Evolution of Electric Vehicles (EV) and Infrastructure Challenges

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Electric automobile, early 20’s
An Advertisement for the "One Hundred Mile Fritchle" (Denver Republican, December 11, 1910)

The 100-Mile Fritchle Electric Now Holds All Records for Hill Climbing, Mileage Per Charge, Durability and Economy of Upkeep

Four years ago an electric Fritchle was the proud among all competitors.

Four years ago a Fritchle Electric with a Model 24, 24volt Fritchle Battery made the first trip from Denver to Colorado Springs.

ELECTRIC AUTO RUN TO COLORADO SPRINGS

The Fritchle Electric is thoroughly tested and compared with the gasoline in every respect both in economy and performance. The Fritchle Electric is the winner on every test made, proving that the Fritchle Electric is the ideal automobile.

One hundred miles a day is no big thing with a Fritchle Electric car, if the grade being 5 per cent, you are never handicapped by up hill grades.

The tests prove nothing so far as economy and driving is concerned. The Fritchle Electric car has been driven 100 miles per day and also 300 miles per day, and in every test the Fritchle Electric is the winner.

The Fritchle Electric car has been driven 100 miles per day and also 300 miles per day, and in every test the Fritchle Electric is the winner.

STANDING CHALLENGE

Any automobile manufacturer or gasoline manufacturer can enter a 100 mile challenge with a Fritchle Electric car and any other automobile of his choice and the Fritchle Electric will stand the test.
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Henry Ford's Vehicles</td>
<td>$500</td>
<td>$14,000</td>
</tr>
<tr>
<td>Oliver Fritchle's Vehicles</td>
<td>$3,500</td>
<td>$105,000</td>
</tr>
</tbody>
</table>
Which year over 60% of the vehicles maybe EV’s?
Acceptance of electric cars was initially hampered by a lack of power infrastructure, but by 1912, many homes were wired for electricity, enabling a surge in the popularity of the cars. In the United States by the turn of the century, 40 percent of automobiles were powered by steam, 38 percent by electricity, and 22 percent by gasoline. A total of 33,842 electric cars were registered in the United States, and the U.S. became the country where electric cars had gained the most acceptance. Most early electric vehicles were massive, ornate carriages designed for the upper-class customers that made them popular. They featured luxurious interiors and were replete with expensive materials. Sales of electric cars peaked in the early 1910s.
Some Definitions

- **EV**: Electric Vehicles (Electric drive motors)

- **HEV**: Hybrid Electric Vehicles (Example – Prius; Gasoline engine with electric drive)

- **PEV**: Plug-in Electric Vehicles (Examples – PHEV and BEV)

- **PHEV**: Plug-in Hybrid Electric Vehicles (Example – Plug-in Prius; Some electric range then gasoline engine with electric drive)

- **BEV**: Battery Electric Vehicles (Example – Tesla; all electric, no gasoline engine)

- **kW & kWh**: Which one is comparable to a gallon of fuel? kWh
# Annually Applied Technology Projections for Newly Deployed PEVs and Chargers

## Electric Range and Charger Power Level Projections

<table>
<thead>
<tr>
<th></th>
<th>PHEVs</th>
<th>BEVs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(As-of-2017)</strong></td>
<td>(By 2025)</td>
<td></td>
</tr>
<tr>
<td>Electric Range (miles):</td>
<td>29.6  ➔ 40.0</td>
<td>121.8 ➔ 210.0</td>
</tr>
<tr>
<td>Residential L2 (kW):</td>
<td>3.6  ➔ 4.9</td>
<td>6.6  ➔ 11.4</td>
</tr>
<tr>
<td>Destination L2 (kW):</td>
<td>3.6  ➔ 4.9</td>
<td>6.6  ➔ 6.6</td>
</tr>
</tbody>
</table>

Source: California Energy Commission and NREL
### Projections for Statewide PEV Charger Demand

#### Demand for L2 Destination (Workplace and Public) Chargers
(The Default Scenario)

<table>
<thead>
<tr>
<th></th>
<th>Total PEVs</th>
<th>Lower Estimate (Chargers)</th>
<th>Higher Estimate (Chargers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As of 2017</td>
<td>239,328</td>
<td>21,502</td>
<td>28,701</td>
</tr>
<tr>
<td>By 2020</td>
<td>645,093</td>
<td>53,173</td>
<td>70,368</td>
</tr>
<tr>
<td>By 2025</td>
<td>1,321,371</td>
<td>99,333</td>
<td>133,270</td>
</tr>
</tbody>
</table>

#### Demand for DC Fast Chargers
(The Default Scenario)

<table>
<thead>
<tr>
<th></th>
<th>Total BEVs</th>
<th>Lower Estimate (Chargers)</th>
<th>Higher Estimate (Chargers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As of 2017</td>
<td>133,386</td>
<td>2,005</td>
<td>5,877</td>
</tr>
<tr>
<td>By 2020</td>
<td>356,814</td>
<td>4,881</td>
<td>13,752</td>
</tr>
<tr>
<td>By 2025</td>
<td>729,094</td>
<td>9,061</td>
<td>24,967</td>
</tr>
</tbody>
</table>

Source: California Energy Commission and NREL
The Statewide Aggregated Electricity Load for a Typical Weekday

Source: California Energy Commission and NREL
## Cost to Travel 100 miles

<table>
<thead>
<tr>
<th></th>
<th>Fuel Cost</th>
<th>MPG</th>
<th>Gal/100mi</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>$3.81</td>
<td>31</td>
<td>3.23</td>
<td>$12.31</td>
</tr>
<tr>
<td>Diesel</td>
<td>$4.11</td>
<td>40</td>
<td>2.50</td>
<td>$10.28</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>$3.99</td>
<td>40</td>
<td>2.50</td>
<td>$9.98</td>
</tr>
<tr>
<td>E85</td>
<td>$3.72</td>
<td>26</td>
<td>3.85</td>
<td>$14.31</td>
</tr>
<tr>
<td>LPG/Propane</td>
<td>$2.35</td>
<td>29</td>
<td>3.45</td>
<td>$8.10</td>
</tr>
<tr>
<td>CNG</td>
<td>$1.75</td>
<td>29</td>
<td>3.45</td>
<td>$6.03</td>
</tr>
<tr>
<td>Electricity</td>
<td>$0.10kWh</td>
<td>3.5mi/kWh</td>
<td>28.6 kWh</td>
<td>$2.86</td>
</tr>
</tbody>
</table>

Source: Oregon DOT
EV Charger Installation Cost
2013 INL Study

<table>
<thead>
<tr>
<th>Type</th>
<th>Residential Level 2</th>
<th>Workplace Level 2</th>
<th>Public Level 2</th>
<th>Blink DC Fast Charger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs</td>
<td>$8,000</td>
<td>$5,960</td>
<td>$12,660</td>
<td>$50,000</td>
</tr>
<tr>
<td>Minimum</td>
<td>$1,354</td>
<td>$2,223</td>
<td>$3,108</td>
<td>$22,626</td>
</tr>
<tr>
<td>Mean</td>
<td>A Few Hundred</td>
<td>$624</td>
<td>$600</td>
<td>$8,500</td>
</tr>
</tbody>
</table>
Figure: Energy Consumption by Sector
Figure: Energy Flow for Electric Vehicle.
Figure: Energy Flow for Gasoline Vehicle.
SIGI – Sustainable Integrated Grid Initiative

About

SIGI was established as part of the WCGEC, is located at BCOE's Center for Environmental Research and Technology (CE-CERT) and is one of the largest integrated renewable energy projects of its kind in the state. A key component of the project is to demonstrate that electric vehicles can be seamlessly introduced into the existing grid system through “smart integration” of renewable energy, storage and advanced dispatch controls.

Key Project Features

Load Management
- Reduces risk of grid failure/blackout (due to decreased peaks)
- Increased predictability of demand (flattens peak demand)

Outage Prevention
- Relieves stress on grid

Outage Support
- Battery dedicated to critical loads

Distributed Energy Resource Support
- Microgrids support distributed solar systems

Project Partners
SIGI: Citywide EV Chargers
One megawatt-hour of battery energy storage was installed at UC Riverside’s Winston Chung Hall. The system is physically comprised of two 500 kilowatt-hour systems; each with its own inverter, battery management system (BMS), and control hardware. The Princeton Power Systems bi-directional inverters are capable of charging the batteries at a rate of up to 95kW, and discharging at up to 100kW. The Battery Energy Systems BMS provides real-time data of the system, including pack state-of-charge, pack voltage, and pack current. The control hardware provides a gateway to inverter control, inverter data, and BMS data, and allows implementation of different control algorithms such as peak-shaving, and demand-response.

500 kilowatt-hours of battery energy storage were installed in CE-CERT’s 1200 building. This system has a similar design to the systems in Winston Chung Hall and uses the same components as well.
Results of the Administration Building’s new configuration with PV production, shown in green with 100 kW inverter limiting solar production during mid-day hours. The figure shows actual data for May 3rd and May 4th 2016. The net electricity usage of the building, as seen by the power company meter, is shown in blue.

The blue values above horizontal zero axis are energy being imported from the grid at night while, the blue values under zero axis are energy being exported to the grid during the day due to surplus solar production. This building is net zero because the exported energy is larger than the imported energy usage.
Operational Results: Level 3 EV Charging Characteristics

August 1 2016

- BMW i3 Stop at 75% Charge 11:58 AM, 57.0 kW Jump
- Nissan Leaf Charge 12:01 PM, 33.7 kW Jump
- BMW i3 Stop at 42% Charge 11:16 AM, 63.5 kW Jump
- Nissan Leaf Charge 12:01 PM, 33.7 kW Jump
- BMW i3 End of Charge 12:46 PM, 60.3 kW
- BMW i3 End of Second Charge/ Nissan Leaf Begin Charge 11:54 AM
- BMW i3 Begin Second Charge at 42% 11:41 AM
- BMW i3 End at 80% Charge 1:19 PM, 33.7 kW Jump
- BMW i3 End at 93% Charge 1:33 PM, 23.4 kW Drop
- BMW i3 Begin Third Charge at 76% 1:08 PM
- Chevy Spark Charge 2:50 PM, 53.5 kW Jump
- Chevy Spark End of Charge 3:06 PM, 48.3 kW Drop
- Chevy Spark Begin Charge 2:34 PM
SIGI
Trolley V2G Bi-Directional DC Port

Benefits

- Bypasses on-board AC charger
- Data line integration
- CAN Bus Monitoring
- DC connection
- Contactors for safety
- 100 kW micro-grid integration
SIGI
Light Duty V2G Micro-grid Integration

Goals
- Integration on .5 MW mobile battery trailer platform
- Capable of 30kW DC bi-directional operation
- Evaluate operation in micro-grid setting
- Integrate with DR operations
- Respond to vehicle state, driver behavior, building needs and solar generation variability
Questions