitivity Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Central Scenario</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PEV Total</strong></td>
<td>15M (linear growth to 20% of LDV sales in 2030)</td>
<td>9M (growth to 10% of 2030 sales)</td>
</tr>
<tr>
<td><strong>PEV Mix</strong></td>
<td>Mix</td>
<td>Long / Short</td>
</tr>
<tr>
<td>PHEV20</td>
<td>10%</td>
<td>PHEV20 0% / 40%</td>
</tr>
<tr>
<td>PHEV50</td>
<td>35%</td>
<td>PHEV50 50% / 0%</td>
</tr>
<tr>
<td>PHEV20-SUV</td>
<td>5%</td>
<td>PHEV20-SUV 0% / 10%</td>
</tr>
<tr>
<td>BEV100</td>
<td>15%</td>
<td>BEV100 0% / 50%</td>
</tr>
<tr>
<td>BEV250</td>
<td>30%</td>
<td>BEV250 40% / 0%</td>
</tr>
<tr>
<td>BEV250-SUV</td>
<td>5%</td>
<td>BEV250-SUV 10% / 0%</td>
</tr>
<tr>
<td><strong>Share of PEVs in Cities</strong></td>
<td>83% (based on existing HEVs)</td>
<td>71% (based on existing LDVs)</td>
</tr>
<tr>
<td><strong>PHEV:BEV Ratio</strong></td>
<td>1:1</td>
<td>4:1 to 1:4</td>
</tr>
<tr>
<td><strong>PHEV Support</strong></td>
<td>Half of full support</td>
<td>No PHEV support to full support</td>
</tr>
<tr>
<td><strong>SUV Share</strong></td>
<td>10%</td>
<td>5% to 50%</td>
</tr>
<tr>
<td><strong>% Home Charging</strong></td>
<td>88%</td>
<td>88%, 85%, and 82%</td>
</tr>
<tr>
<td><strong>Interstate Coverage</strong></td>
<td>Full Interstate</td>
<td>Mega-regions to Full Interstate</td>
</tr>
<tr>
<td><strong>Corridor DCFC Spacing</strong></td>
<td>70 miles</td>
<td>40 to 100 miles</td>
</tr>
<tr>
<td><strong>DCFC Charge Time</strong></td>
<td>20 minutes (150 kW)</td>
<td>10 to 30 minutes (400 to 100 kW)</td>
</tr>
</tbody>
</table>

- **15M PEVs Nationally**: 15 million PEVs nationally.
- **Preference for long range PEVs**: Preference for long range PEVs.
- **Equal shares of PHEV & BEV**: Equal shares of PHEV and BEV.
- **Majority of charging at home locations**: Majority of charging at home locations.
- **Full corridor coverage**: Full corridor coverage.
Interstate Corridors Station Siting

Full Interstate Coverage
- 285 – 713 Stations

Mega-Region Coverage
- 96 – 239 Stations

Long Distance Travel OD Pairs
- 174 – 436 Stations

Long-Distance Informed Coverage
- 96 – 239 Stations

Also considered: Link counts from Highway Performance Monitoring Region