Opportunities and Challenges for Plug-in Electric Vehicles

Contents

Technical Information

Definitions

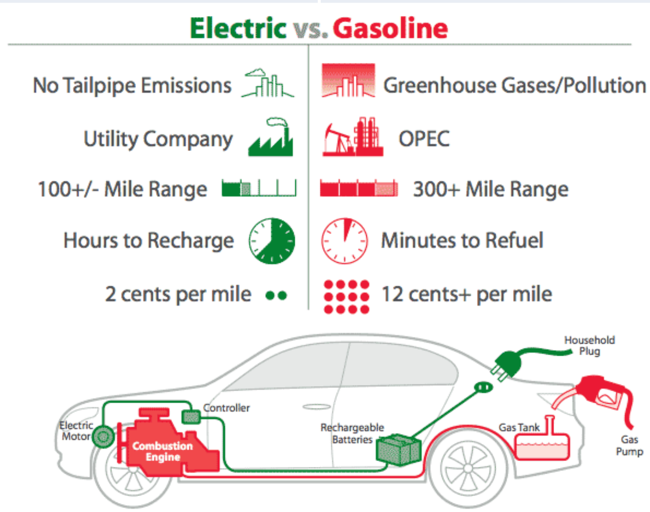
PEV
Plug-in Electric Vehicle

BEV	PHEV-10, 20, 30, 40 etc.	EREV
Battery Electric Vehicle	Plug-in Hybrid Electric Vehicle (electric range = 10, 20, 30, 40 miles)	Extended Range Electric Vehicle
Nissan Leaf, Tesla Roadster	Toyota Prius PHEV	Chevy Volt

Source: www.goelectricdrive.com

Comparison of Transportation Technologies

	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



[1]Source: 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.

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

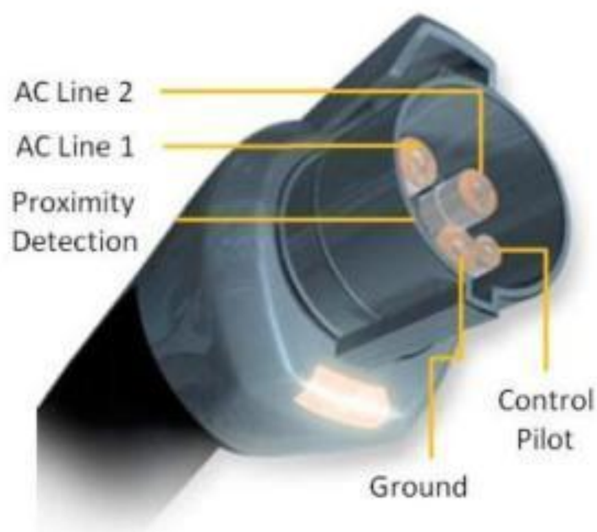
Tesla Roadster

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	*Under development; target 80% complete charge in 10-25 minutes (500V, 100A, 50 kW)*					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.

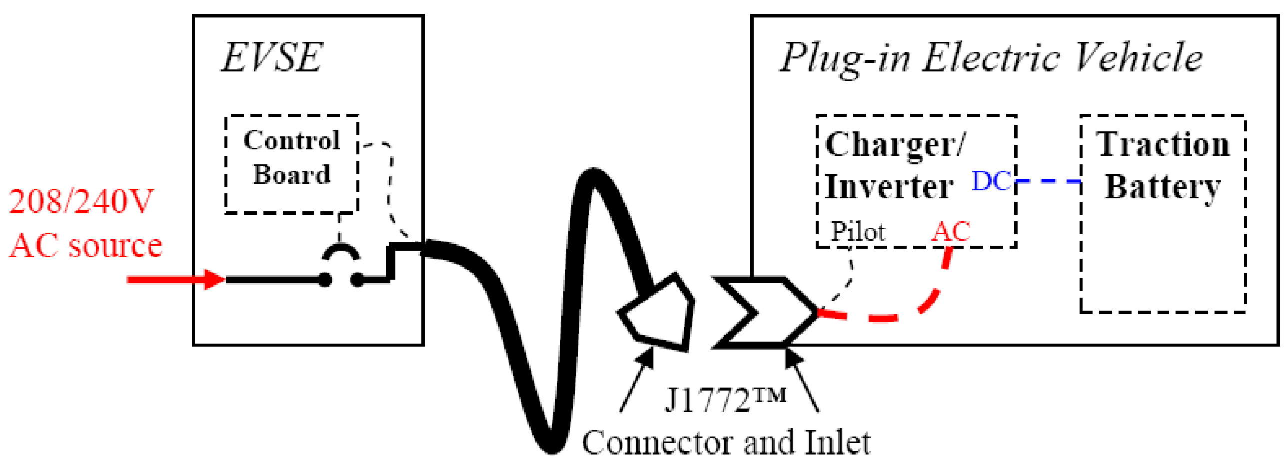


Level 1

Level 2

Electric Vehicle Supply Equipment (EVSE) Level 2 High Level Description

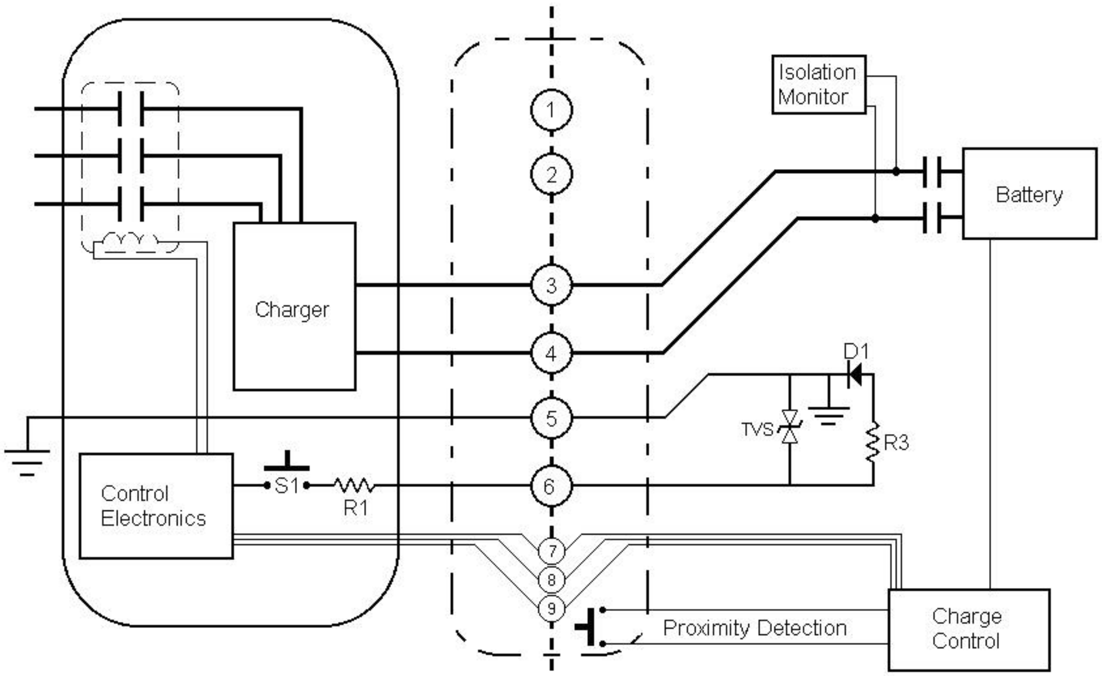
- A Level 2 Electric Vehicle Supply Equipment (EVSE) is an alternating current (AC) electrical pass-through device that provides added user protection for providing power to plug-in Electric Vehicles (EV's). An EVSE is so named, defined and mandated from the definition found in the National Electric 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.



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

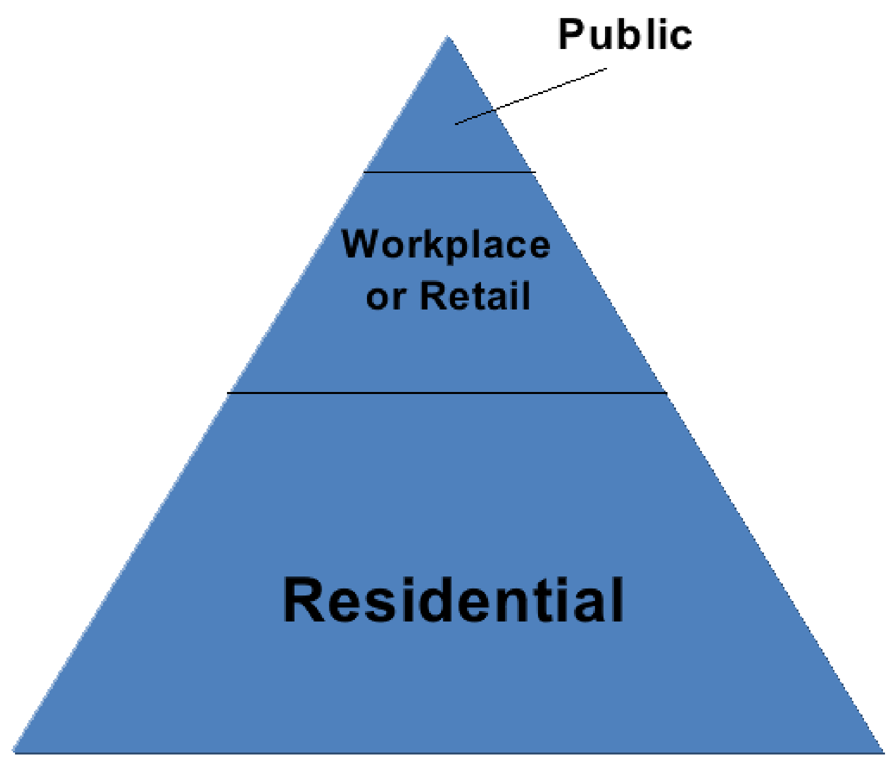
Charging Infrastructure Options

- 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



EPRI ELECTRIC POWER RESEARCH INSTITUTE

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

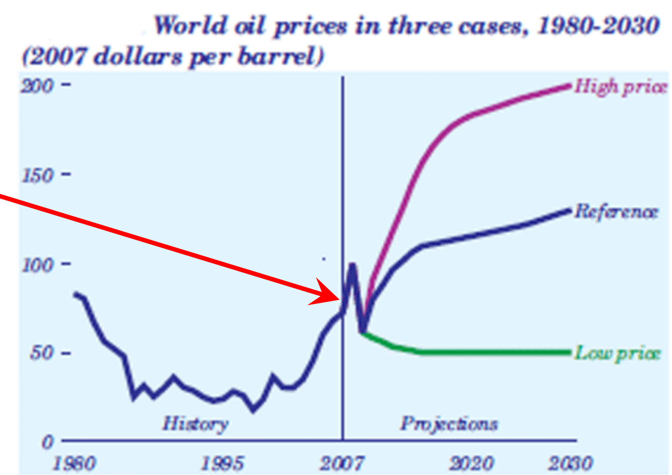
Opportunities

Value Proposition

Key Issues	Plug-in Electric Vehicles as a Solution
Foreign oil dependency	60% US oil is imported 70% of all US oil used for transportation 97% of transportation fueled by oil
Climate change	Multiple studies confirm reduced CO_2 and improved air quality impacts from PEVs
Energy cost (transportation costs)	Fueling cost = ¼ of gasoline $2-3 = 100 miles Short-term gasoline market volatility
Jobs	Several US companies / organizations have capabilities that support PEVs

Managing Energy Costs

Projected Oil Price (AEO 2010)



Oil Dependency Imposes Significant Costs on the US

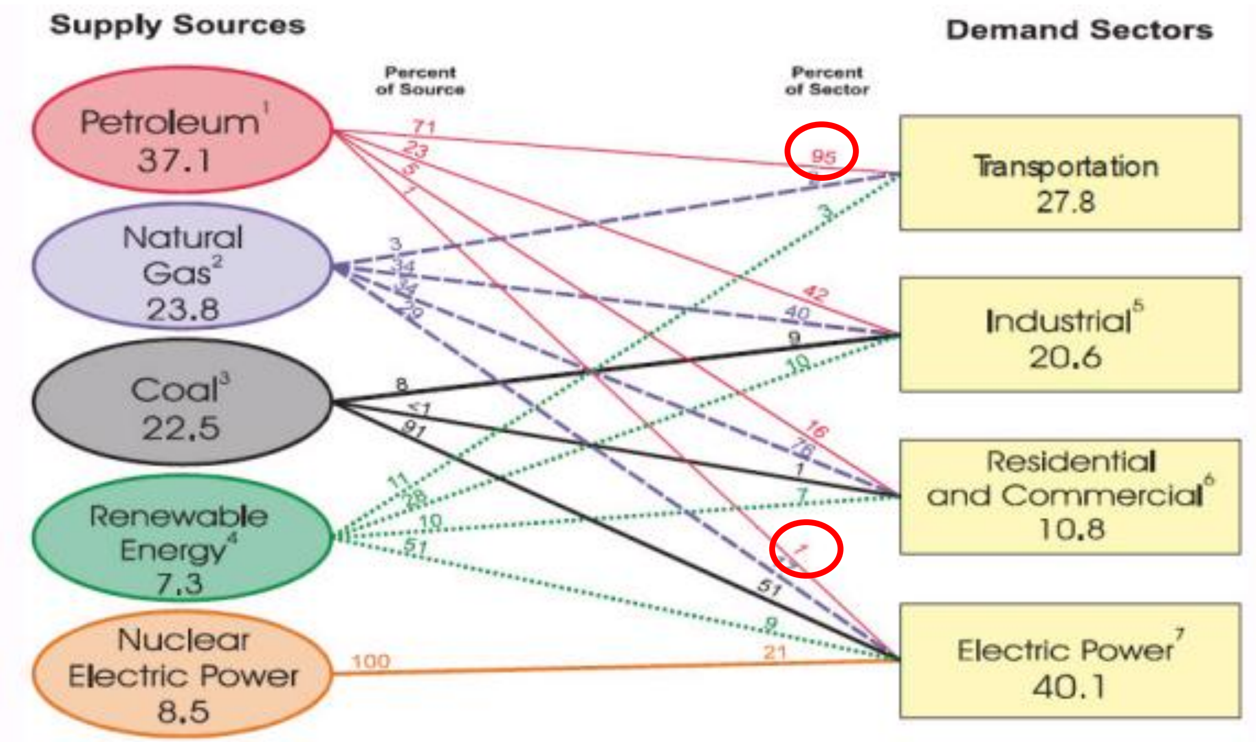
• Oil price spikes have contributed to every recent U.S. recession; according to the Department of Energy, oil dependence has cost our economy $5 trillion since 1970 ($580 billion in 2008).

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

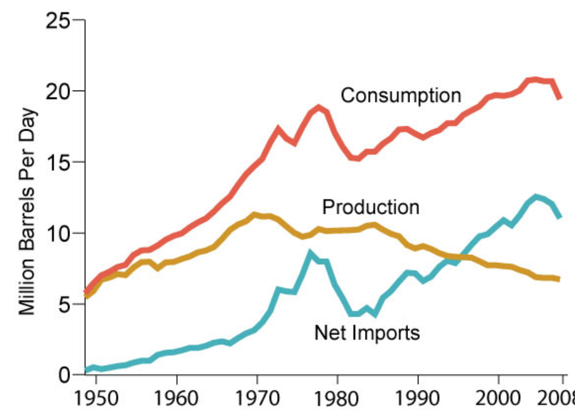
• Global dependence on oil reduces the United States' ability to develop strong and effective foreign policy against nations that undermine local and global security.

• 40 percent of all U.S. CO_2 emissions are from the transportation sector, which would be largely unaffected by a nationwide CO_2 cap and trade program.

Promoting Energy Independence

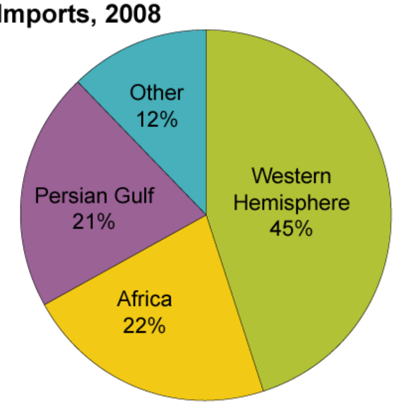


Consumption, Production, and Import Trends (1949-2008).



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

Sources of U.S. Net Petroleum Imports, 2008

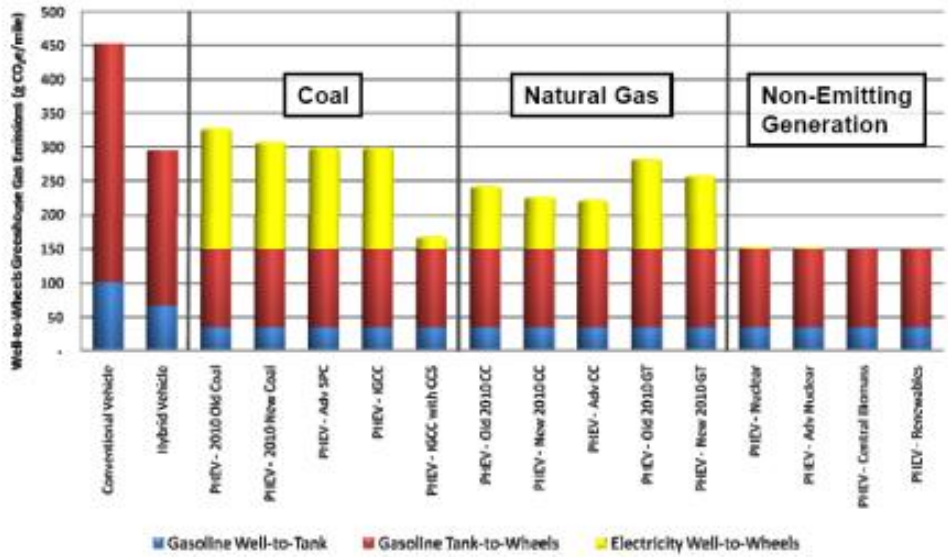


Source: U.S. Energy Information Administration.

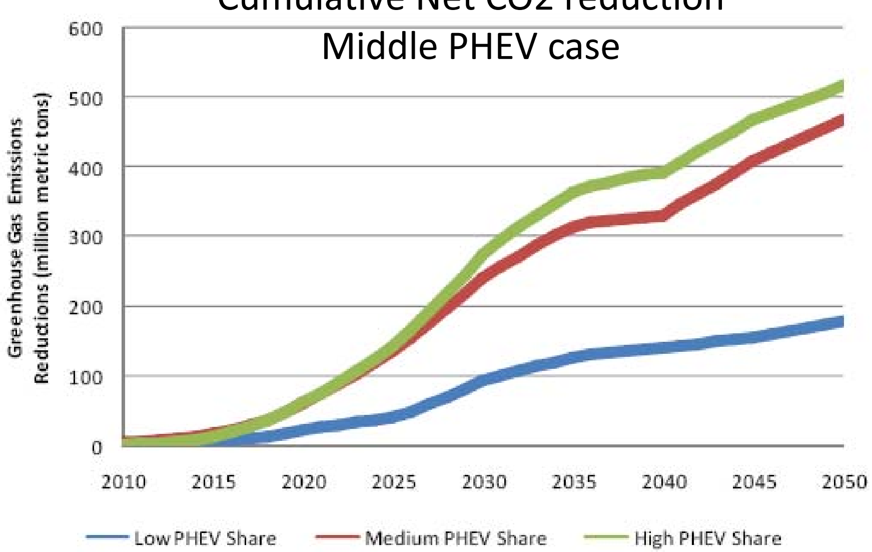
Foreign oil dependency:
60% of US oil is imported.
40% of US imports sourced from Persian Gulf, Venezuela, and Nigeria combined.

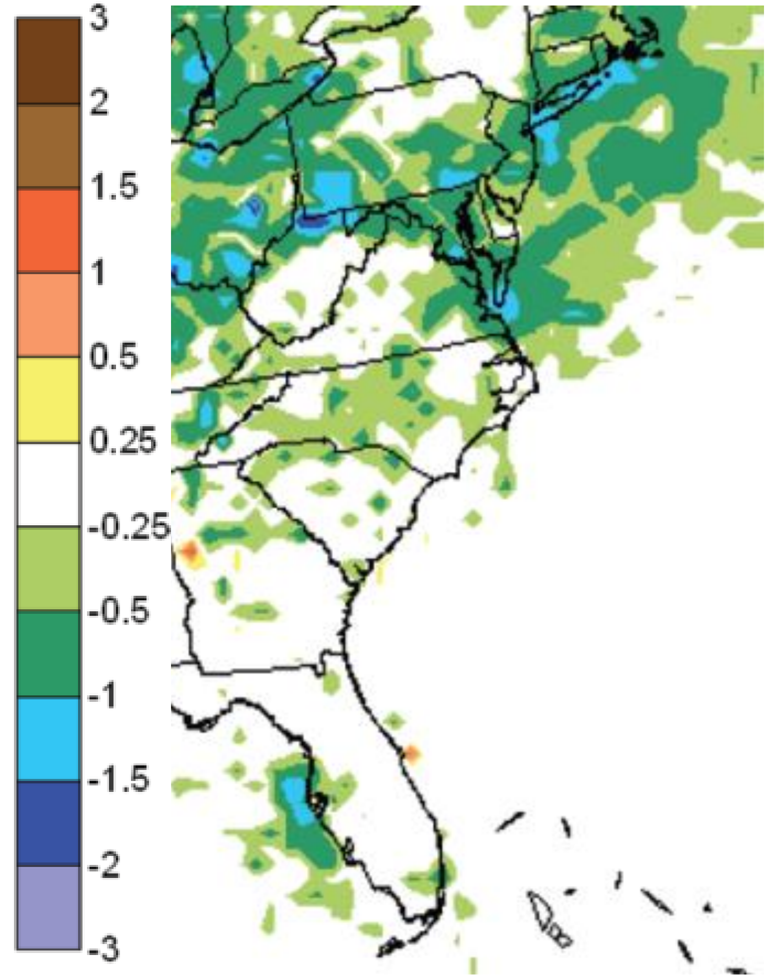
Helping Improve the Environment

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



Cumulative Net CO2 reduction
Middle PHEV case

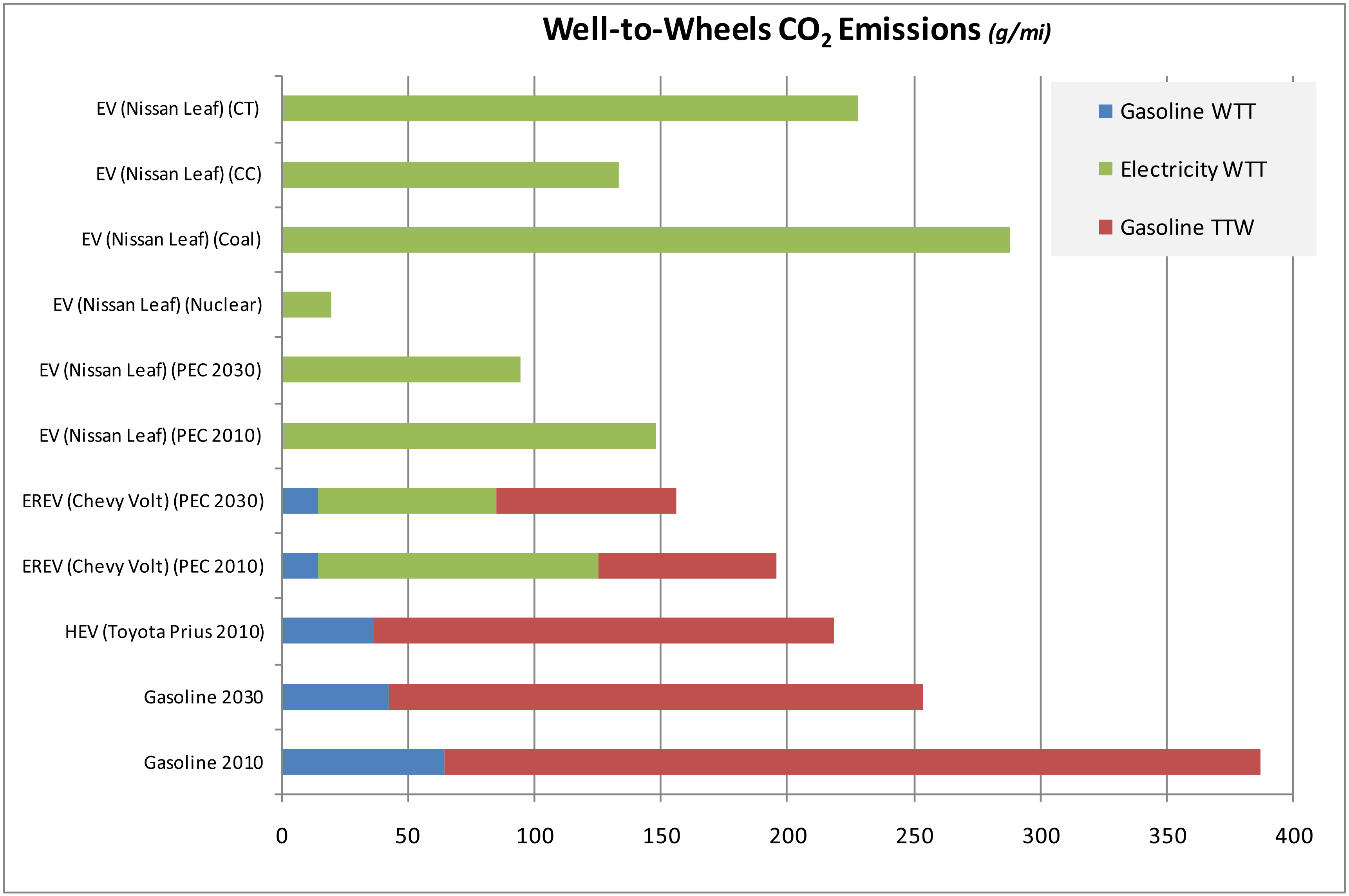




Annual 4th Highest 8-hr Ozone Difference (ppb): PHEV middle case vs. base case

Source: EPRI/NRDC 2007 Impact Study

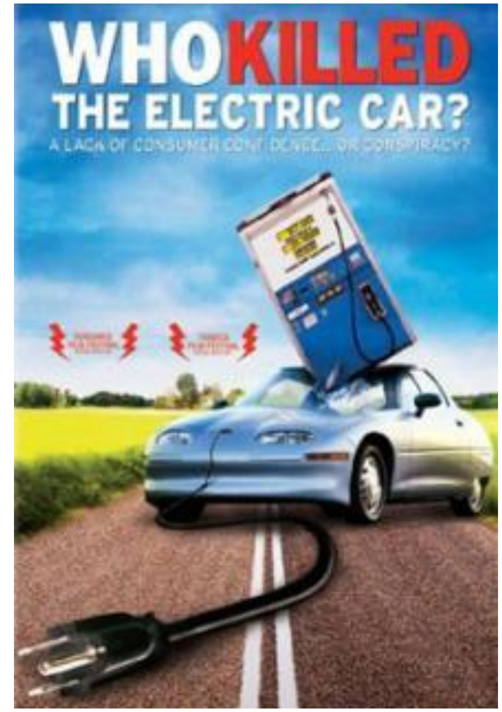
Helping Improve the Environment



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

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



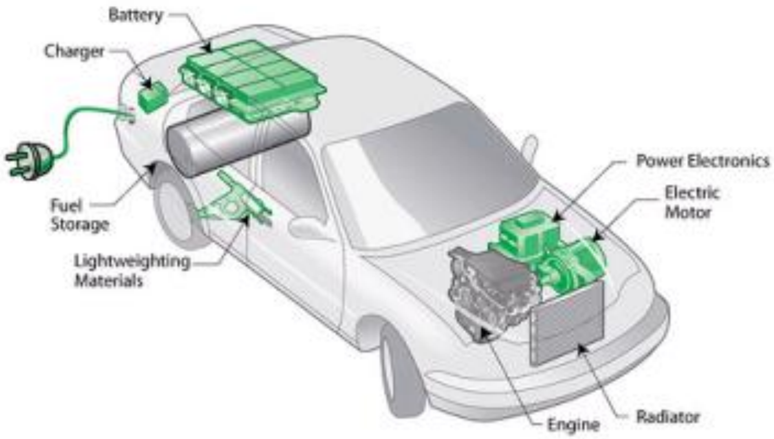
Potential Job Creation

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

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

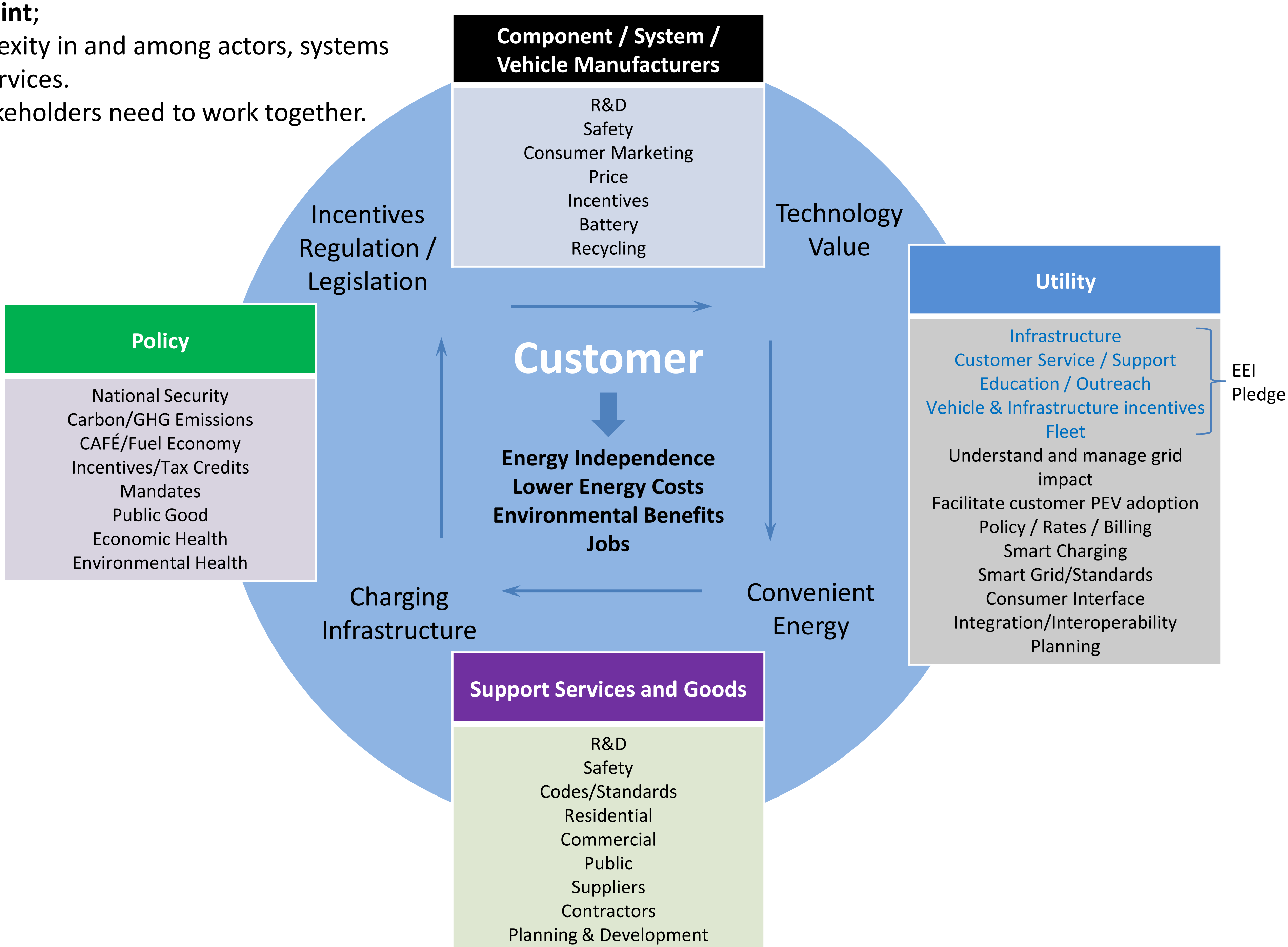
Market Projection

Electricity Grid Impacts

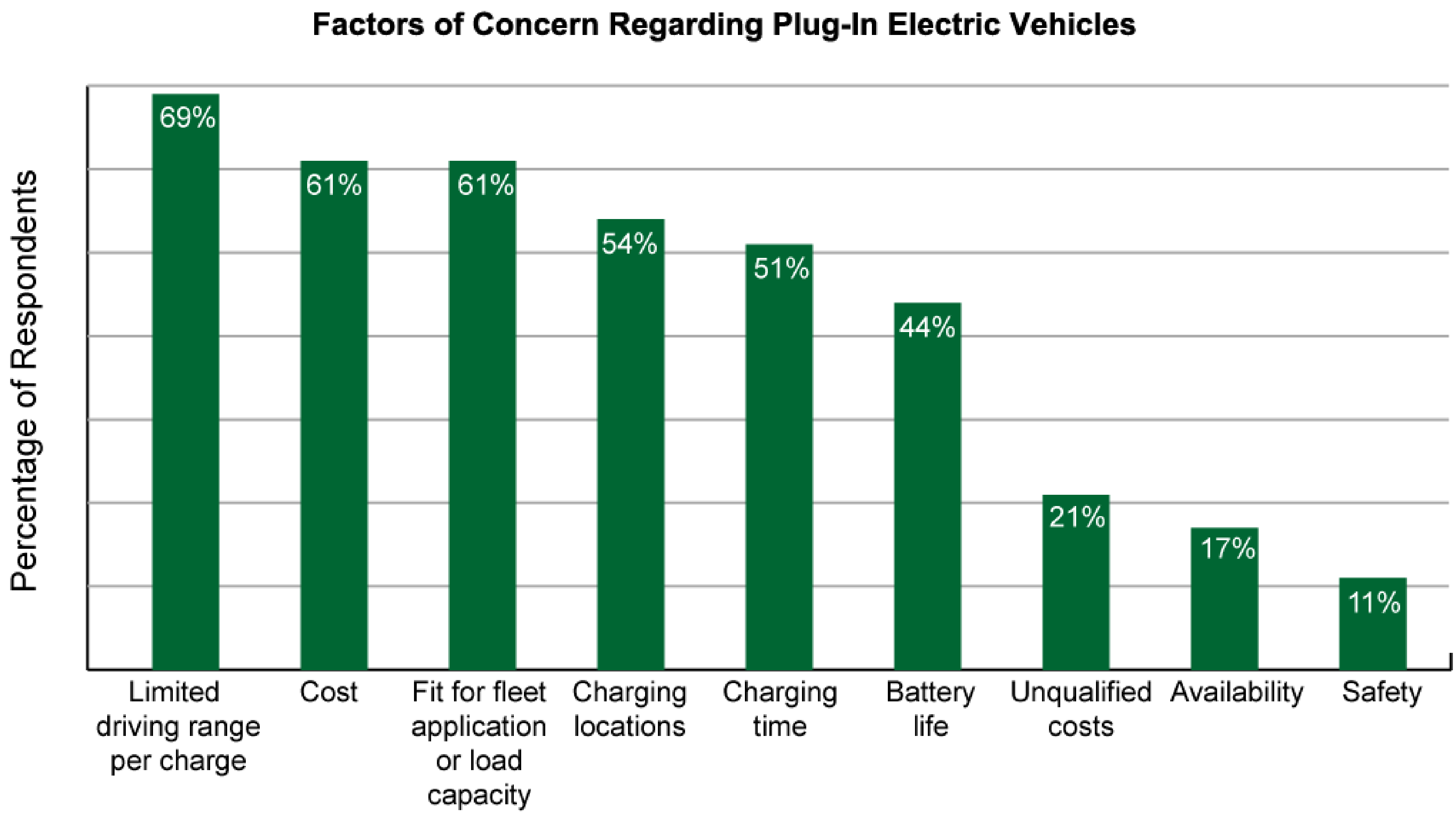
Battery Technology Development

Plug-in Electric Vehicle Stakeholder Map

Key Point;
Complexity in and among actors, systems and services.
All stakeholders need to work together.



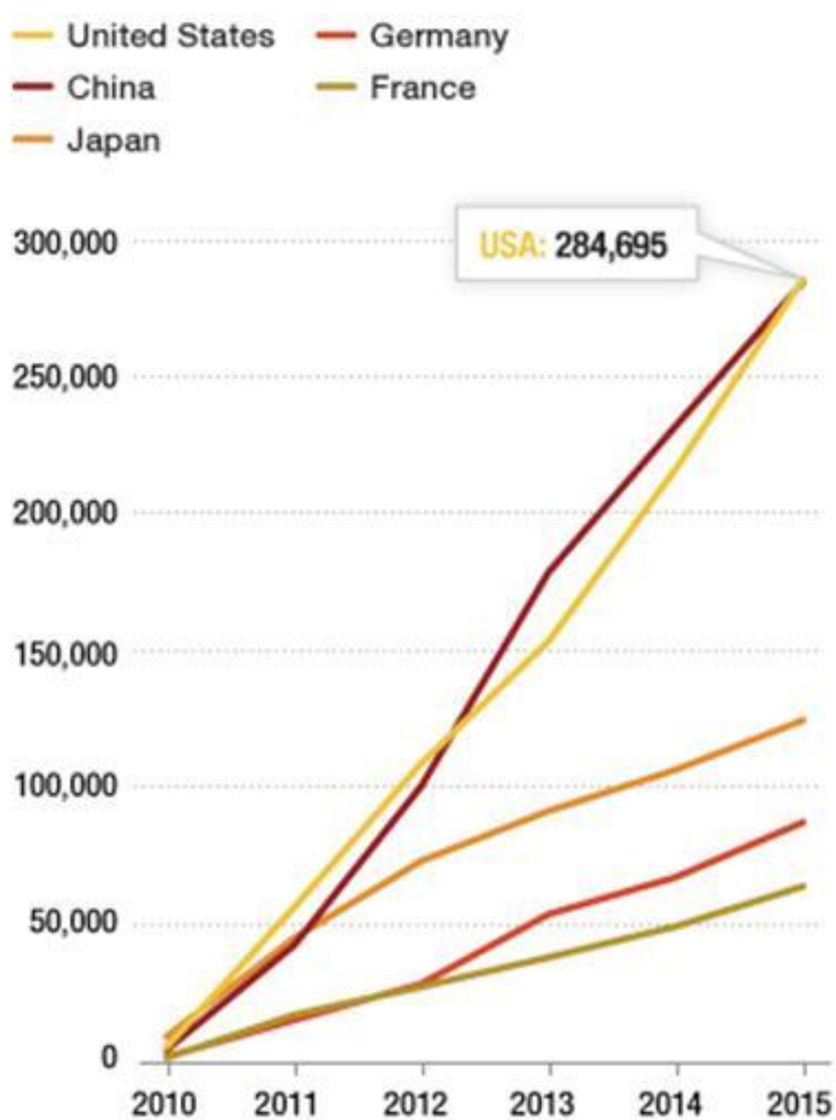
Customer Concerns



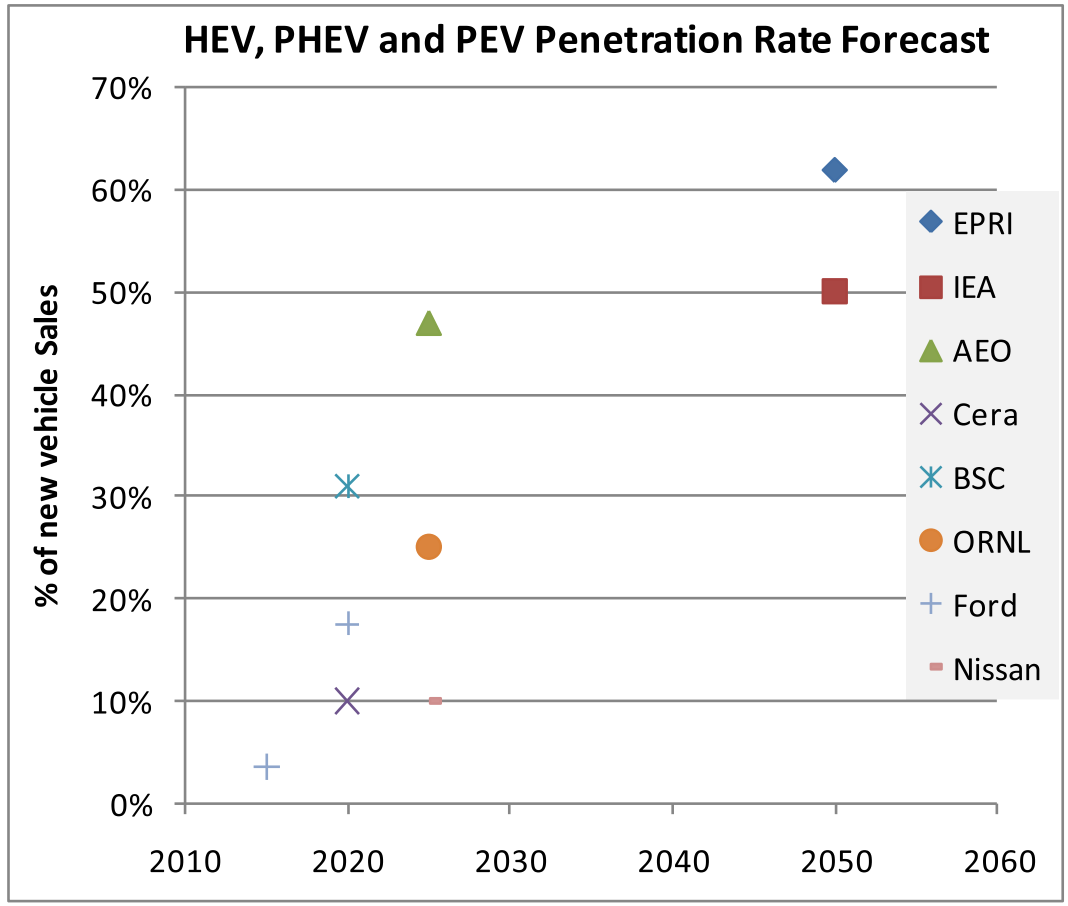
PEV Market Penetration

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

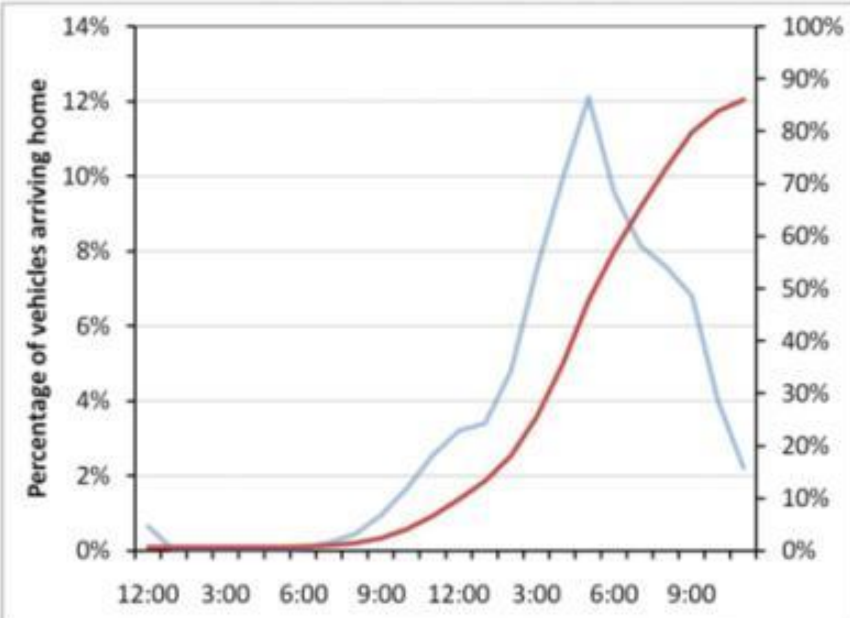


	EPRI	International Energy Agency (IEA)	AEO 2010	Nissan USA	Ford	CERA	Boston Consulting Group
% new vehicle sales (Aggressive Scenario)	62	50	47[1]	10 (20-25)	2-5[2] 10-25	10 (20)	31[1] (42)
Year	2050	2050	2025	2025	2015 2020	2020	2020

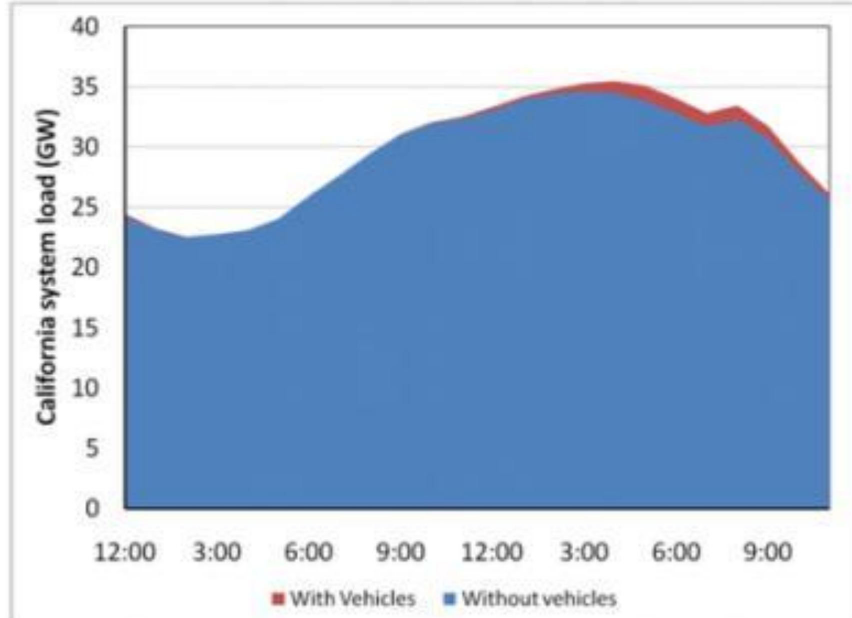
Notes:
1. Includes hybrid vehicles

Transmission System Impacts

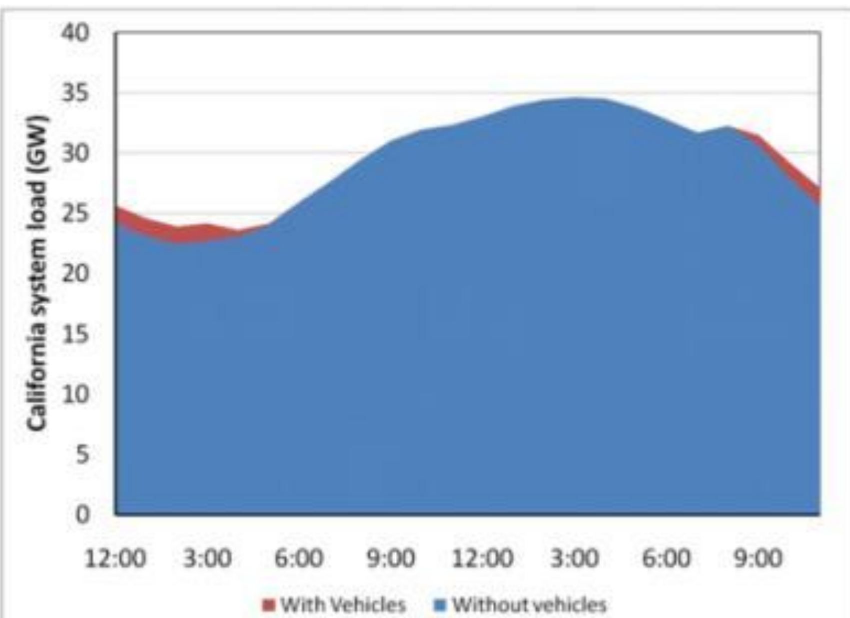
Source; Effects of transportation electrification on the electricity grid
Marcus Alexander Manager, Vehicle Systems Analysis
Workshop 4 – Plug-in Electric Vehicle Integration Issue July 15, 2009



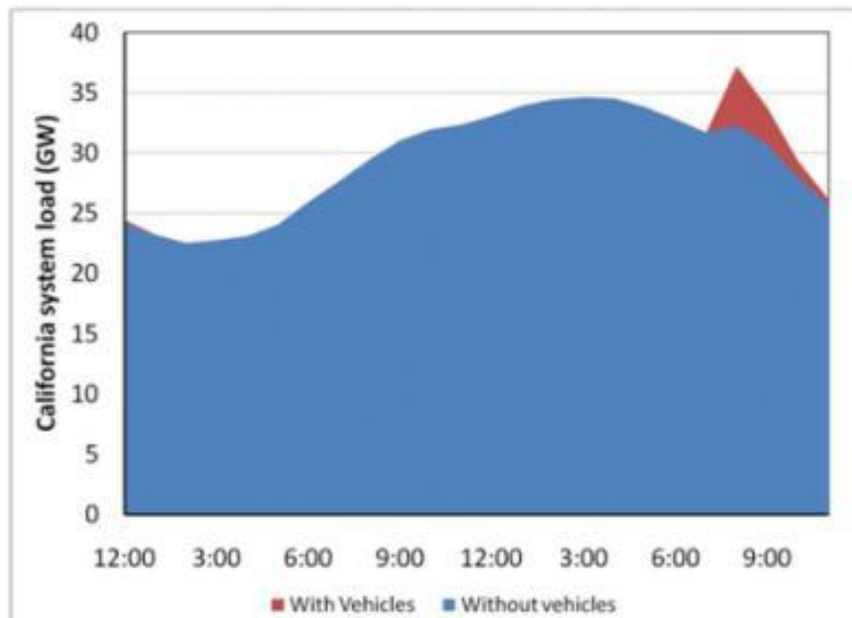
Maximum home arrival is 12% at 5 PM
By 8 PM, 70% of drivers have arrived home



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



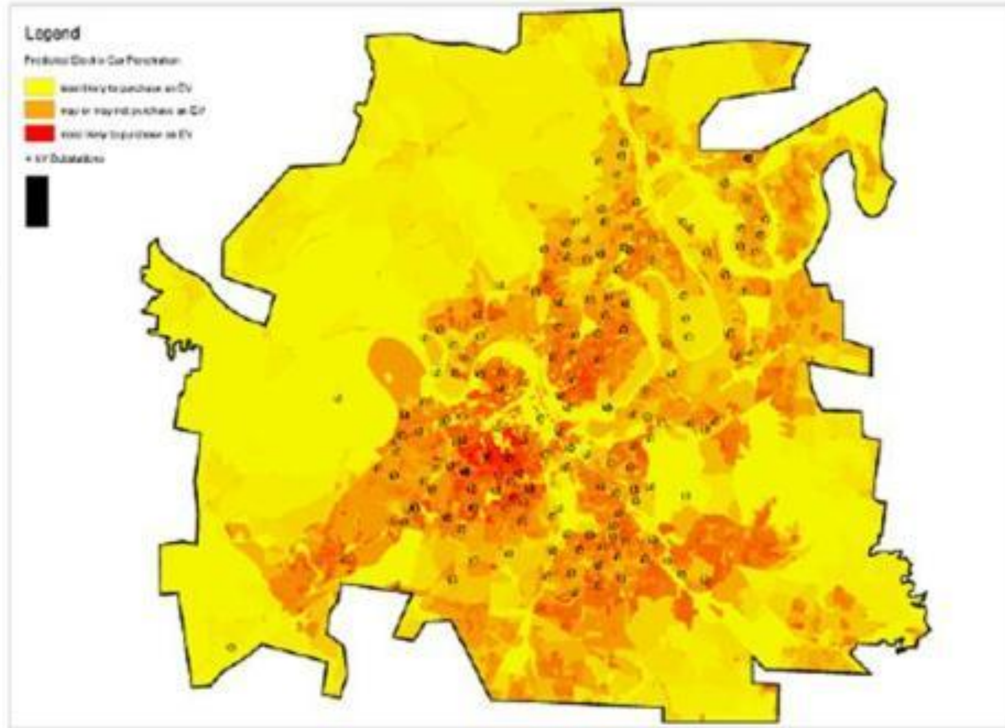
The same 2 million vehicles can be charged overnight with no increase in peak load

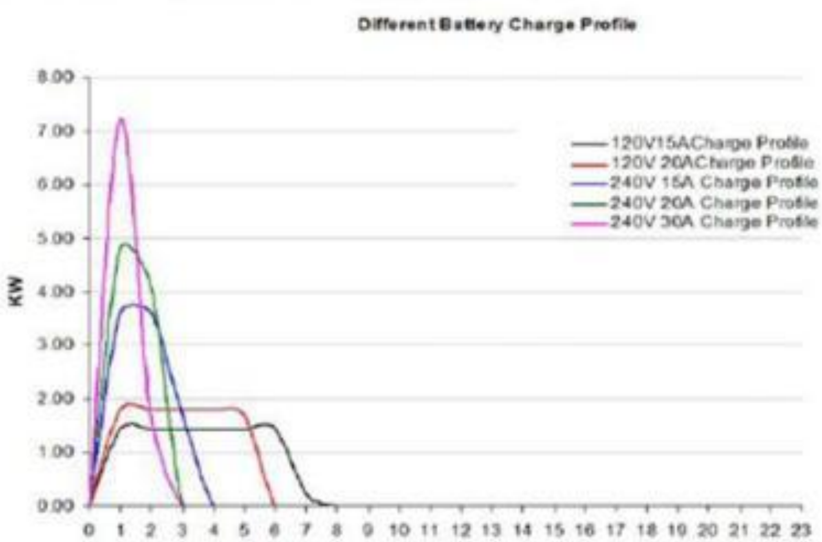


2 million badly controlled vehicles can create a new peak
This would be a serious disruption

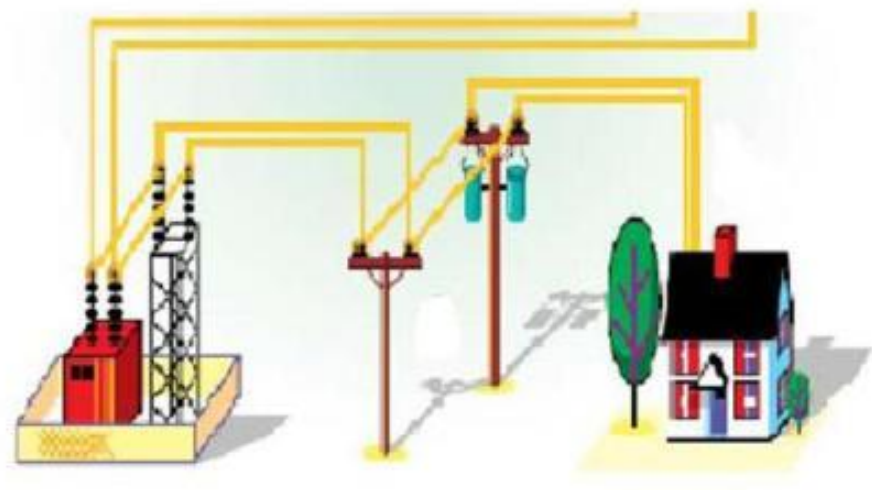
Distribution Impact Considerations

- 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

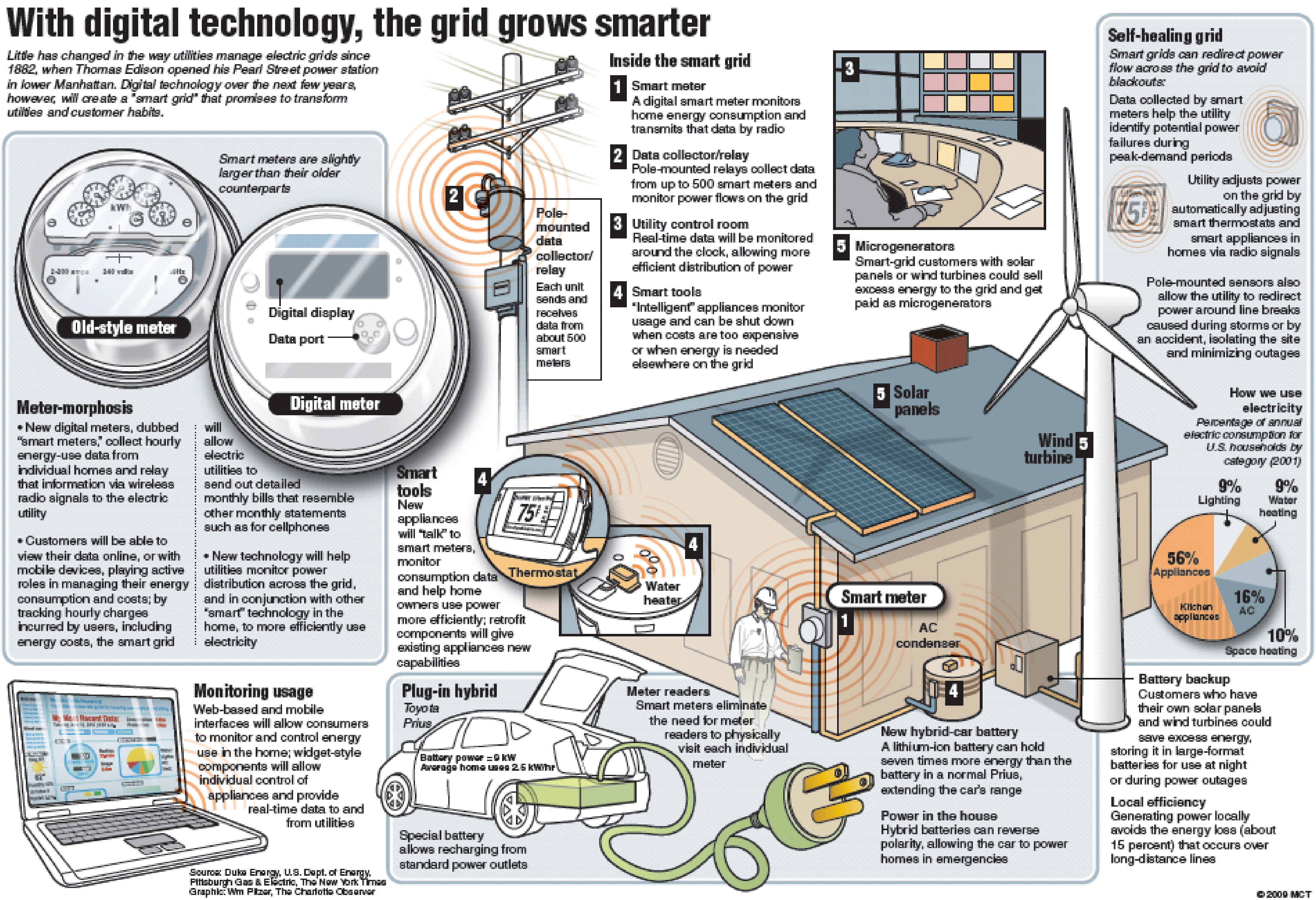




Source: EPRI EV Charge Profiles

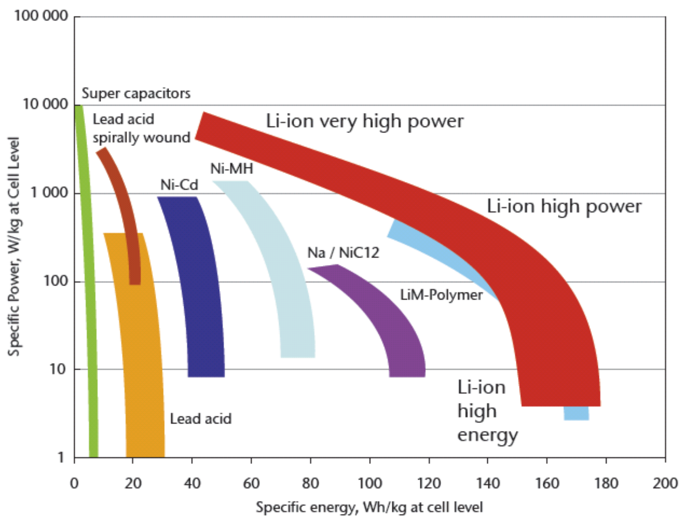


Connection of PEVs to the Electricity Grid



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

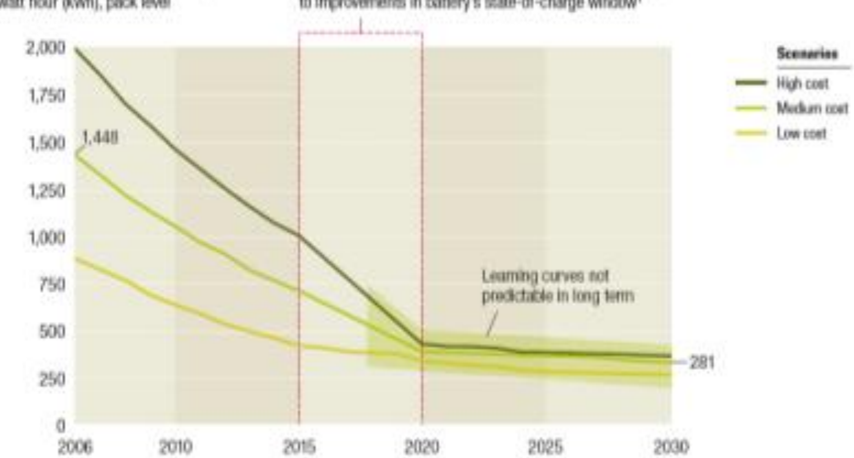
- ARRA goal 2 is to cut cost of batteries 50% by 2013 and eventually reduce the sticker price of an electric car to match gasoline counterpart
- Nissan and GM indicate current costs < $750/kWh
- Cost expected to drop to $250-350/kWh by 2020
- Improvement in economies of scale and manufacturing
- Improvement 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.

Lithium-ion battery cost assumptions,
$ per kilowatt hour (kWh), pack level

Projected breakthrough for materials and/or productivity, in addition to improvements in battery's state-of-charge window[1]



[1] 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

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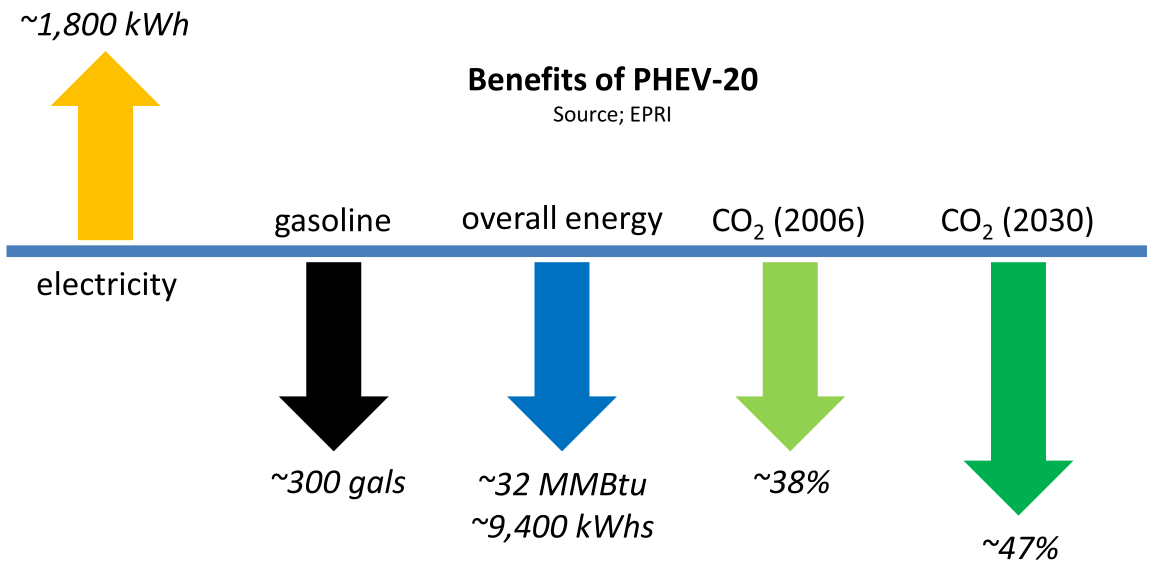
Conclusions

Significant opportunity exists for;

- **Reducing foreign oil dependency**
- **Lowering CO_2 emissions**
- **Lowering overall energy bills**
- **Job creation**



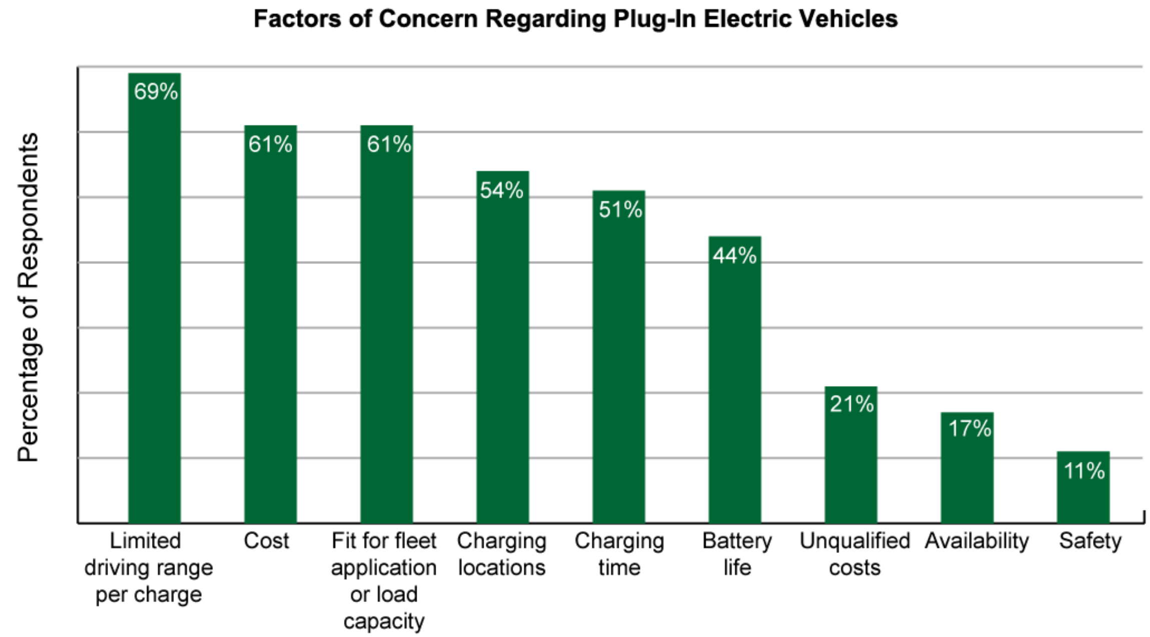
Electricity grid impacts are long term and utility companies have dealt with similar growth 3 times before. Good planning is key;

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

Note: 125,000 Btu (energy content of 1 gallon of gasoline) x 300 gals = 37,500,00 Btu = 11,000 kWh

Conclusions

Battery technology development is key to address several factors of customer concern

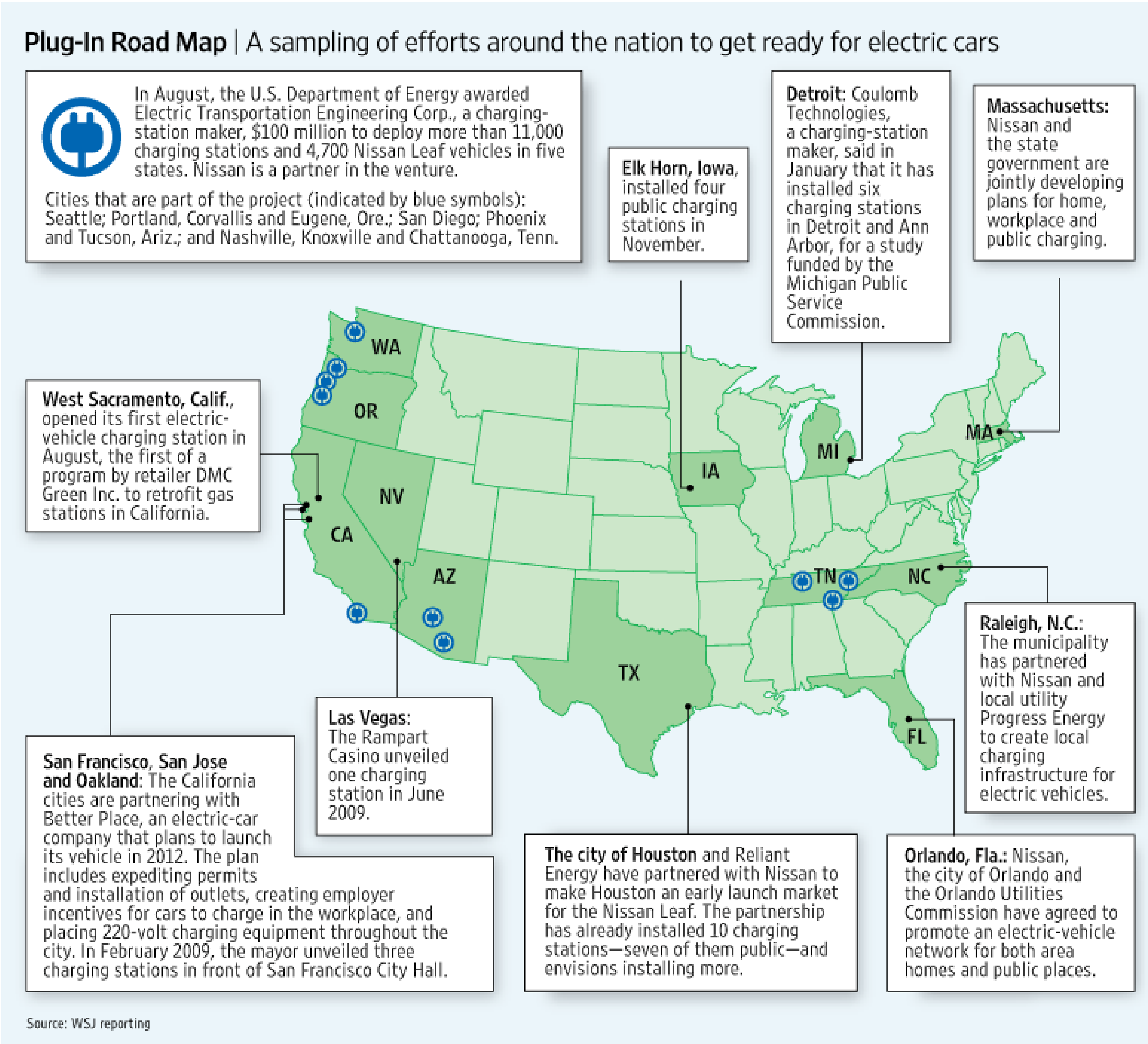


Market penetration forecasts are all over the map. However 3 factors could play a key role:

- **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



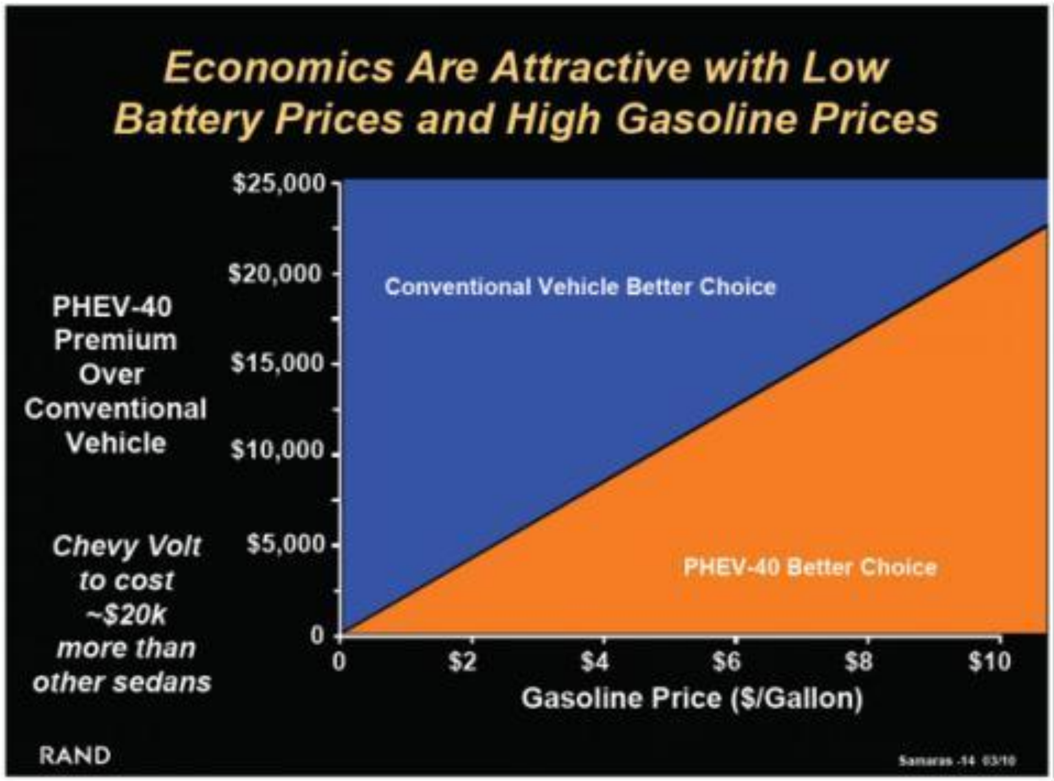
Source: *Charging Ahead*, The Wall Street Journal, May 10th 2010.

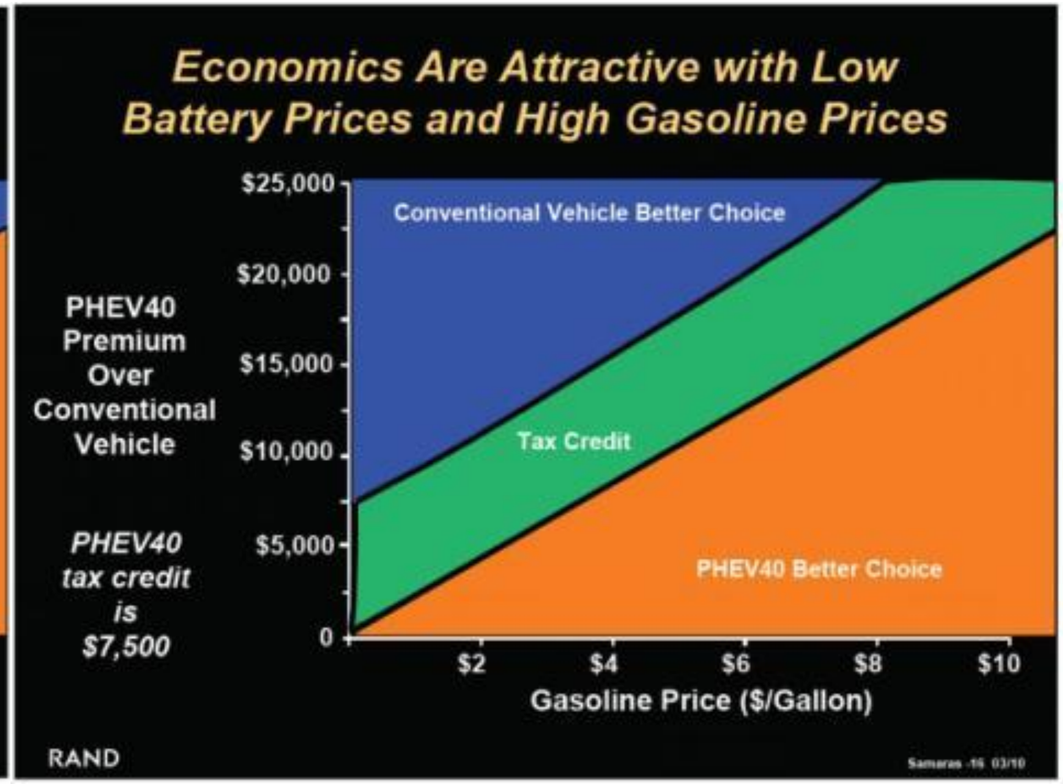
Questions?

www.GoElectricDrive.com

Appendix

PEV Economics





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