Electrifying Fleets and Demonstrating Zero Emissions Technology

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Key Research Areas

- **Co-optimizing fuels and engines** – R&D to maximize performance, efficiency, and compatibility with existing infrastructure

- **Increasing sustainable mobility** – connected and autonomous transportation innovations for intelligent, efficient, integrated network

- **Reducing expense of battery development** – Computer-Aided Engineering for Electric-Drive Vehicle Batteries (CAEBAT) tool

- **Improving efficiency of heavy-duty vehicles** – commercial truck fuel, engine, thermal management, and powertrain innovation

- **Demonstrating electrification of vehicles** – energy storage for plug-in electric and fuel cell electric vehicles; power electronics; and infrastructure R&D to boost performance and market viability
CONSORTIUM
7 labs, 30+ projects, 65 researchers, $34M* over 3 years.

SMART MOBILITY LAB

Connected & Automated Vehicles

Advanced Fueling Infrastructure

Urban Science

Mobility Decision Science

Multi-Modal Transport

*Based on anticipated funding
**Expected EV Growth**

**37%**
Year-over-year national sales growth of EVs in 2016
*Source: Insideevs.com*

**62%**
Year-over-year national EV sales growth in 2017
*Source: Insideevs.com*

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**2025 Sales Projections**

- **Aggressive Scenario:** 3.1M
- **Moderate Scenario:** 1.7M
- **Conservative Scenario:** 1.0M

Aggressive Scenario assumes a CAGR of 29%

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**2017** to **2025**

- **GTM Research**
- **Bloomberg**
- **IEI / EEI**
- **Navigant**
- **Ann. Energy Outlk**
- **Barclay's**
- **Med**
- **Low**

**Sources embedded in chart above**
EV – Battery costs

Cost Trends for Lithium-based EV Batteries

Graphite/High Voltage NMC

Si

Silicon/High Voltage NMC

Lithium-Metal or Lithium/Sulfur

Li-Metal Battery projection assumes cycle life, cell scale-up, and catastrophic failure issues have been resolved

System Cost ($/kWh)

2015=$268/kWh
2016=$245/kWh
2017=$219/kWh

5x excess Lithium, 10% Sulfur $320/kWh

$229/kWh

$212/kWh

4V, NMC

4.2V, 10% Si

4.7 Volt

4.7 Volt, 30% Si

1.5x excess Li, 75% S, ~$80/kWh

Year

2012

2014

2016

2018

2020

2022

2024

2026

2028

2030
Combination of fast charge batteries and a network of high capacity chargers can minimize range anxiety, promote the market penetration of BEVs, and increase total electric miles driven.

<table>
<thead>
<tr>
<th>Type of Charging Station</th>
<th>Level 2 220V (~7.2kW)</th>
<th>DC Fast Charger (50kW)</th>
<th>Tesla Super Charger (140 kW)</th>
<th>Extreme Fast-Charging (350kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to charge (for 200 miles)</td>
<td>8 hours</td>
<td>2 hours</td>
<td>25 mins</td>
<td>10-15 mins</td>
</tr>
</tbody>
</table>

Charging Device

EV, Renewable Energy, Buildings, and Energy Storage - Working Together

Developing Systems Integrated Applications

**Managed Charging**
Evaluate functionality and value of load management to reduce charging costs and contribute to standards development.

**Local Power Quality**
Leverage charge system power electronics to monitor and enhance local power quality and grid stability in scenarios with high penetration of renewables.

**Emergency Backup Power**
Explore strategies for enabling the export of vehicle power to assist in grid outages and disaster-recovery efforts.

**Bi-Directional Power Flow**
Develop and evaluate integrated V2G systems, which can reduce local peak-power demands and access grid service value potential.

Vehicle-to-Grid Challenges

**Life Impacts**
Can functionality be added with little or no impact on battery and vehicle performance?

**Information Flow and Control**
How is information shared and protected within the systems architecture?

**Holistic Markets and Opportunities**
What role will vehicles play and what value can be created?
NREL’s Electric Futures Study (Transportation)

Answering crucial questions about:

- **Technologies**: What electric technologies are available now, and how might they advance?
- **Consumption**: How might electrification impact electricity demand and use patterns?
- **System Change**: How would the electricity system need to transform to meet changes in demand?
- **Flexibility**: What role might demand-side flexibility play to support reliable operations?
- **Impacts**: What are the potential costs, benefits, and impacts of widespread electrification?
Changing Electric Paradigm

**ELECTRIFICATION**
Critical to long-term carbon goals and will be a relevant decentralized energy resource

Key technologies:
- Electric vehicles,
- Vehicle to grid/home,
- Smart charging, heat pumps

**DECENTRALIZATION**
Makes customers active elements of the system, though requires significant coordination

Key technologies:
- Energy efficiencies,
- Decentralized storage,
- Microgrids, demand response

**DIGITALIZATION**
Allows for open, real-time, automated communication and operation of the system

Key technologies:
- Network technologies (smart metering, remote control and automation systems, smart sensors, optimization and aggregation platforms) and customer technologies (smart appliances and devices, Internet-of-Things)

Sources: World Economic Forum
Yard Tractor Usage Map – PANYNJ terminal
Current Announcements

- California CEC approval of 3 utilities $738M investment
- NYPA approval of $250M (throughout state, including airport)
- NJ’s PSEG $300M investment
- VW Electrify America $2B investment
Thank You

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