Opportunities and Challenges for Plug-in Electric Vehicles
Contents

Technical Information
• Definitions
• Transportation Technologies
• Plug-in Electric Vehicles
• PEV Charging
• Code and Standards

Opportunities
• Value Proposition
• Benefits of Plug-in Electric Vehicles

Challenges
• Collaboration - PEV Stakeholders
• Customer Concerns
• Market Projection
• Electricity Grid Impacts
• Battery Technology Development
Technical Information
Definitions

PEV
Plug-in Electric Vehicle

BEV
Battery Electric Vehicle
Nissan Leaf, Tesla Roadster

PHEV-10, 20, 30, 40 etc.
Plug-in Hybrid Electric Vehicle
(electric range = 10, 20, 30, 40 miles)
Toyota Prius PHEV

EREV
Extended Range Electric Vehicle
Chevy Volt

Source: www.goelectricdrive.com
## Comparison of Transportation Technologies

<table>
<thead>
<tr>
<th></th>
<th>Electricity</th>
<th>Gasoline</th>
<th>CNG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Cost</strong>¹</td>
<td>$0.75</td>
<td>$3.50</td>
<td>$1.91</td>
</tr>
<tr>
<td><strong>Fuel Economy</strong></td>
<td>50+ mpg</td>
<td>27.5 mpg</td>
<td>25 mpg</td>
</tr>
<tr>
<td><strong>Infrastructure</strong></td>
<td>Extensive</td>
<td>Extensive</td>
<td>Very Limited</td>
</tr>
<tr>
<td><strong>Vehicle Cost</strong></td>
<td>+$8-12k</td>
<td>Baseline</td>
<td>+$8-12k</td>
</tr>
<tr>
<td><strong>Emissions; CO₂</strong></td>
<td>&lt; 200 g/mile</td>
<td>400 g/mile</td>
<td>300 g/mile</td>
</tr>
<tr>
<td><strong>Emissions; other</strong></td>
<td>NOx, SO₂</td>
<td>VOC, NOx, PM</td>
<td>NOx</td>
</tr>
<tr>
<td><strong>Pros</strong></td>
<td>No tailpipe emissions</td>
<td>High efficiency and performance</td>
<td>Known technology</td>
</tr>
<tr>
<td></td>
<td>High battery cost</td>
<td>Electricity widely available and inexpensive</td>
<td></td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td>High battery cost</td>
<td>Long refueling / charging times</td>
<td>Limited availability in long term</td>
</tr>
<tr>
<td></td>
<td>Long refueling / charging times</td>
<td>Some additional infrastructure required</td>
<td></td>
</tr>
</tbody>
</table>
# PEV Introductions

Key Point: Nearly every automaker has a plug-in vehicle planned over the next 3 years.

<table>
<thead>
<tr>
<th>PHEV or EREV</th>
<th>ALL ELECTRIC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production</strong></td>
<td></td>
</tr>
<tr>
<td>GM PHEV</td>
<td>Nissan Leaf</td>
</tr>
<tr>
<td>Cadillac Converj</td>
<td>Smart ED</td>
</tr>
<tr>
<td>Chevrolet Volt</td>
<td>Mitsubishi iMIEV</td>
</tr>
<tr>
<td>BYD 3DFM</td>
<td></td>
</tr>
<tr>
<td>Toyota Prius</td>
<td></td>
</tr>
<tr>
<td>Fiskar Karma</td>
<td></td>
</tr>
<tr>
<td><strong>Demo/Concept</strong></td>
<td></td>
</tr>
<tr>
<td>Ford Escape PHEV</td>
<td></td>
</tr>
<tr>
<td>BMW Concept</td>
<td>Chrysler/Fiat EV</td>
</tr>
<tr>
<td>VW Golf TwinDrive</td>
<td>Mini-E</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyundai Blue-Will</td>
<td></td>
</tr>
<tr>
<td>Volvo C30</td>
<td></td>
</tr>
<tr>
<td>Kia Ray</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercedes BlueCell</td>
<td></td>
</tr>
<tr>
<td>Tesla Model S</td>
<td></td>
</tr>
<tr>
<td>Toyota FT-EV</td>
<td></td>
</tr>
</tbody>
</table>
# PEV Comparison and Performance Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Chevrolet Volt</th>
<th>Nissan Leaf</th>
<th>Tesla Roadster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch date</td>
<td>November 2010</td>
<td>December 2010</td>
<td>In Production</td>
</tr>
<tr>
<td>MSRP / tax credit</td>
<td>$41,000 / 7,500</td>
<td>$32,800 / 7,500</td>
<td>$109,000 / 7,500</td>
</tr>
<tr>
<td>Lease details</td>
<td>$350/month, $2,500 down, 36 months</td>
<td>$350/month, $2,000 down, 36 months</td>
<td></td>
</tr>
<tr>
<td>Initial production #</td>
<td>10,000 (2011), 45,000 (2012) up to 60,000 capacity</td>
<td>Up to; 50,000 (Japan, 2011), 150,000 (TN, 2012), 50,000 (UK, 2013)</td>
<td>1,200 sold (July 2010)</td>
</tr>
<tr>
<td>Type / # seats</td>
<td>Sedan / 5</td>
<td>Sedan / 5</td>
<td>Coupe / 2</td>
</tr>
<tr>
<td>EV (IC engine) range</td>
<td>25-50 (260)</td>
<td>100 (N/A)</td>
<td>244 (N/A)</td>
</tr>
<tr>
<td>IC engine</td>
<td>Gas / 1.4 liter / 74 hp / 55 kW</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Electrical motor</td>
<td>149 hp / 111 kW</td>
<td>107 hp / 80 kW</td>
<td>288 hp / 215 kW</td>
</tr>
<tr>
<td>performance</td>
<td>273 ft-lbs / 373 Nm</td>
<td>210 ft-lbs / 280 Nm</td>
<td>280 ft-lbs / 380 Nm</td>
</tr>
<tr>
<td>0 – 60 mph</td>
<td>9.0 s</td>
<td>11.5 s</td>
<td>3.9 s</td>
</tr>
<tr>
<td>Battery capacity</td>
<td>16 kWh (10.4 kWh useable)</td>
<td>24 kWh</td>
<td>53 kWh</td>
</tr>
<tr>
<td>Battery type</td>
<td>Li-ion, 220 cells</td>
<td>Laminated Li-ion</td>
<td>Li-ion, 6,831 cells</td>
</tr>
<tr>
<td>Charge time</td>
<td>8-9 / 3 hrs</td>
<td>20 / 8 hrs</td>
<td>48 / 3.5 hrs</td>
</tr>
<tr>
<td></td>
<td>120V-12A / 240V-15A</td>
<td>120V-12A / 240V-15A</td>
<td>120V-12A / 240V-90A</td>
</tr>
<tr>
<td>Battery weight (lbs)</td>
<td>375</td>
<td>440</td>
<td>992</td>
</tr>
<tr>
<td>Vehicle weight (lbs)</td>
<td>3,790</td>
<td>3,400</td>
<td>2,723</td>
</tr>
</tbody>
</table>
Charging Infrastructure Standards

**Key Point:** The industry has agreed up upon a single charging connection standard – SAE J1772

<table>
<thead>
<tr>
<th></th>
<th>Voltage</th>
<th>Max Current</th>
<th>Likely Current</th>
<th>Charge Time (average)</th>
<th>Charge Time (full charge BEV)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Level 1</td>
<td>120 V</td>
<td>16 A</td>
<td>12 A</td>
<td>8-12 hrs</td>
<td>16-20 hrs</td>
<td>Hair Dryer</td>
</tr>
<tr>
<td>AC Level 2</td>
<td>208/240 V</td>
<td>80 A</td>
<td>16-30 A</td>
<td>2-3 hrs</td>
<td>6-8 hrs</td>
<td>Clothes Dryer</td>
</tr>
<tr>
<td>DC Fast</td>
<td>500V, 100A, 50 kW</td>
<td>80 A</td>
<td>16-30 A</td>
<td>2-3 hrs</td>
<td>6-8 hrs</td>
<td>Small Building</td>
</tr>
</tbody>
</table>

Level 1 can utilize a standard household outlet and stand alone cord set, but Level 2 requires a hardwired cord set into a special box with safety electronics.
Electric Vehicle Supply Equipment (EVSE) Level 2
High Level Description

– A Level 2 Electric Vehicle Supply Equipment (EVSE) is an alternating current (AC) electrical pass-through device that provides added user protection for providing power to plug-in Electric Vehicles (EV’s). An EVSE is so named, defined and mandated from the definition found in the National Electric Code® Article 625.2f and is part of the larger Electric Vehicle Charging System which also includes the EV’s onboard charger (inverter and battery management system).

– An EVSE takes AC power from a supply circuit, offers protection, and then provides an SAE J1772™ specified connector to the user. The user plugs this connector into their Electric Vehicle to deliver AC power to the vehicle’s onboard charger.

Source: Eaton
DC Level 2 (Fast Charging)

- 125A, 208VAC or 100A 480 V 3-phase, 3-wire
- ~50kW, 400V output
- Direct access to battery while charging

Source: Eaton
Charging Infrastructure Options

• Electric Vehicle Supply Equipment (EVSE) functionality
  – Basic: Safety appliance incorporating customer operability
  – Smart: Additional control, access, measurement, and billing options

• EVSE sourcing options
  – Dealer option
    • Level 1 included with vehicle purchase
    • Level 2 option (basic)
      – Option for purchase/lease unit with vehicles
  – 3rd Party option
    • Independent companies with multiple EVSE options, including network management, access control, energy measurement, etc.
  – Utility option
    • Under consideration nationwide
Charging Locations

- **Residential**
  - Default charging
  - AC Level 1 or 2
  - $500-2,000 hardware (L2)
  - $500-$1,500+ installation

- **Workplace/Retail**
  - 2nd most common location
  - AC Level 2
  - $2,000-8,000 hardware
  - Similar range for installation

- **Public**
  - Retail, decks, curbside
  - AC Level 2, DC Fast
  - Similar costs for workplace (L2)
    - DC Fast Charging unknown
Codes and Standards

• SAE
  – J1772™ – Charging system and connector for AC and DC
  – J2836™ – Charging communication use cases
    • J2836/1 – Utility / Smart Grid
    • J2836/2 – DC Charge Control
    • J2836/3 – Reverse Power Flow
    • J2836/4 – Diagnostics
    • J2836/5 – Consumer Interaction
  – J2847 – Charging communication messages
    • J2847/1 – J2847/5 – Mapped to J2836
  – J2931 – Charging communication protocol
    • J2931/1 – General Info
    • J2931/2 – FSK Over Control Pilot
    • J2931/3 – Narrowband PLC (G3, ITU G.hn)
    • J2931/4 – Broadband PLC (HomePlug GP)

• UL
  – UL2594 – AC Charging System
  – UL2202 – DC Charging System
  – UL2231 – Personnel Protection
  – UL1998 – Software Protection Systems

• NFPA 70 NEC Article 625

• FCC Part 15 – EMI

• EPRI Infrastructure Working Council (IWC)

• NIST SGIP
  – PAP11
  – V2G PEVWG

• NEMA 05EV EVSE Section

• IEEE
  – 1547 – Interconnection of DER
  – P1901 – Broadband PLC
  – P2030.1 – Electric Transportation Infrastructure

• National Petroleum Council Fuel-SITG – Electricity as a Fuel

Source: Eaton
Opportunities
Value Proposition

Key Issues

- Foreign oil dependency
- Climate change
- Energy cost (transportation costs)
- Jobs

Plug-in Electric Vehicles as a Solution

- 60% US oil is imported
- 70% of all US oil used for transportation
- 97% of transportation fueled by oil
- Multiple studies confirm reduced CO₂ and improved air quality impacts from PEVs
- Fueling cost = ¼ of gasoline
  - $2-3 = 100 miles
- Short-term gasoline market volatility
- Several US companies / organizations have capabilities that support PEVs
Managing Energy Costs

Historical Costs

Projected Oil Price (AEO 2010)

Oil Dependency Imposes Significant Costs on the US

• Oil price spikes have contributed to every recent U.S. recession; according to the Department of Energy, oil dependence has cost our economy $5 trillion since 1970 ($580 billion in 2008).

• According to the Rand Corporation, U.S. armed forces spend up to $83 billion annually protecting vulnerable infrastructure and patrolling oil transit routes.

• Global dependence on oil reduces the United States’ ability to develop strong and effective foreign policy against nations that undermine local and global security.

• 40 percent of all U.S. CO₂ emissions are from the transportation sector, which would be largely unaffected by a nationwide CO₂ cap and trade program.
Promoting Energy Independence

Foreign oil dependency:
60% of US oil is imported.
40% of US imports sourced from Persian Gulf, Venezuela, and Nigeria combined.
Helping Improve the Environment

- CO2 (g) per Mile
  - CV vs. HEV vs. PHEV w/ Various Grid Sources

- Cumulative Net CO2 reduction
  - Middle PHEV case

- Annual 4th Highest 8-hr Ozone Difference (ppb): PHEV middle case vs. base case

Source: EPRI/NRDC 2007 Impact Study
Helping Improve the Environment

Key:
Gasoline 2010 = 27.5 mpg; 2010 CAFE standards
Gasoline 2030 = 42 mpg; NHTSA / EPA proposed Greenhouse Gas and Fuel Efficiency Standards
HEV = hybrid electric vehicle
EREV = extended range electric vehicle
EV = electric vehicle

Well-to-Wheels CO₂ Emissions (g/mi)

Gasoline WTT
Electricity WTT
Gasoline TTW
PEVs are not new... but this time it’s different

- **Technology**
  - Plug-in *hybrid* electric technology
  - Improved batteries with higher energy density/longer range

- **Marketplace**
  - Driving factors include gas/oil prices, energy security, GHGs
  - Not just California
  - Broad support and incentives

- **Customer Features**
  - Instant torque
  - Preconditioning the cabin
  - Internet connected
Potential Job Creation
North Carolina / Florida companies with plug-in electric vehicle technology capability

Smart metering and charging
- Elster
- Consert
- Car Charging Group, Inc
- eLutions, Inc
- FALCO Electronics
- NovaCharge
- Gasoline Equipment Systems
  - K&K Electric
  - Palmer Electric
  - Siemens Energy, Inc.
  - TLC Engineering
- Dyer, Riddle, Mills, and Precourt, Inc

Grid hardware and charging infrastructure
- ABB
- Eaton
- SPX (Charlotte)
- Schneider Electric
- AMP Systems
- Car Charging Group, Inc
- Matern Professional Engineering, Inc
- Palmer Electric
- RubeLab
- SunWise Power Systems
- One World Sustainable

Advanced electronics and chargers
- Delta Electronics (RTP)
- Cree (RTP)
- Eaton Cutler-Hammer
- Electronic System Services, Inc. (ESSI)
- EVnetics
- Patco Electronics Inc
- Solitron Electronics Inc
- Sussex Semiconductor, Inc

Vehicle Conversions
- AVRC in Raleigh
- Hybrid Technologies (Mooresville)
- Li-ion Motors (Charlotte)
- Foreign Affairs Auto (PHEV retrofit)
- GatorMoto
- PHEV Conversions (New Port Richey)
  - Secari Motor Company
  - World Class Exotics LLC

Batteries
- Celgard (Charlotte)
- Blue Nano (Huntersville)
- SAFT
- Alegna Innovations, LLC
- Precision Tool and Engineering
- Planar Energy
- ENER1
- G4 Synergetics Corporation
- US Lithium Energetics

Home Builders
Southern Traditions Development
(Home tour stop for 2011 International Builders’s Show in Orlando. Intends to use EVSE as a one of the selling features in their green homes. Intend to demo PHEV or EV with home during show.)

Major Vehicle Original Equipment Manufacturers (OEMs)
- Thomas-built for plug-in buses
- John Deere for tractors and heavy equipment
- Mac/Volvo for trucks
- DesignLine for buses (Charlotte)
- Avera Motors
- Black Bay Technologies
Challenges
Key Challenges

Collaboration - PEV Stakeholders

Customer Concerns

Market Projection

Electricity Grid Impacts

Battery Technology Development
Plug-in Electric Vehicle Stakeholder Map

**Key Point:**
Complexity in and among actors, systems and services.
All stakeholders need to work together.
Customer Concerns

Factors of Concern Regarding Plug-In Electric Vehicles

- Limited driving range per charge: 69%
- Cost: 61%
- Fit for fleet application or load capacity: 61%
- Charging locations: 54%
- Charging time: 51%
- Battery life: 44%
- Unqualified costs: 21%
- Availability: 17%
- Safety: 11%
PEV Market Penetration

Obama Administration has set a goal of achieving 1 million PEVs on the road in five years

Plug-in vehicle market penetration forecasts:

Source: Pike Research
Credit: Stephanie d'Otreppe / NPR

Notes:
1. Includes hybrid vehicles
Transmission System Impacts

Maximum home arrival is 12% at 5 PM
By 8 PM, 70% of drivers have arrived home

This is the demand for 2 million simulated vehicles verses the demand for July 7, 2009; average load is 700W per vehicle

The same 2 million vehicles can be charged overnight with no increase in peak load

2 million badly controlled vehicles can create a new peak
This would be a serious disruption

Source: Effects of transportation electrification on the electricity grid
Marcus Alexander Manager, Vehicle Systems Analysis
Workshop 4 – Plug-in Electric Vehicle Integration Issue July 15, 2009
Distribution Impact Considerations

- PEV Penetration Level
- PEV Concentration Level
- Electrical Characteristics of Chargers
- Charging Profiles (battery size, charge level & time)
- Network Location
- Coincident to Peak
- Smart Grid Enabled or Not Controllable

![Image of distribution network and charge profiles with source: EPRI EV Charge Profiles]
Connection of PEVs to the Electricity Grid

With digital technology, the grid grows smarter

Little has changed in the way utilities manage electric grids since 1882, when Thomas Edison opened his Pearl Street power station in lower Manhattan. Digital technology over the next few years, however, will create a "smart grid" that promises to transform utilities and customer habits.

Inside the smart grid

1. Smart meter
   A digital smart meter monitors home energy consumption and transmits that data by radio.
2. Data collector/relay
   Pole-mounted relays collect data from up to 500 smart meters and monitor power flows on the grid.
3. Utility control room
   Real-time data will be monitored around the clock, allowing more efficient distribution of power.
4. Smart tools
   "Intelligent" appliances monitor usage and can be shut down when costs are too expensive or when energy is needed elsewhere on the grid.
5. Microgenerators
   Smart-grid customers with solar panels or wind turbines could sell excess energy to the grid and get paid as microgenerators.

Self-healing grid

Smart grids can redirect power flow across the grid to avoid blackouts.

How we use electricity

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage of annual electric consumption for U.S. households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>9%</td>
</tr>
<tr>
<td>Water heating</td>
<td>9%</td>
</tr>
<tr>
<td>Appliances</td>
<td>56%</td>
</tr>
<tr>
<td>Kitchen appliances</td>
<td>16%</td>
</tr>
<tr>
<td>Space heating</td>
<td>10%</td>
</tr>
</tbody>
</table>


©2009 MCT
Battery Technology Developments

ARRA goal 2 is to cut cost of batteries 50% by 2013 and eventually reduce the sticker price of an electric car to match gasoline counterpart

- Nissan and GM indicate current costs < $750/kWh
- Cost expected to drop to $250-350/kWh by 2020
- Improvement in economies of scale and manufacturing
- Improvement in mechanical design will help manufacturing
- Improvements in performance (durability, power density) etc.) and range

**KEY POINT:** Among battery technologies, lithium-ion batteries have a clear edge over other approaches when optimised for both energy and power density.
Conclusion

Mike Waters, P.E.

Progress Energy
Efficiency & Innovative Technology Department
Emerging Technology & Alternative Energy Section
Conclusions

Significant opportunity exists for;
• Reducing foreign oil dependency
• Lowering CO$_2$ emissions
• Lowering overall energy bills
• Job creation

Electricity grid impacts are long term and utility companies have dealt with similar growth 3 times before. Good planning is key;
• 60 yrs ago – appliances
• 40 yrs ago – air conditioning
• 20 yrs ago – electronics

Benefits of PHEV-20
Source; EPRI

gasoline
~300 gals

overall energy
~32 MMBtu
~9,400 kWhs

CO$_2$ (2006)
~38%

CO$_2$ (2030)
~47%

~1,800 kWh

Note: 125,000 Btu (energy content of 1 gallon of gasoline) x 300 gals = 37,500,00 Btu = 11,000 kWh
Battery technology development is key to address several factors of customer concern

Market penetration forecasts are all over the map. However 3 factors could play a key role:
• Government incentives
• Rising fuel economy requirements and gas prices
• Automakers introducing PEVs. 108 PEV models will be introduced by 2015.

Significant effort is currently underway in the US in preparation for the arrival of PEVs.
US Gets Ready for PEVs

Plug-In Road Map | A sampling of efforts around the nation to get ready for electric cars

- **West Sacramento, Calif.**: Opened its first electric-vehicle charging station in August, the first of a program by retailer DMC Green Inc. to retrofit gas stations in California.

- **San Francisco, San Jose, and Oakland**: The California cities are partnering with Better Place, an electric-car company that plans to launch its vehicle in 2012. The plan includes expediting permits and installation of outlets, creating employer incentives for cars to charge in the workplace, and placing 220-volt charging equipment throughout the city. In February 2009, the mayor unveiled three charging stations in front of San Francisco City Hall.

- **Elk Horn, Iowa**: Installed four public charging stations in November.

- **Detroit**: Coulomb Technologies, a charging-station maker, said in January that it has installed six charging stations in Detroit and Ann Arbor, for a study funded by the Michigan Public Service Commission.

- **Massachusetts**: Nissan and the state government are jointly developing plans for home, workplace and public charging.

- **Raleigh, N.C.**: The municipality has partnered with Nissan and local utility Progress Energy to create local charging infrastructure for electric vehicles.

- **Las Vegas**: The Rampart Casino unveiled one charging station in June 2009.

- **Orlando, Fla.**: Nissan, the city of Orlando and the Orlando Utilities Commission have agreed to promote an electric-vehicle network for both area homes and public places.

Appendix
PEV Economics

Source: Environmental, Security, and Economic Issues of Electricity as a Transportation Fuel Constantine Samaras March 15, 2010