

Opportunities and Challenges for Plug-in Electric Vehicles

Contents

Technical Information

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

Opportunities

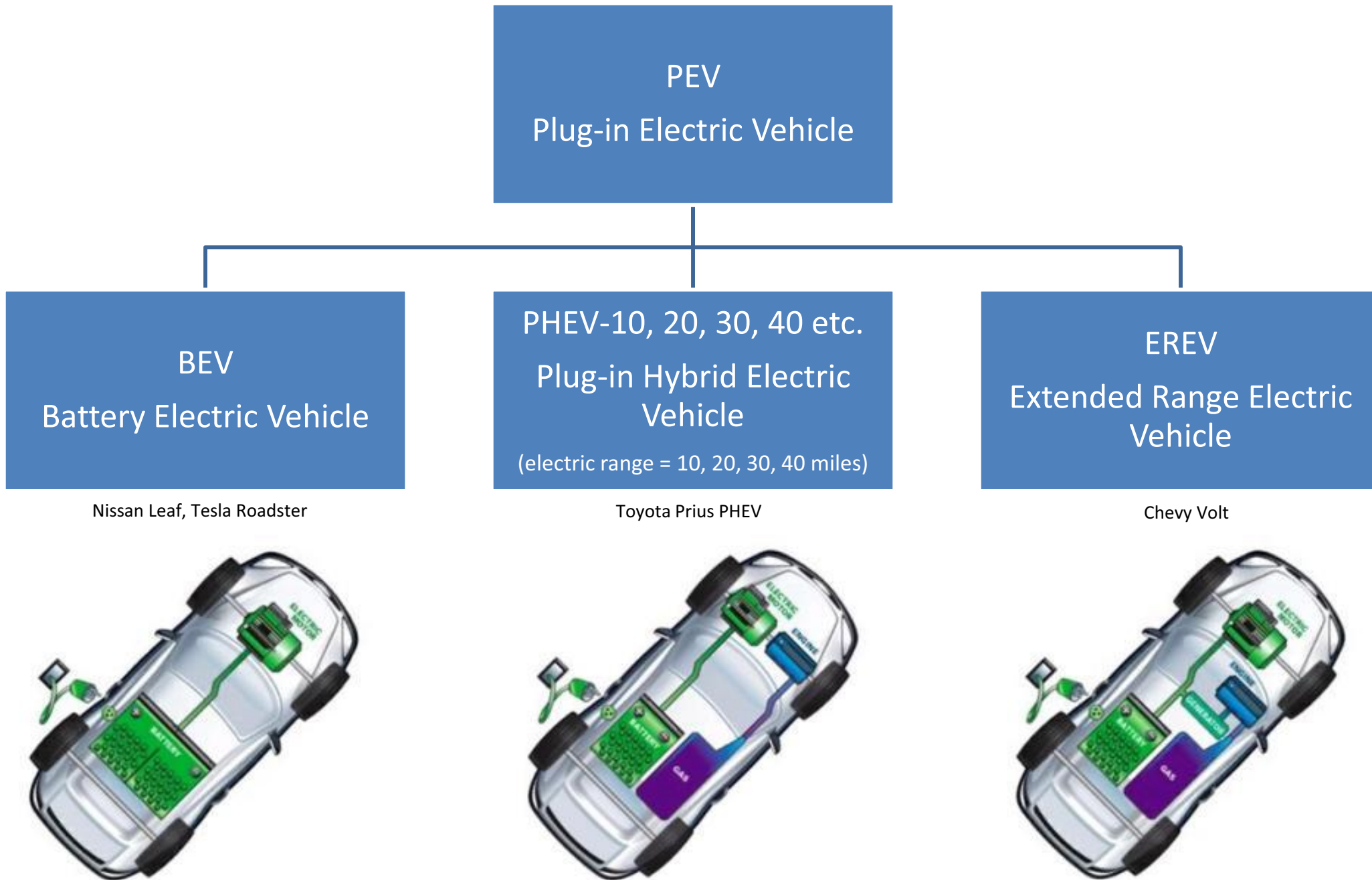
- Value Proposition
- Benefits of Plug-in Electric Vehicles

Challenges

- Collaboration - PEV Stakeholders
- Customer Concerns
- Market Projection
- Electricity Grid Impacts
- Battery Technology Development

Technical Information

Definitions



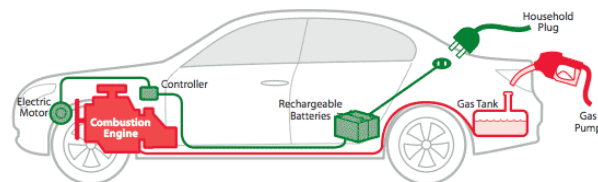
Comparison of Transportation Technologies

5

	Electricity	Gasoline	CNG
Fuel Cost ¹	\$0.75	\$3.50	\$1.91
Fuel Economy	50+ mpg	27.5 mpg	25 mpg
Infrastructure	Extensive	Extensive	Very Limited
Vehicle Cost	+\$8-12k	Baseline	+\$8-12k
Emissions; CO ₂	< 200 g/mile	400 g/mile	300 g/mile
Emissions; other	NOx, SO ₂	VOC, NOx, PM	NOx
Pros	No tailpipe emissions High efficiency and performance Electricity widely available and inexpensive	Known technology	High energy density and quick refueling Domestic fuel sources available
Cons	High battery cost Long refueling / charging times Some additional infrastructure required	Limited availability in long term	Safety concerns Volatile price Lack of roadside infrastructure

Electric vs. Gasoline

No Tailpipe Emissions	Greenhouse Gases/Pollution
Utility Company	OPEC
100+/- Mile Range	300+ Mile Range
Hours to Recharge	Minutes to Refuel
2 cents per mile	12 cents+ per mile



¹Source: From Clean Cities Alternative Fuel Price Report July 2010

PEV Introductions

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

PHEV or EREV

ALL ELECTRIC

Production



GM PHEV



Chevrolet Volt



Toyota Prius



Cadillac Converj



BYD 3DFM



Fisker Karma



Nissan Leaf



Smart ED



Mitsubishi iMIEV



Ford Focus



Ford Transit
Connect



Tesla

Demo/Concept



Ford Escape PHEV



BMW Concept



VW Golf
TwinDrive



Chrysler/Fiat EV



Mini-E



Subaru R1e



Hyundai Blue-Will



Volvo C30



Kia Ray



Mercedes BlueCell



Tesla Model S



Toyota FT-EV

PEV Comparison and Performance Characteristics

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

Nissan Leaf



Chevy Volt



Tesla Roadster

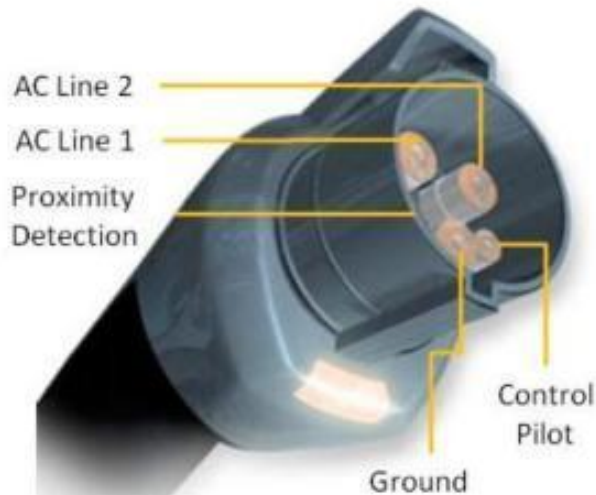


Charging Infrastructure Standards

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

	Voltage	Max Current	Likely Current	Charge Time (average)	Charge Time (full charge BEV)	Reference
AC Level 1	120 V	16 A	12 A	8-12 hrs	16-20 hrs	Hair Dryer
AC Level 2	208/240 V	80 A	16-30 A	2-3 hrs	6-8 hrs	Clothes Dryer
DC Fast	<i>Under development; target 80% complete charge in 10-25 minutes (500V, 100A, 50 kW)</i>					Small Building

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.



Level 1



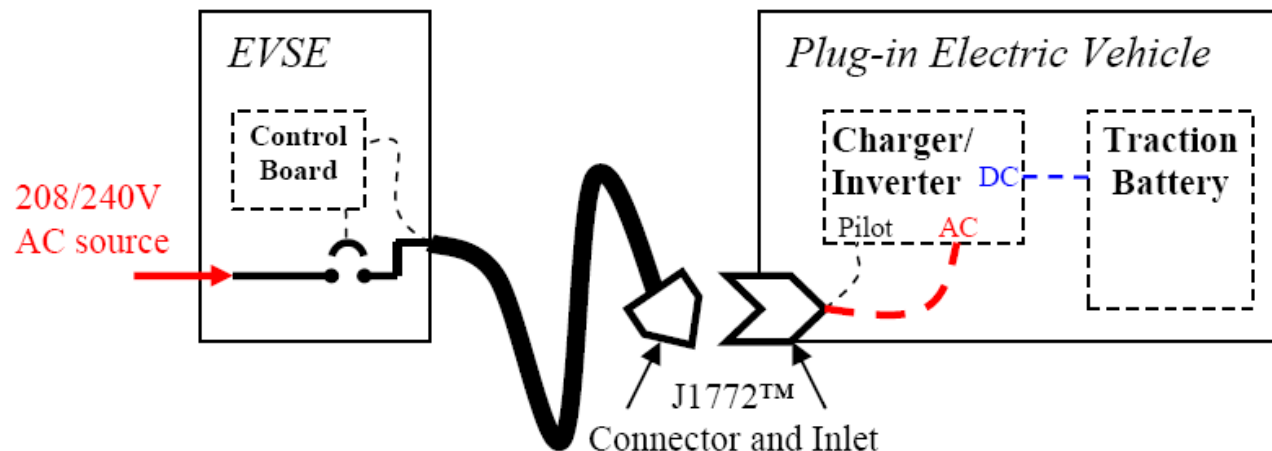
Level 2



Electric Vehicle Supply Equipment (EVSE) Level 2

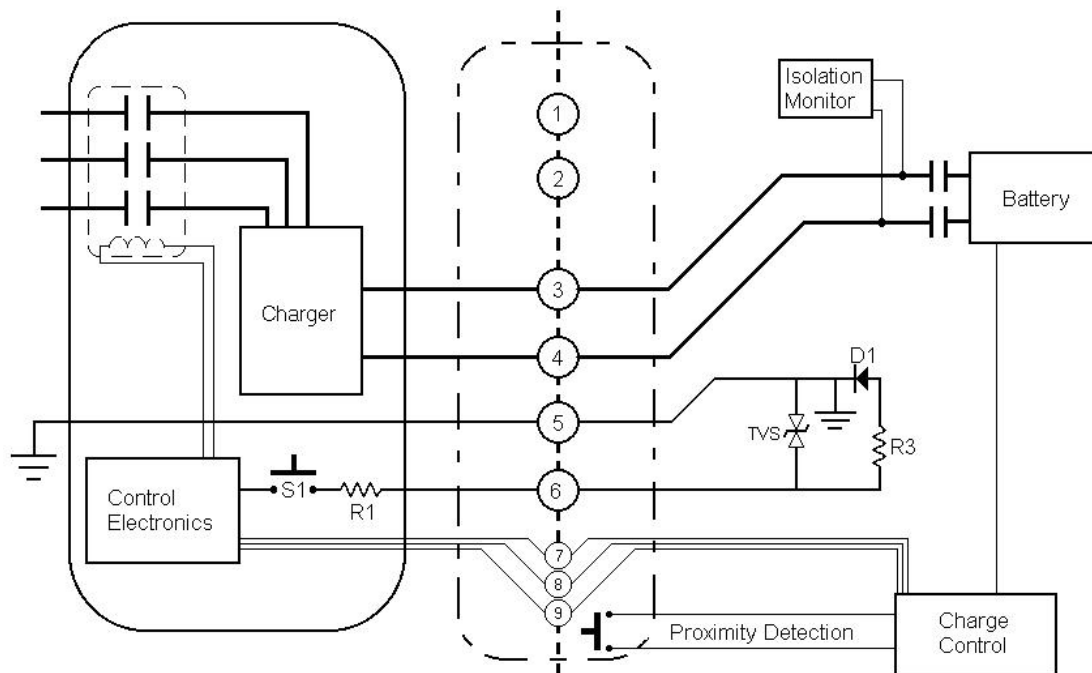
High Level Description

- 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.



DC Level 2 (Fast Charging)

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



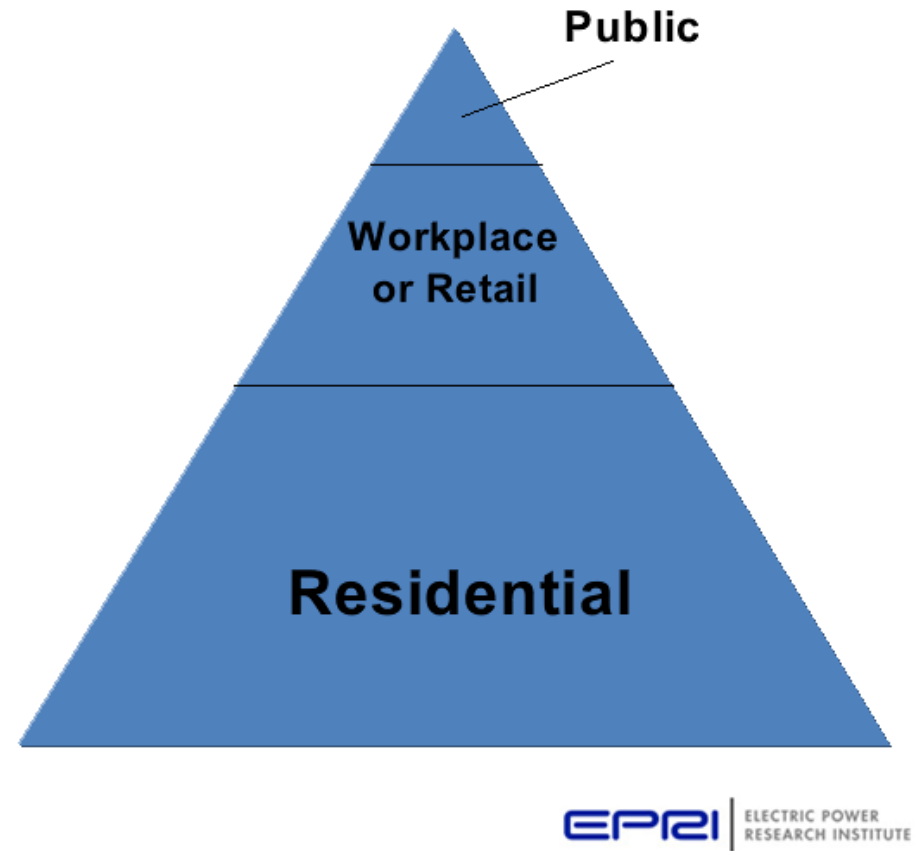
Charging Infrastructure Options

- 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

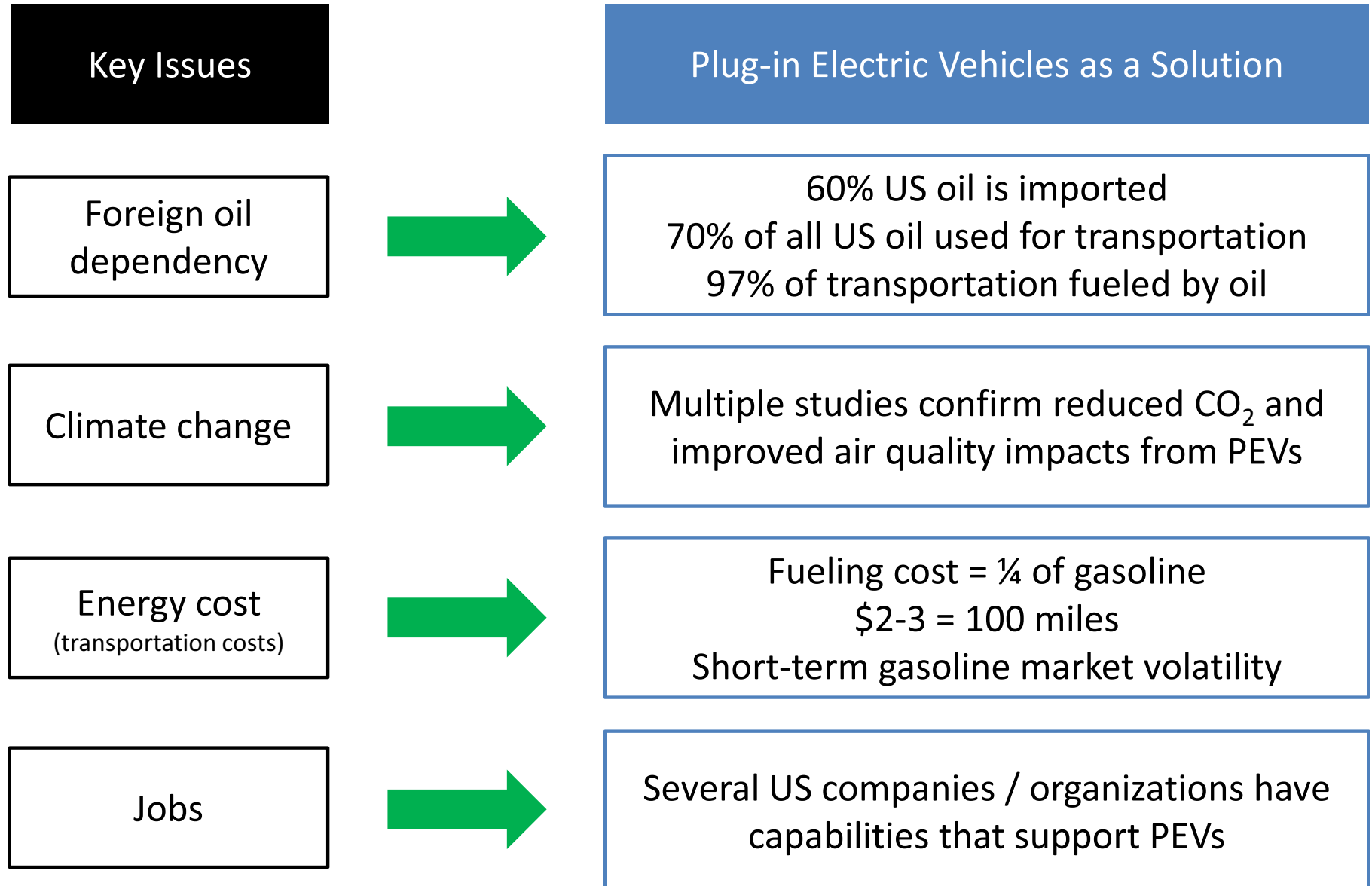
- IEEE

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

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

Opportunities

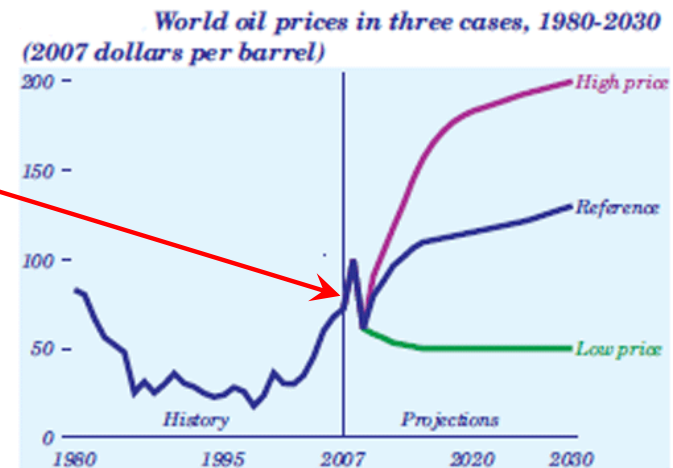
Value Proposition



Managing Energy Costs



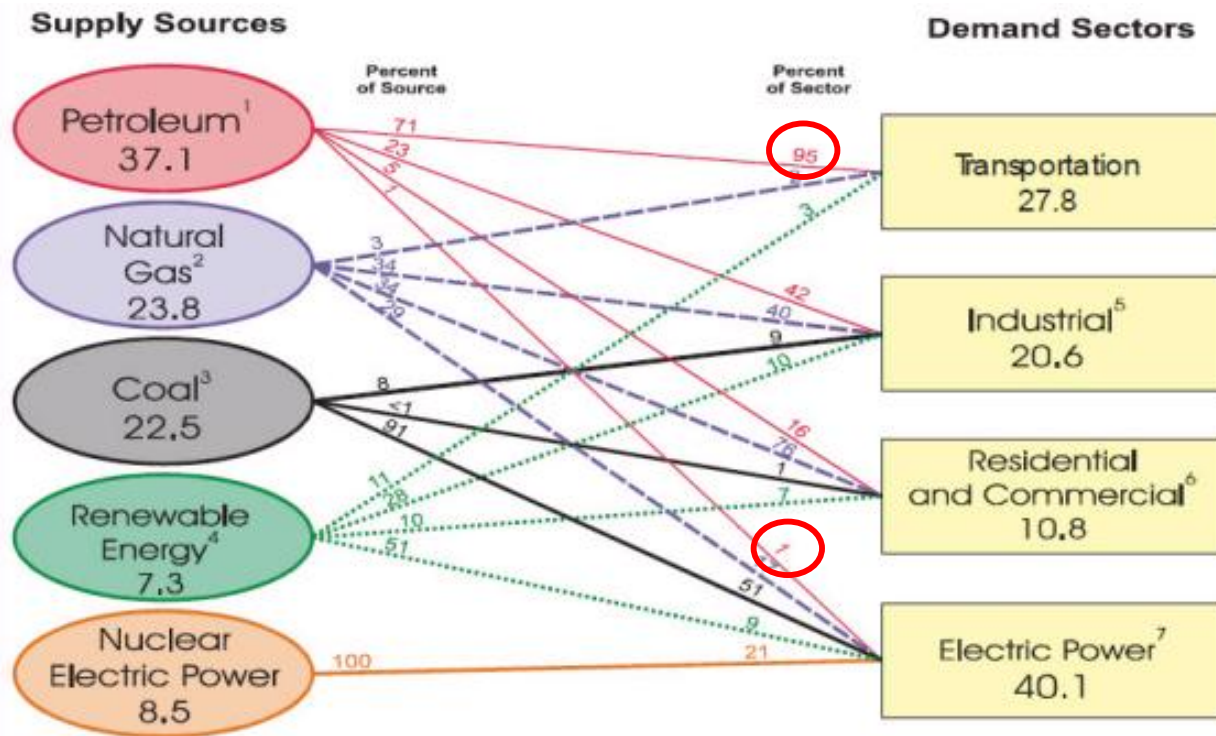
Projected Oil Price (AEO 2010)



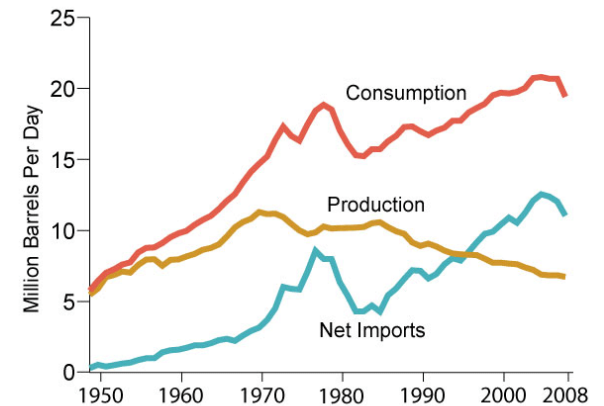
Oil Dependency Imposes Significant Costs on the US

- 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



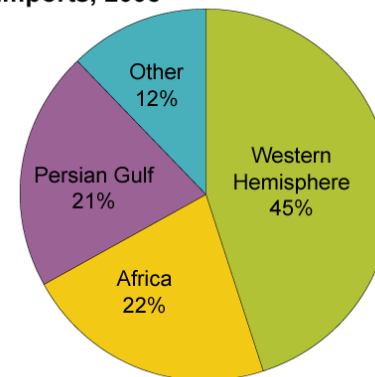
Consumption, Production, and Import Trends (1949-2008).



Source: Energy Information Administration, *Annual Energy Review*, Table 5.1. (June 2008)

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

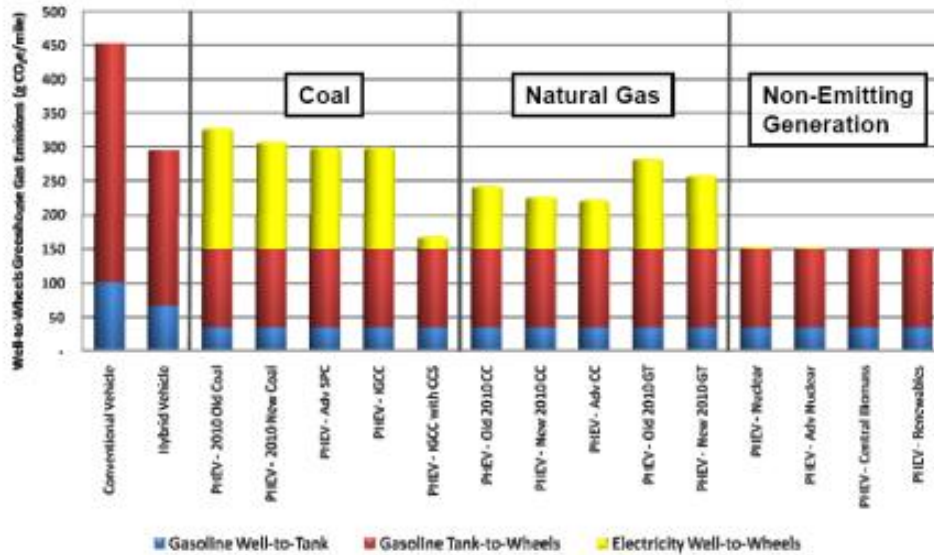
Sources of U.S. Net Petroleum Imports, 2008



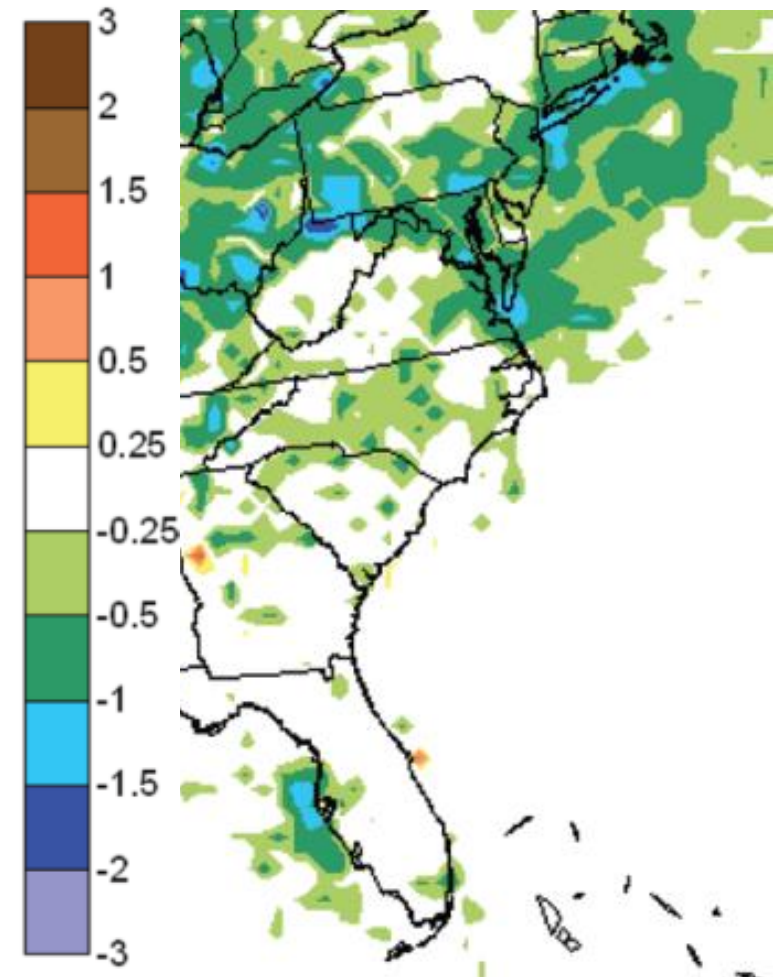
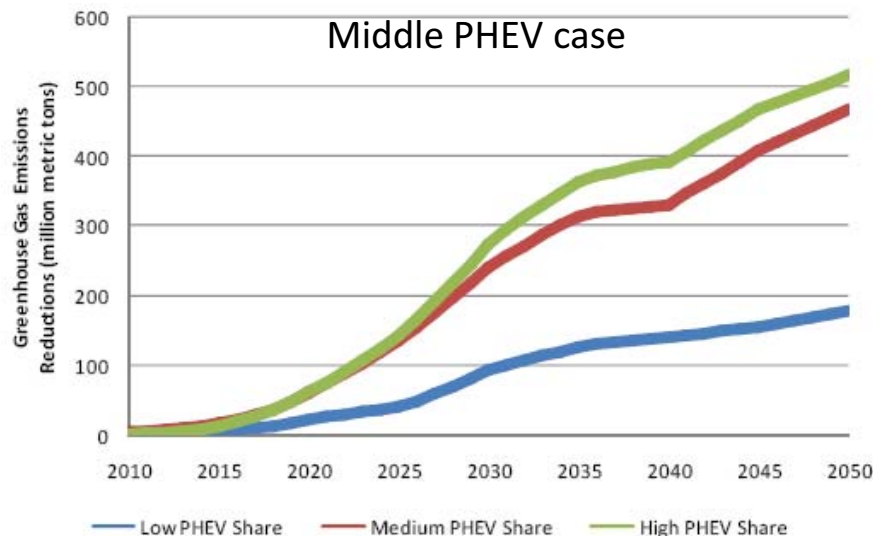
Source: U.S. Energy Information Administration.

Helping Improve the Environment

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



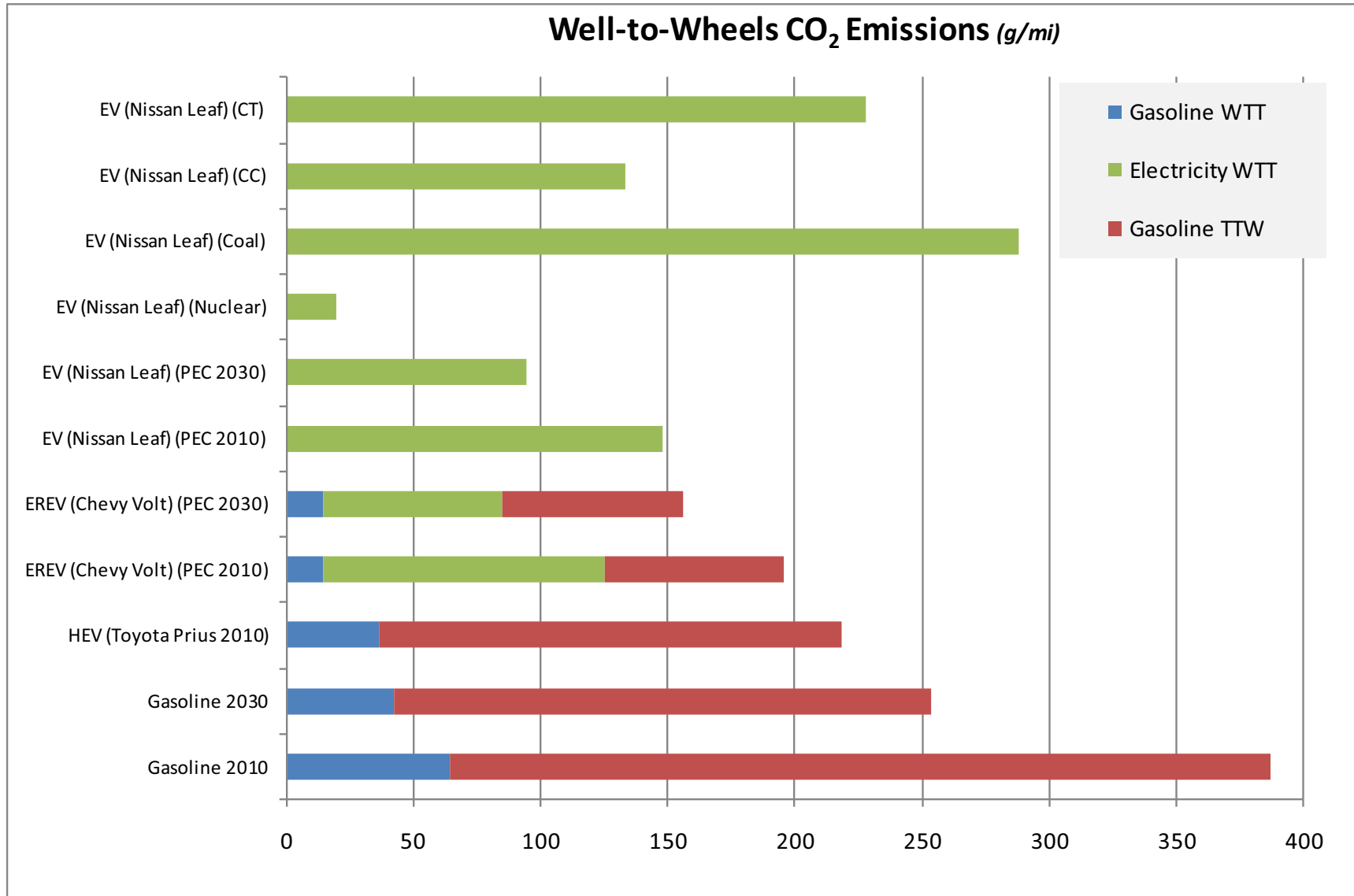
Cumulative Net CO₂ reduction
Middle PHEV case



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

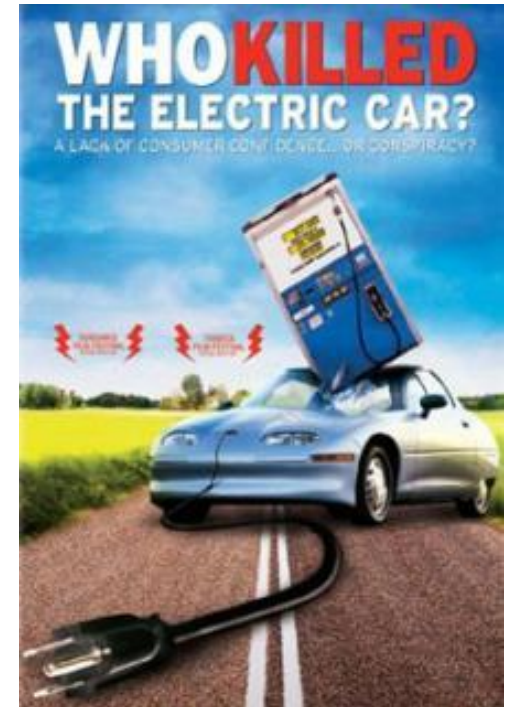
HEV = hybrid electric vehicle

EREV = extended range electric vehicle

EV= electric vehicle

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

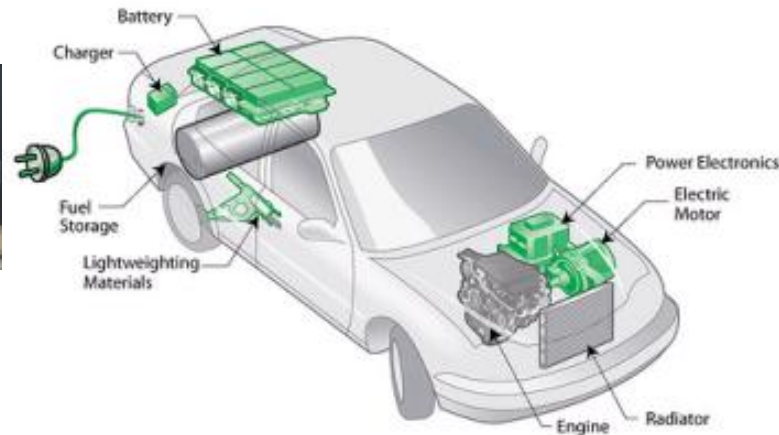
Smart metering and charging

- Elster
- Consort
- 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



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

Advanced electronics and chargers

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

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

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.)

Challenges

Key Challenges

Collaboration - PEV Stakeholders

Customer Concerns

Market Projection

Electricity Grid Impacts

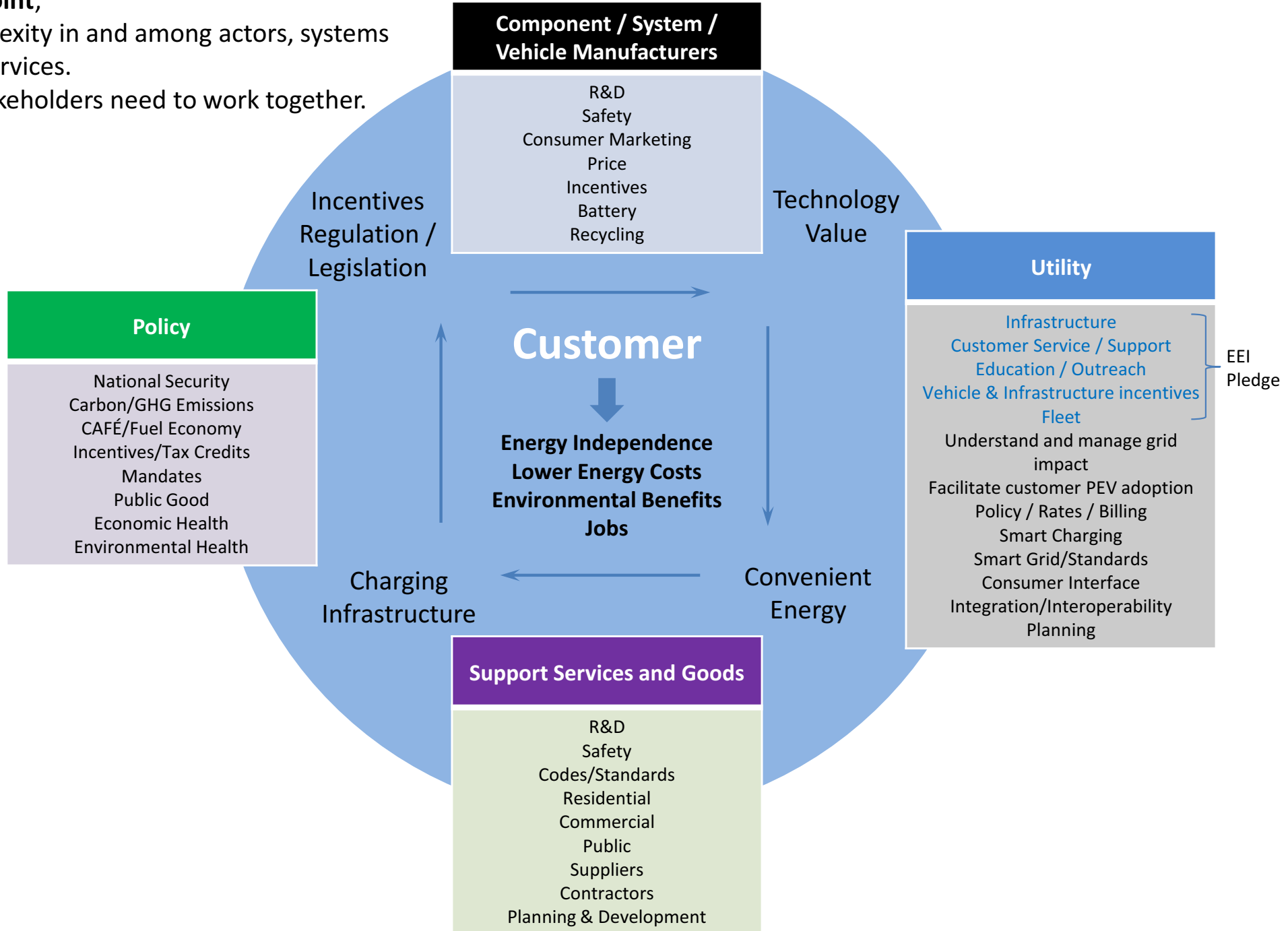
Battery Technology Development

Plug-in Electric Vehicle Stakeholder Map

Key Point;

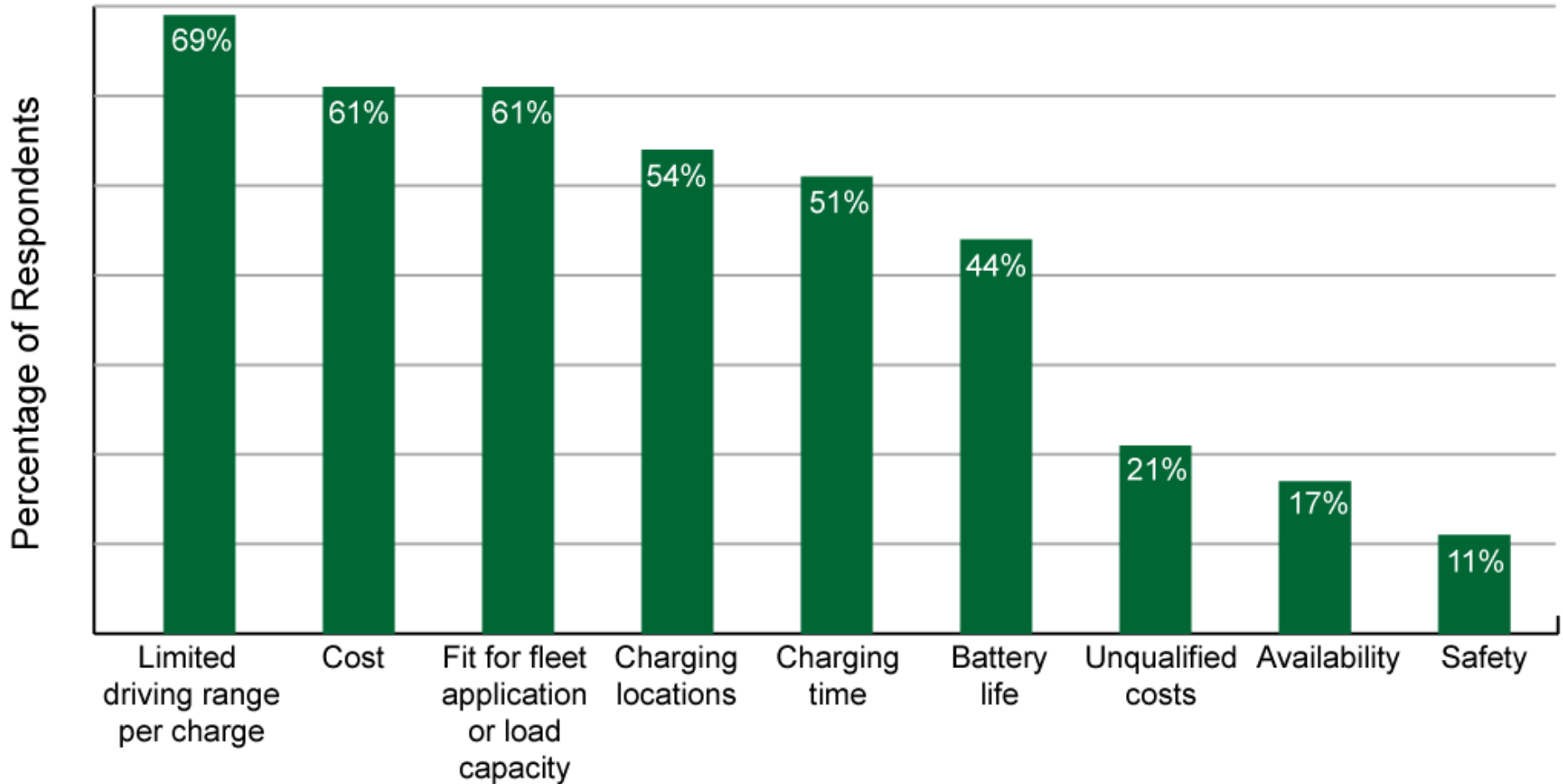
Complexity in and among actors, systems and services.

All stakeholders need to work together.



Customer Concerns

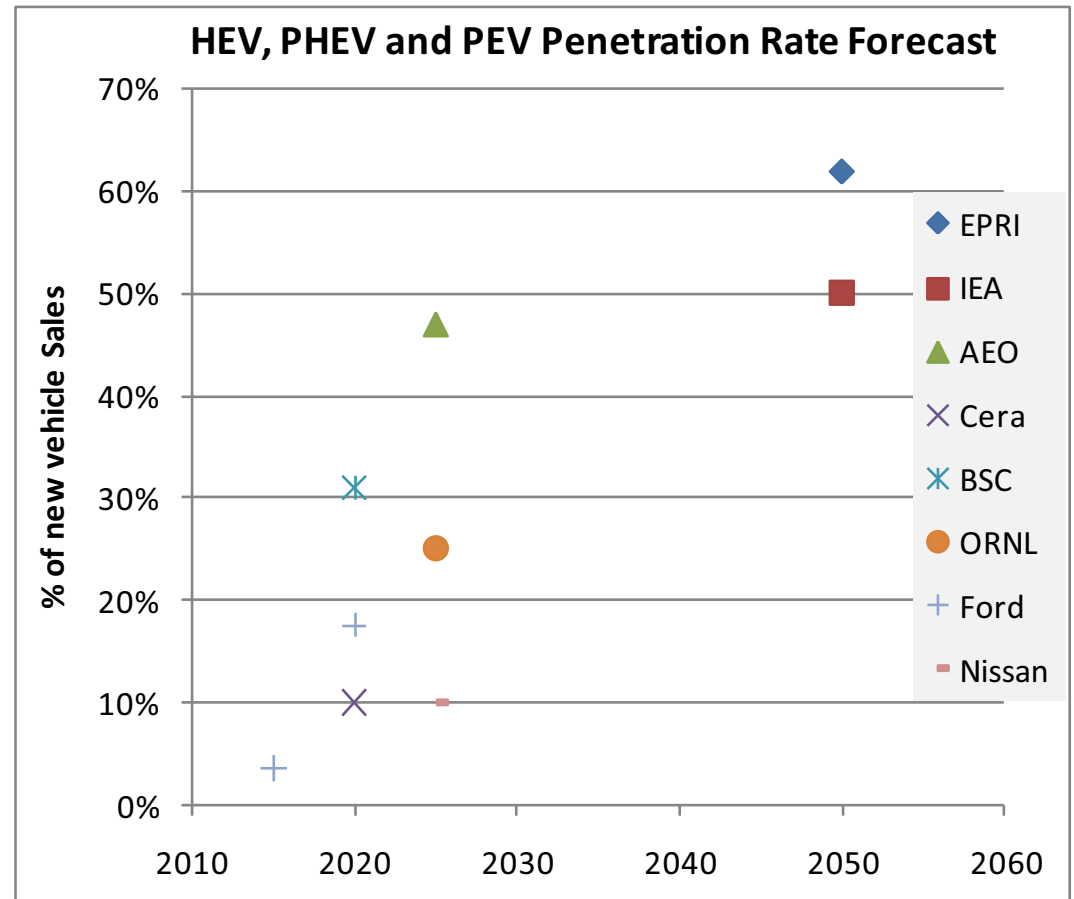
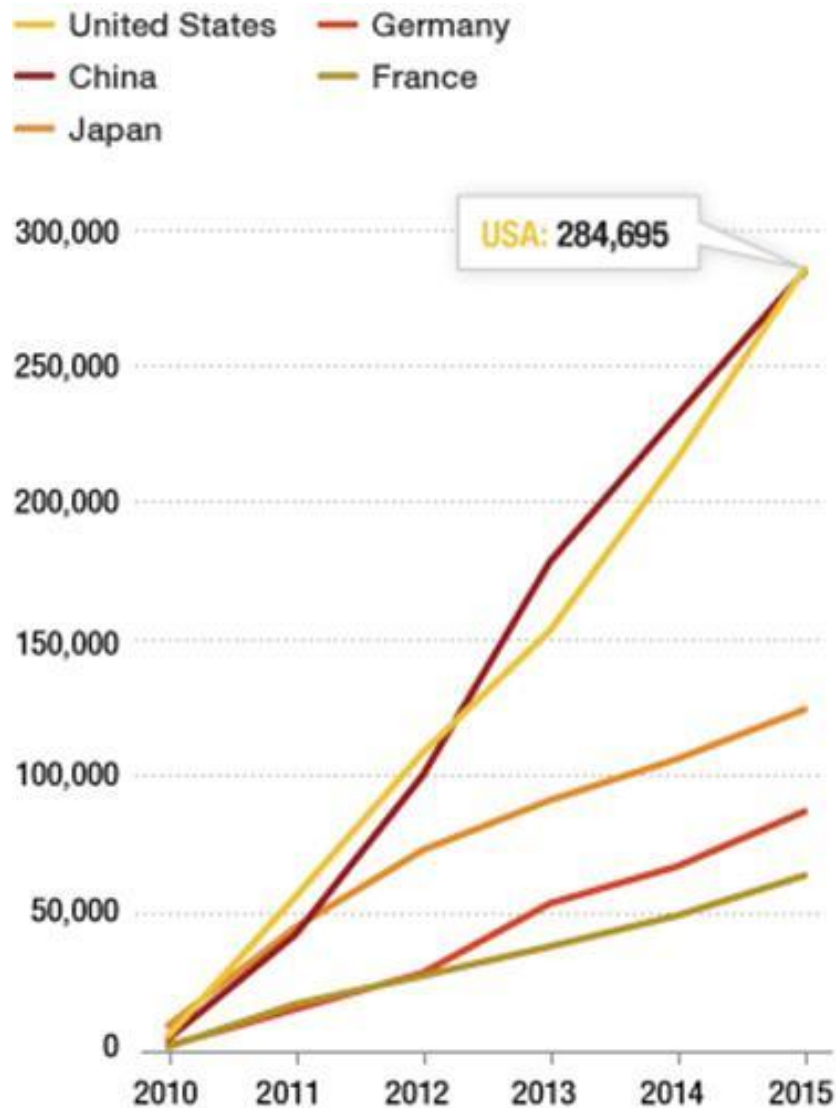
Factors of Concern Regarding Plug-In Electric Vehicles



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:



	EPRI	International Energy Agency (IEA)	AEO 2010	Nissan USA	Ford	CERA	Boston Consulting Group
% new vehicle sales (Aggressive Scenario)	62	50	47 ¹	10 (20-25)	2-5 ² 10-25	10 (20)	31 ¹ (42)
Year	2050	2050	2025	2025	2015 2020	2020	2020

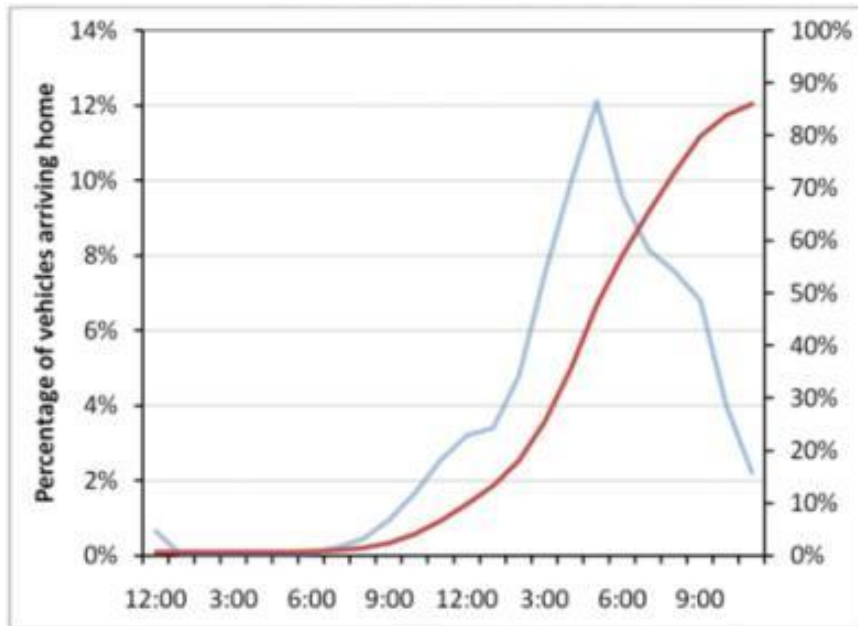
Notes:

1. Includes hybrid vehicles

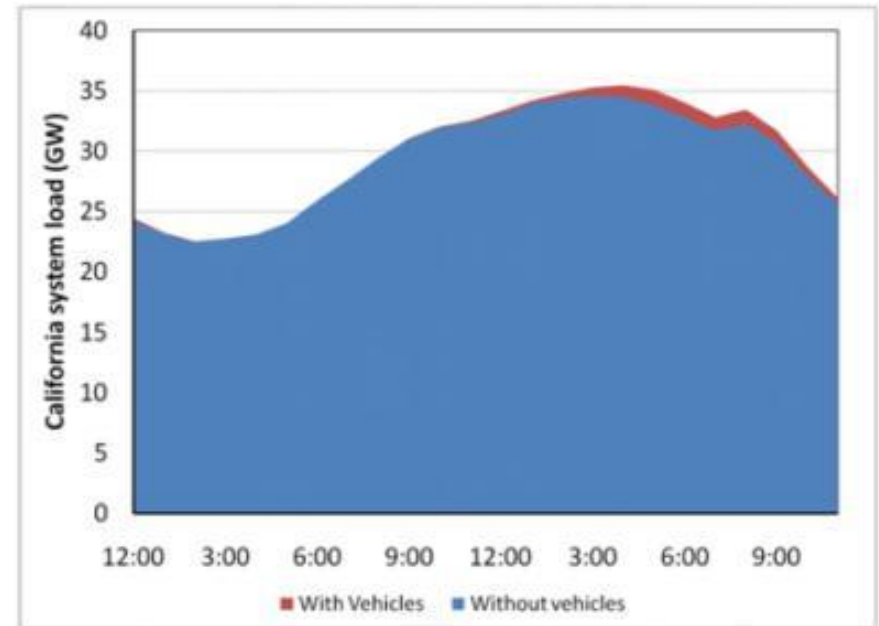
Transmission System Impacts

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

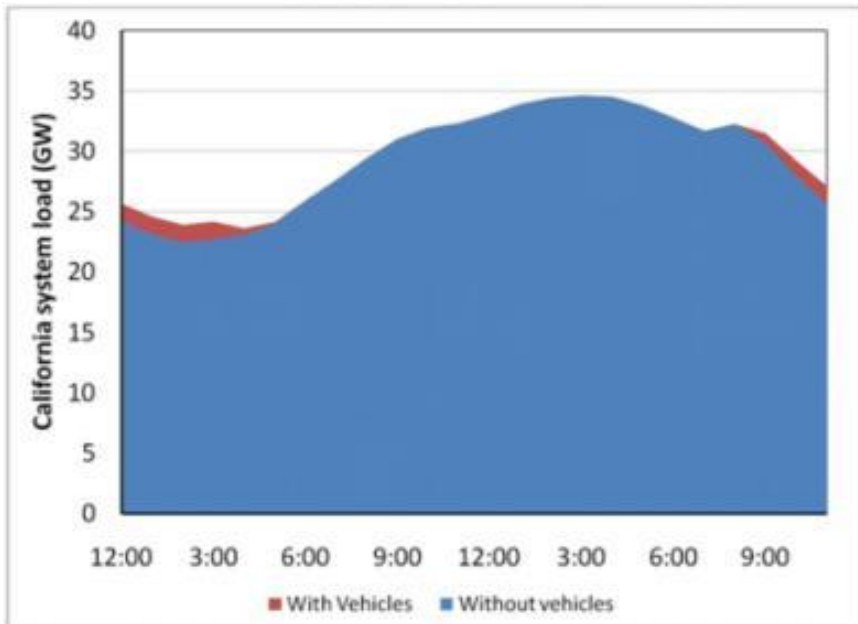
28



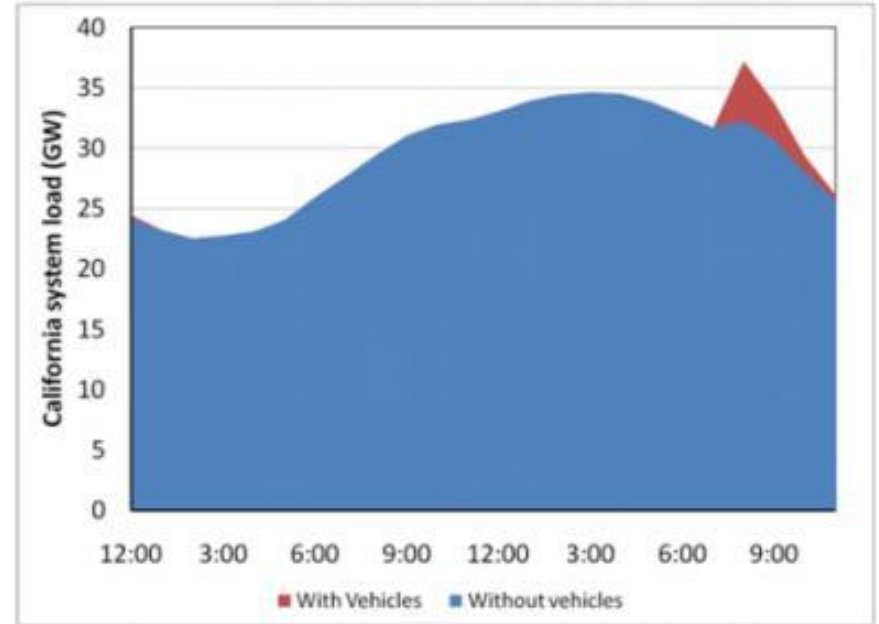
Maximum home arrival is 12% at 5 PM
 By 8 PM, 70% of drivers have arrived home



This is the demand for 2 million simulated vehicles versus 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



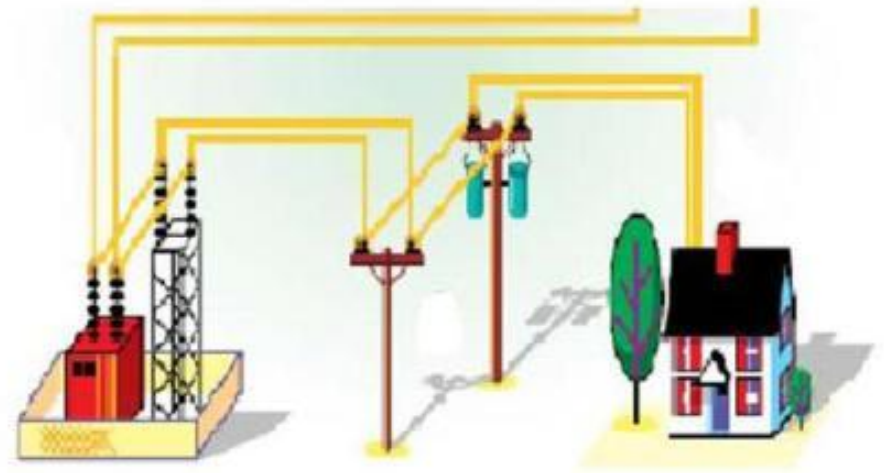
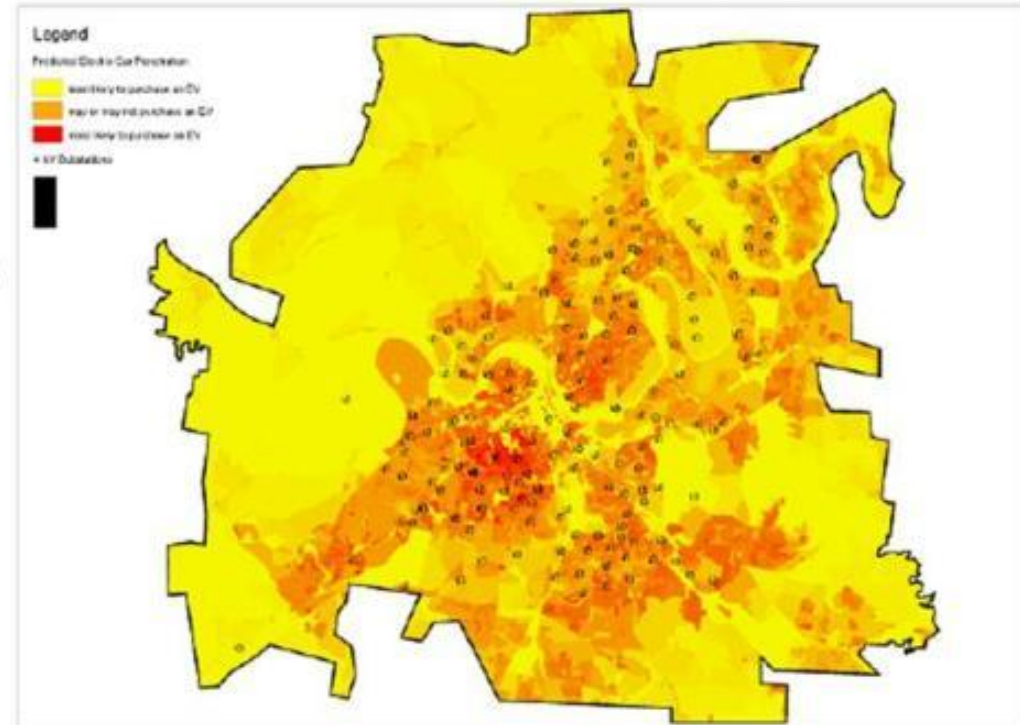
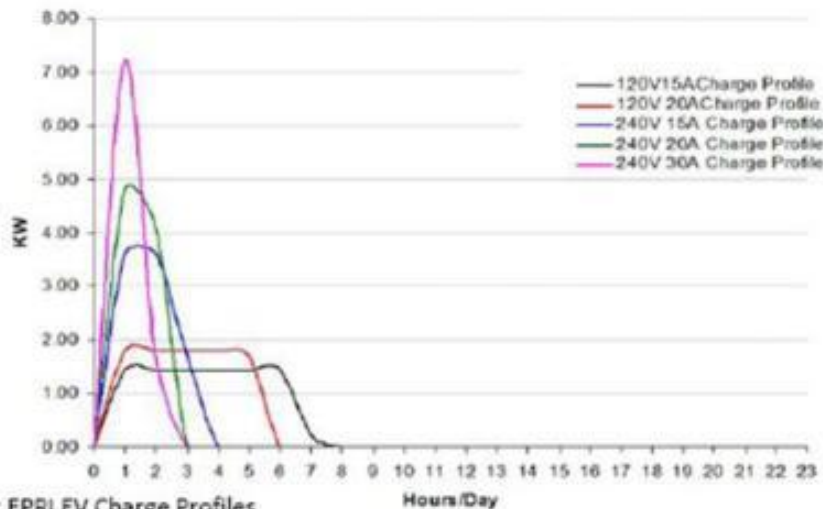
2 million badly controlled vehicles can create a new peak
 This would be a serious disruption

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



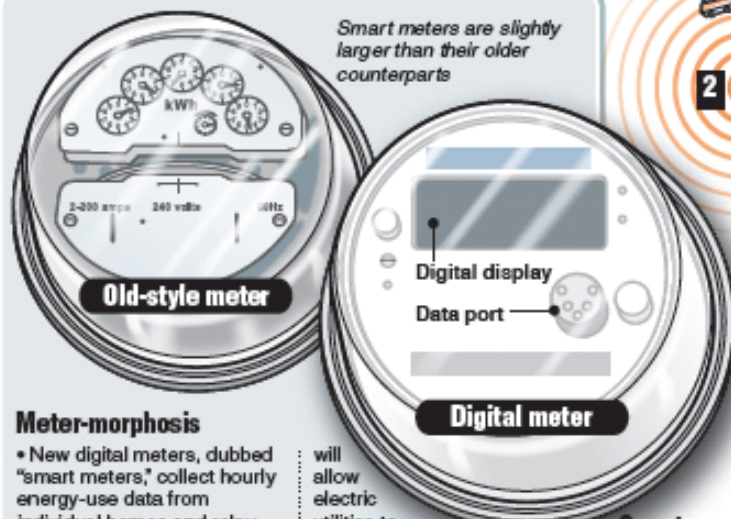
Different Battery Charge Profile



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.



Smart meters are slightly larger than their older counterparts

Meter-morphosis

- New digital meters, dubbed "smart meters," collect hourly energy-use data from individual homes and relay that information via wireless radio signals to the electric utility

will allow electric utilities to send out detailed monthly bills that resemble other monthly statements such as for cellphones

- Customers will be able to view their data online, or with mobile devices, playing active roles in managing their energy consumption and costs; by tracking hourly charges incurred by users, including energy costs, the smart grid

- New technology will help utilities monitor power distribution across the grid, and in conjunction with other "smart" technology in the home, to more efficiently use electricity

Monitoring usage

Web-based and mobile interfaces will allow consumers to monitor and control energy use in the home; widget-style components will allow individual control of appliances and provide real-time data to and from utilities

Source: Duke Energy, U.S. Dept. of Energy, Pittsburgh Gas & Electric, The New York Times
Graphic: Wm Pitzer, The Charlotte Observer

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

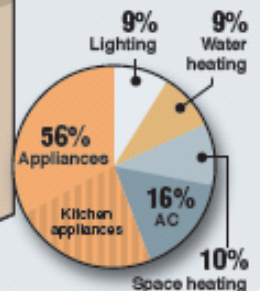
Smart grids can redirect power flow across the grid to avoid blackouts:

Data collected by smart meters help the utility identify potential power failures during peak-demand periods

Utility adjusts power on the grid by automatically adjusting smart thermostats and smart appliances in homes via radio signals

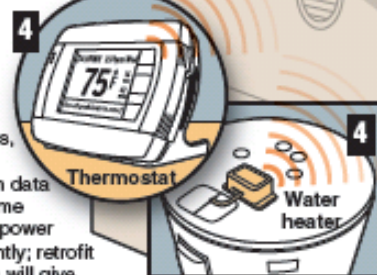
Pole-mounted sensors also allow the utility to redirect power around line breaks caused during storms or by an accident, isolating the site and minimizing outages

How we use electricity
Percentage of annual electric consumption for U.S. households by category (2001)



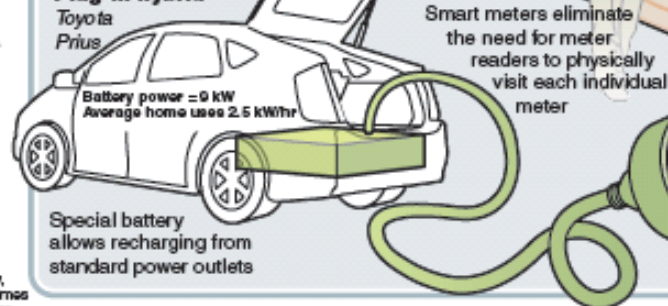
Smart tools

New appliances will "talk" to smart meters, monitor consumption data and help home owners use power more efficiently; retrofit components will give existing appliances new capabilities



Plug-in hybrid

Toyota Prius



Special battery allows recharging from standard power outlets

Meter readers
Smart meters eliminate the need for meter readers to physically visit each individual meter

Smart meter

AC condenser

New hybrid-car battery

A lithium-ion battery can hold seven times more energy than the battery in a normal Prius, extending the car's range

Power in the house
Hybrid batteries can reverse polarity, allowing the car to power homes in emergencies

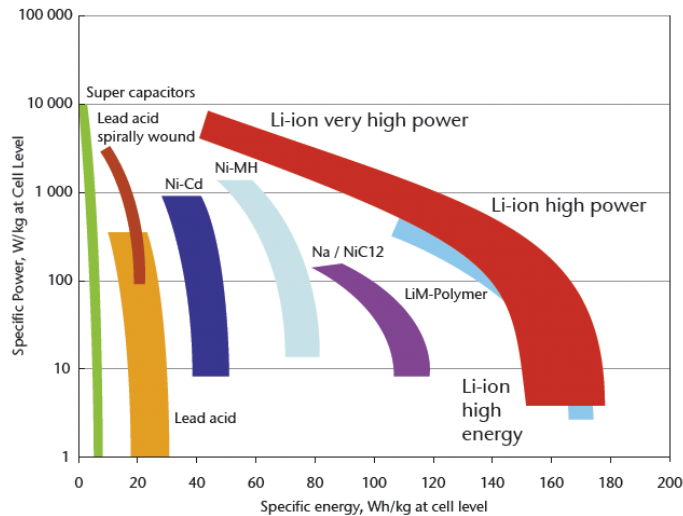
Battery backup

Customers who have their own solar panels and wind turbines could save excess energy, storing it in large-format batteries for use at night or during power outages

Local efficiency
Generating power locally avoids the energy loss (about 15 percent) that occurs over long-distance lines

Battery Technology Developments

Figure 1: Specific energy and specific power of different battery types



Source: Johnson Control – SAFT 2005 and 2007.

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

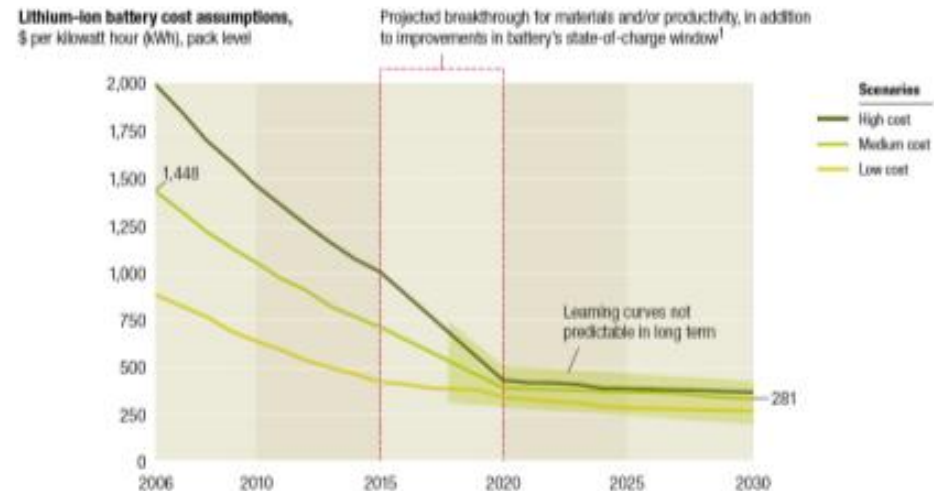
Battery Technology Developments

- 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

Exhibit 4. Battery Costs Will Decline 60 to 65 Percent from 2009 to 2020



Sources: Interviews with component manufacturers, cell producers, tier one suppliers, OEMs, and academic experts; Argonne National Laboratory, BCG analysis.
Note: Exhibit assumes annual production of 50,000 cells and 500 batteries in 2009 and 73 million cells and 1.1 million batteries in 2020. Numbers are rounded.



³ State-of-charge window, is the available capacity in a battery relative to its capacity when full. Conservative applications work within a 65% window, whereas more aggressive applications use 80%; over the next 5 to 10 years, most applications will likely migrate to the higher value.

Source: OEM and supplier interviews conducted in Asia, Europe, and North America; McKinsey analysis

Conclusion

Mike Waters, P.E.

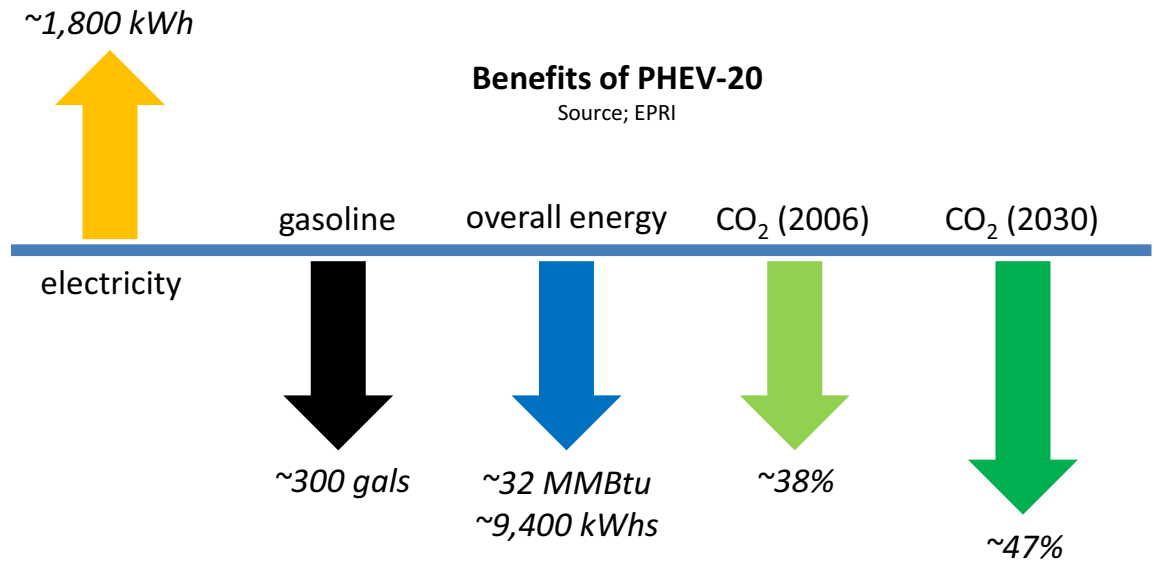
Progress Energy

Efficiency & Innovative Technology Department
Emerging Technology & Alternative Energy Section

Conclusions

Significant opportunity exists for;

- Reducing foreign oil dependency
- Lowering CO₂ emissions
- Lowering overall energy bills
- Job creation

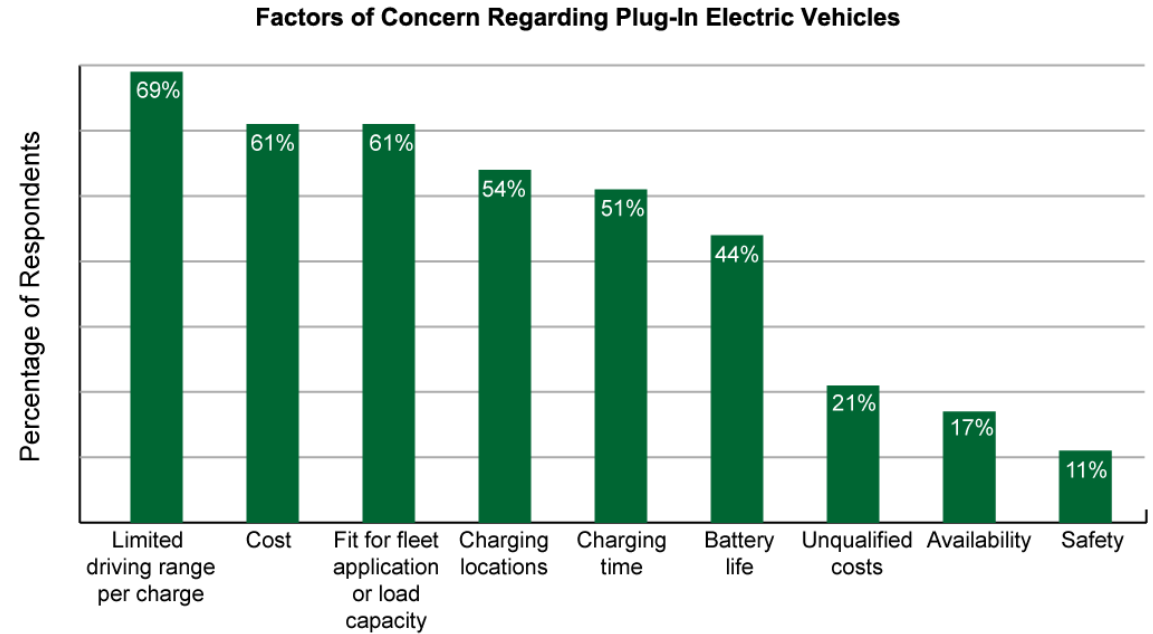


Electricity grid impacts are long term and utility companies have dealt with similar growth 3 times before. Good planning is key;

- 60 yrs ago – appliances
- 40 yrs ago – air conditioning
- 20 yrs ago – electronics

Conclusions

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



In August, the U.S. Department of Energy awarded Electric Transportation Engineering Corp., a charging-station maker, \$100 million to deploy more than 11,000 charging stations and 4,700 Nissan Leaf vehicles in five states. Nissan is a partner in the venture.

Cities that are part of the project (indicated by blue symbols): Seattle; Portland, Corvallis and Eugene, Ore.; San Diego; Phoenix and Tucson, Ariz.; and Nashville, Knoxville and Chattanooga, Tenn.

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.

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.

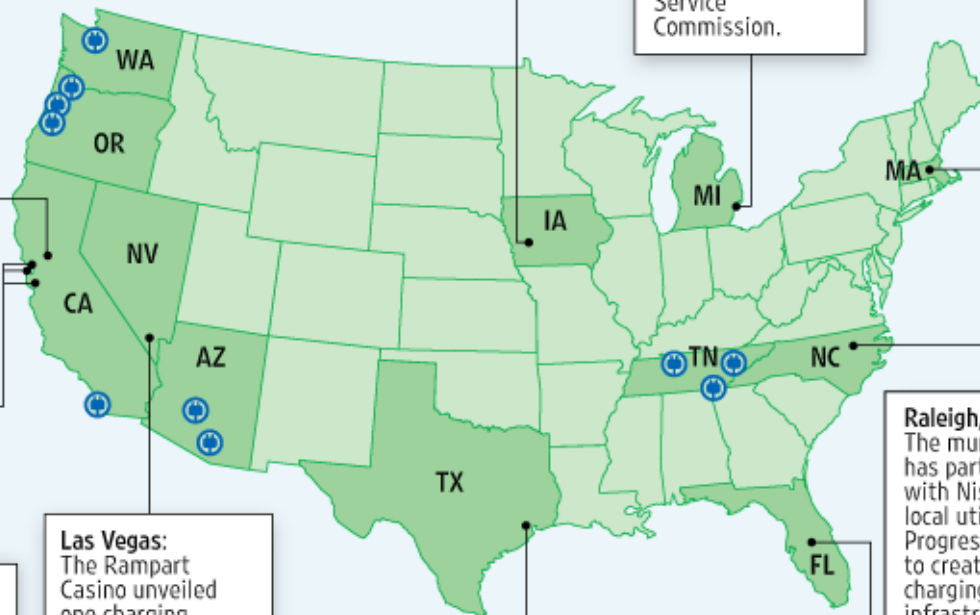
San Francisco, San Jose and Oakland: The California cities are partnering with Better Place, an electric-car company that plans to launch its vehicle in 2012. The plan includes expediting permits and installation of outlets, creating employer incentives for cars to charge in the workplace, and placing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

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

The city of Houston and Reliant Energy have partnered with Nissan to make Houston an early launch market for the Nissan Leaf. The partnership has already installed 10 charging stations—seven of them public—and envisions installing more.

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.

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



Source: *Charging Ahead*, The Wall Street Journal, May 10th 2010.

Questions?

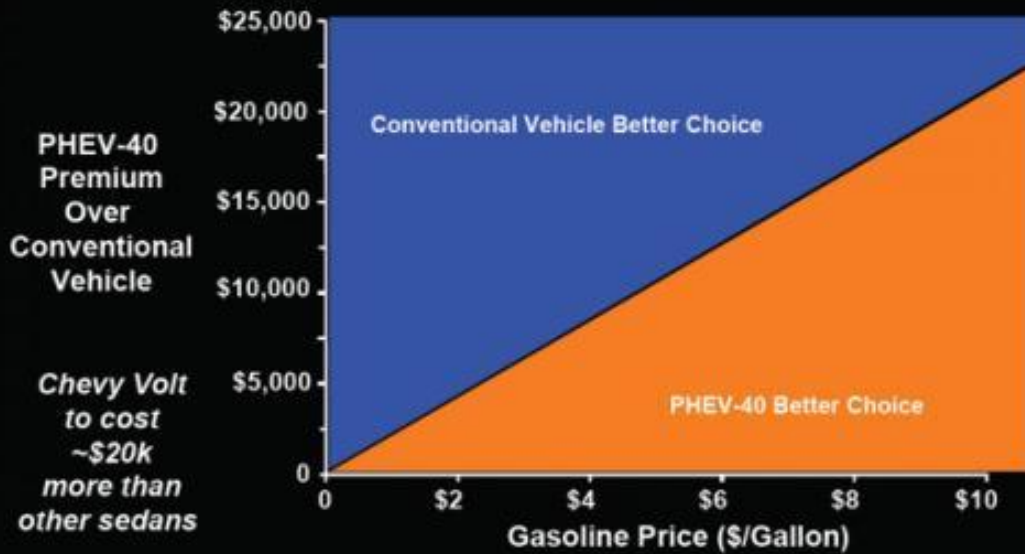
www.GoElectricDrive.com



Appendix

PEV Economics

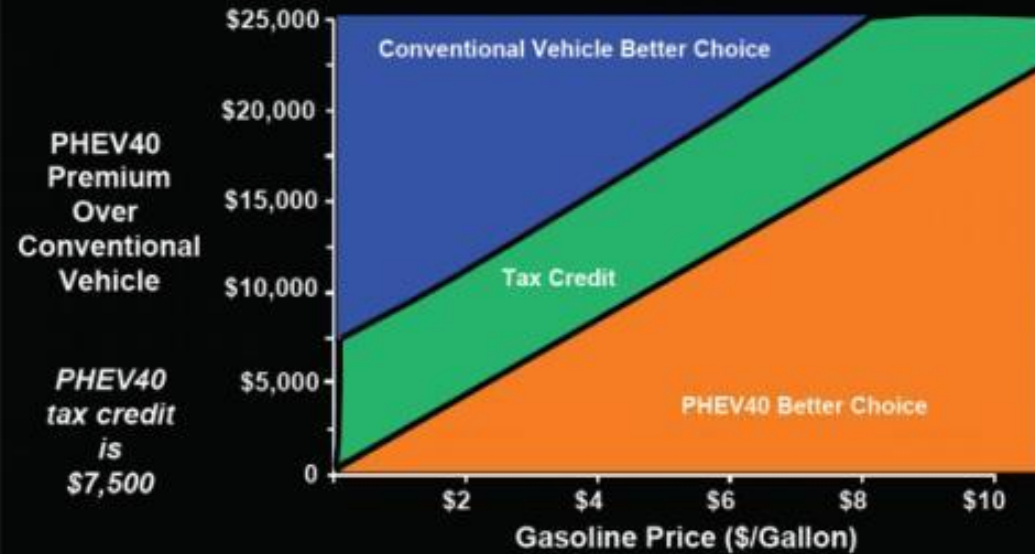
Economics Are Attractive with Low Battery Prices and High Gasoline Prices



RAND

Samaras -14 03/10

Economics Are Attractive with Low Battery Prices and High Gasoline Prices



RAND

Samaras -15 03/10

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