ISEA Transportation Task Force – Plug-in Electric Vehicles and Charging Infrastructure

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Boise, Idaho
April 29, 2014

INL/MIS-14-31744

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Vehicle / Infrastructure Testing Experience

- 144 million test miles accumulated on 11,700 electric drive vehicles and 16,600 charging units
- EV Project: 8,228 Leafs, Volts and Smarts, 12,363 EVSE and DCFC, reporting 4.2 million charge events, 124 million test miles. At one point, 1 million test miles every 5 days
- Charge Point: 4,253 EVSE reporting 1.5 million charges
- PHEVs: 15 models, 434 PHEVs, 4 million test miles
- EREVs: 2 model, 156 EREVs, 2.3 million test miles
- HEVs: 24 models, 58 HEVs, 6.4 million test miles
- Micro hybrid (stop/start) vehicles: 3 models, 7 MHVs, 608,000 test miles
- NEVs: 24 models, 372 NEVs, 200,000 test miles
- BEVs: 48 models, 2,000 BEVs, 5 million test miles
- UEVs: 3 models, 460 UEVs, 1 million test miles
- Other testing includes hydrogen ICE vehicle and infrastructure testing

Why Plug-in Electric Vehicles (PEVs)?

Areas of Concern with Transportation Oil Dependency

- **Energy security**
  - **Insufficient domestic supply of easily obtainable oil forces us to rely on imports**
  - **Global supply has reached "Peak Oil" (?)**
- **Global climate change**
  - **Tailpipe and smoke stack CO_2 emissions**
- **Economic stability**
  - **Unbalanced supply and demand affect all levels of the economy (global, national, personal)**

Advantages to PEVs as a Solution to Oil Dependency

- **Displace petroleum consumption with electricity**
- **Diversify our transportation energy sources**
- **Enable *alternatives***
  - **Use domestically generated electricity from a variety of sources**
  - **Use existing infrastructure**
  - **Leverage nuclear and renewable energy sources (wind, solar, hydropower, geothermal)**

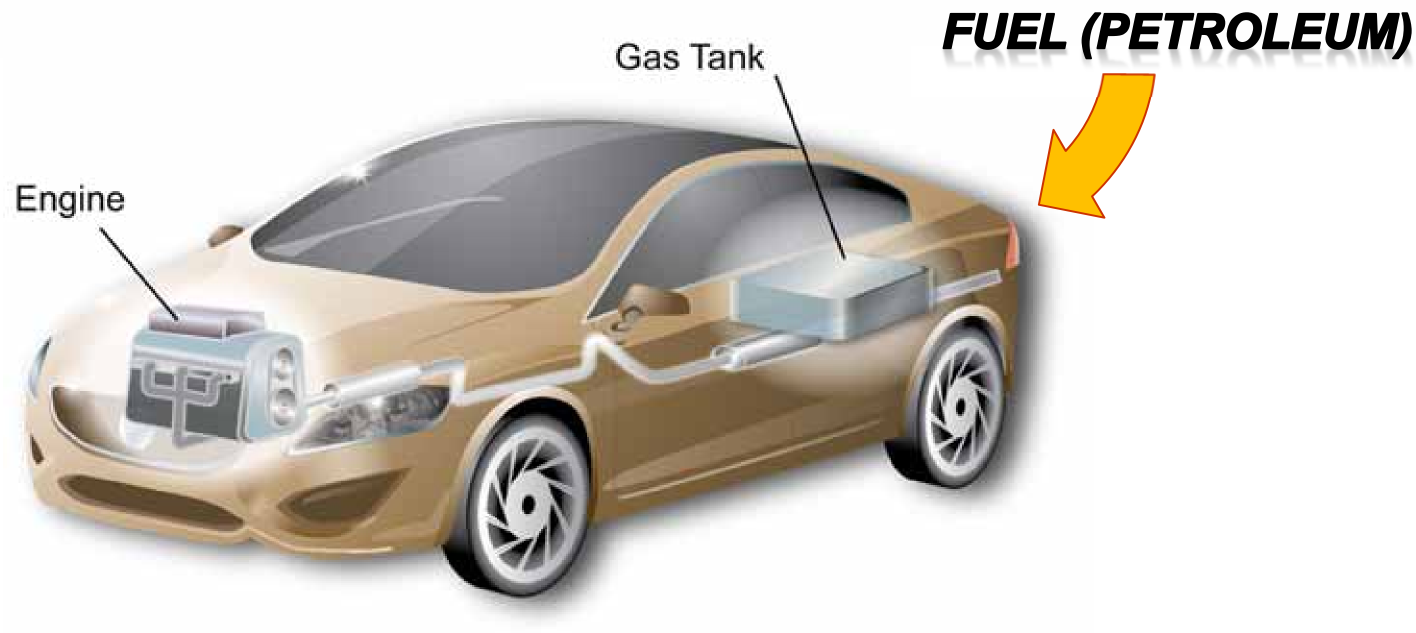
Challenges of PEVs as a Solution to Oil Dependency

- **Current technology limitations (batteries!) and potentially a shortage of domestic materials**
- **Some infrastructure required**
  - **Charging stations (short term)**
  - **Communication between vehicles and electric grid (mid-term)**
  - **Additional electricity generation / transmission / distribution (long-term)**
- **Consumer market acceptance**

Review of Vehicle Technologies

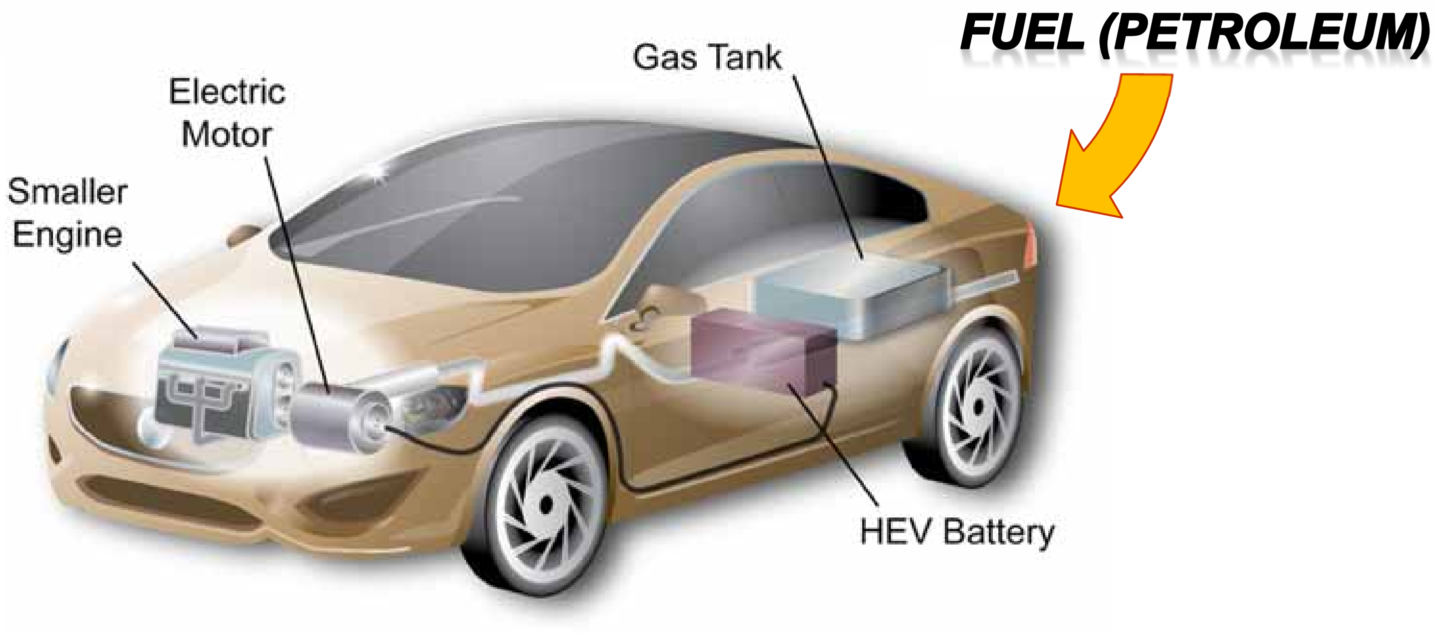
Comparison of Vehicle Technologies

- **Conventional vehicle with internal combustion engine (ICE) only**



Comparison of Vehicle Technology

- **Hybrid Electric Vehicle (HEV) with ICE and electric drive**
- **Does not plug in to electric grid**



Examples:

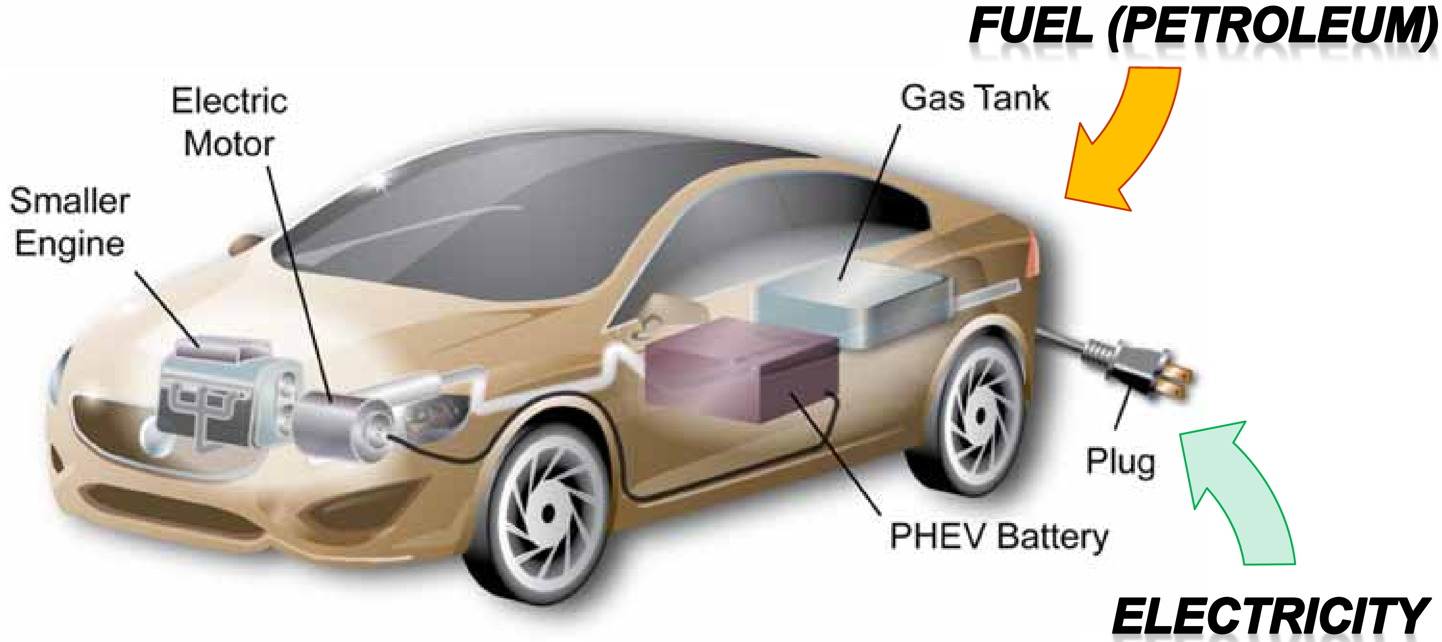
Toyota Prius

Honda Insight

Ford Fusion Hybrid

Comparison of Vehicle Technology

- **Plug-in Hybrid Electric Vehicle (PHEV) with ICE and electric drive**

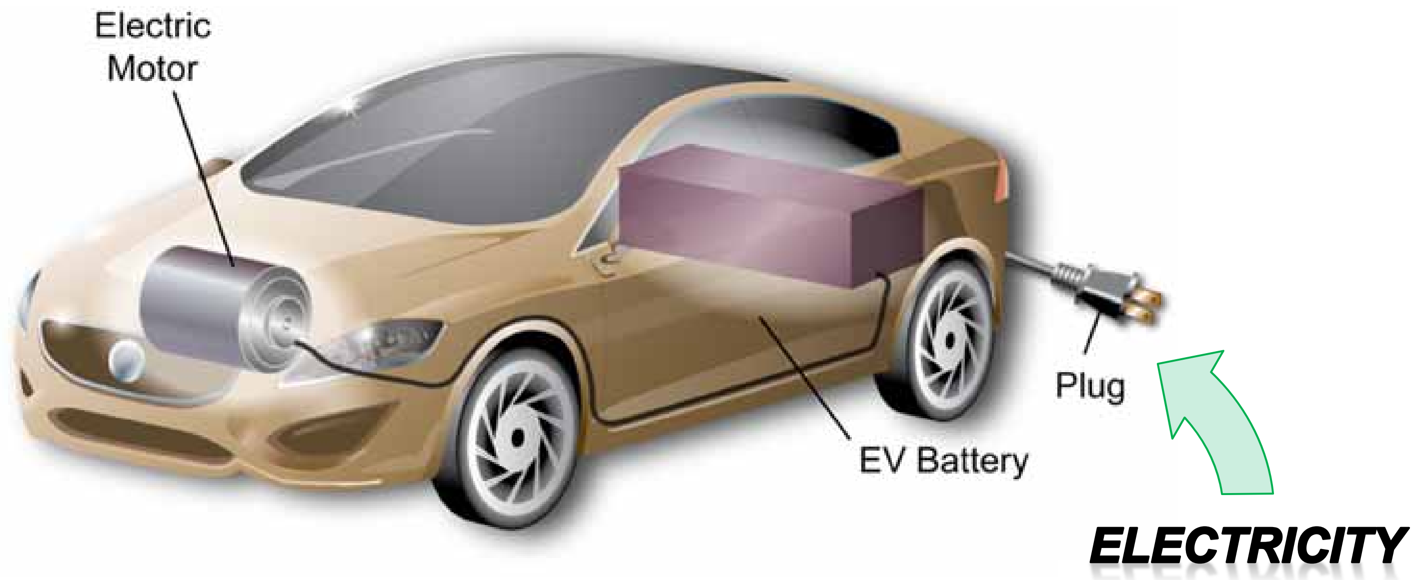


Examples:

Chevy Volt

Comparison of Vehicle Technology

- **Battery Electric Vehicle (BEV) with electric drive only**



Examples:

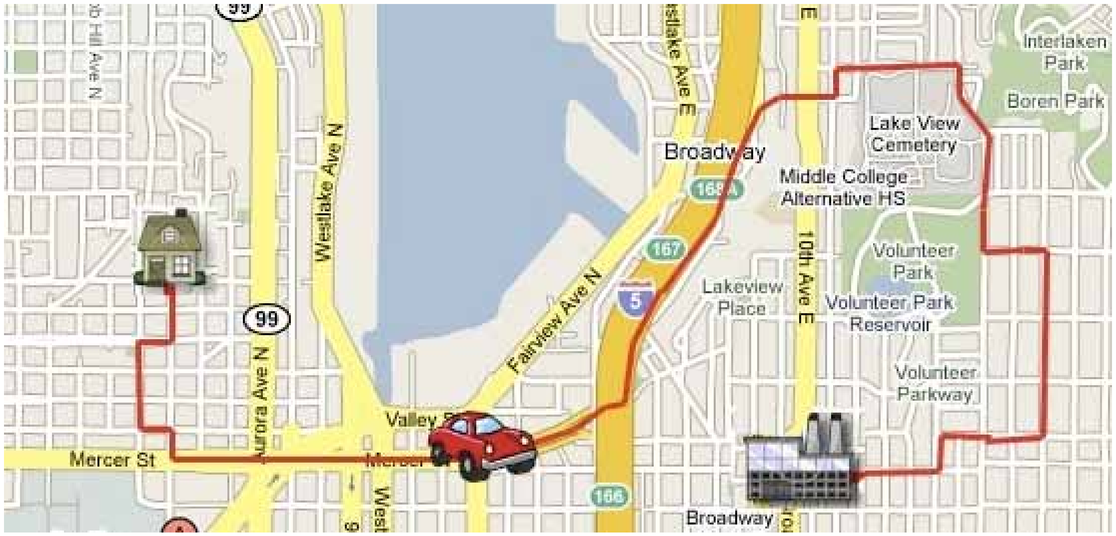
Nissan Leaf ***Tesla Roadster***

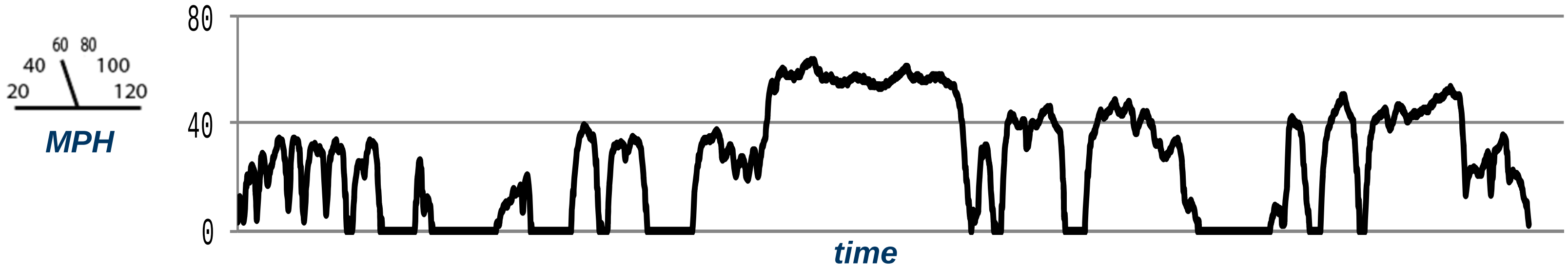
Vehicle Technology Summary

- **ICE: only energy storage is hydrocarbon fuel – typically gasoline or diesel**
- **HEV: has 2 onboard energy sources – typically gasoline and electricity. All energy originates from gasoline and the battery is only used to recover braking energy. It can be charged by the ICE engine when it is efficient to do so**
- **PHEV can be fueled with both gasoline from the pump and electricity from the grid. When the battery is charged, the gasoline engine may not even be used (All Electric Capable), or is used when the electric motor is not powerful enough by itself (Blended). When the battery is nearly empty, the vehicle operates like a typical HEV**
- **BEV has one onboard energy source – electricity, obtained by plugging in (charging). When the battery is depleted, BEVs can't be driven until recharged - like running out of gas, but takes longer to 'refuel'**
- **A PEV includes both PHEVs and BEVs – both are "plugged in"**

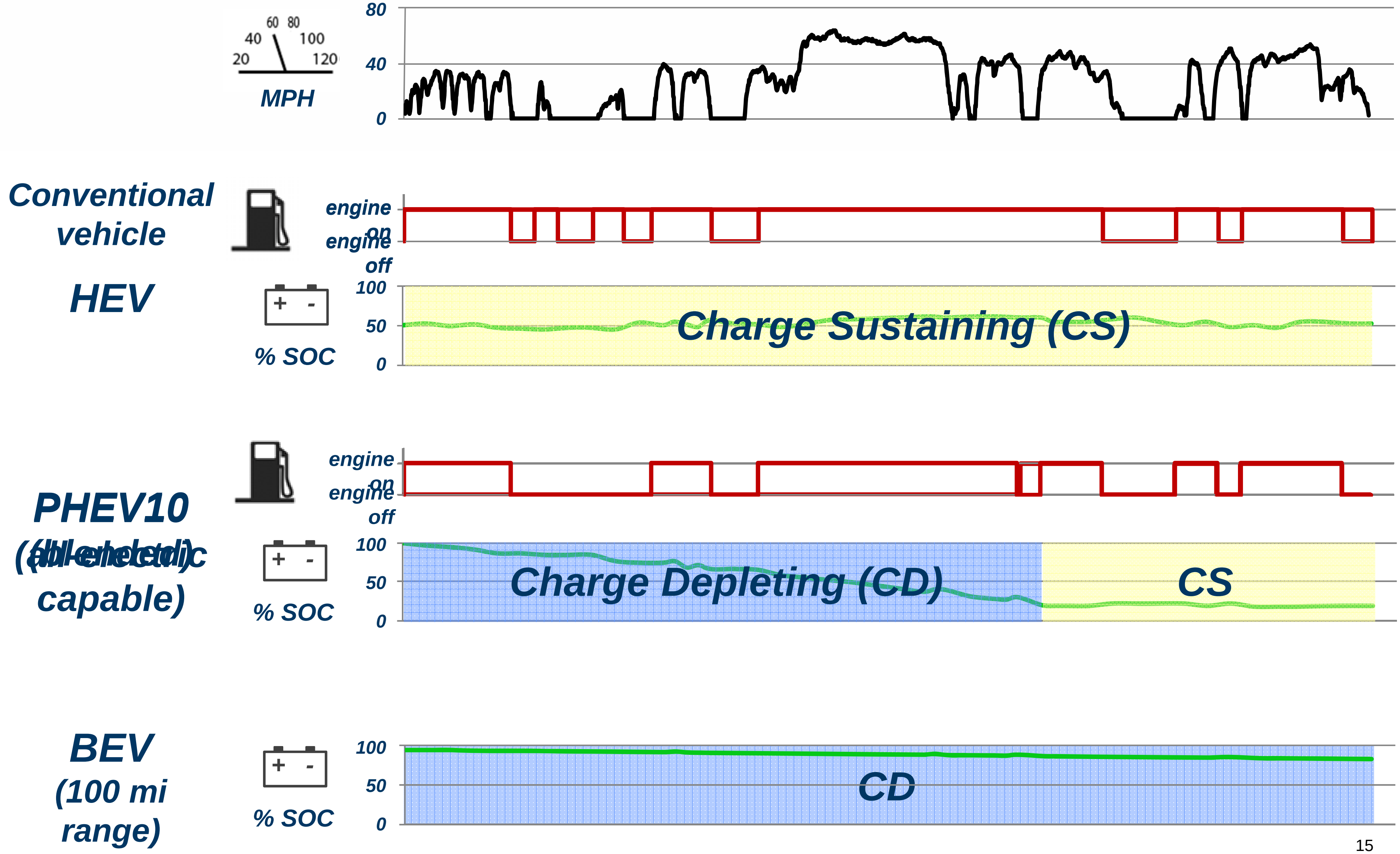
On-Road driving is Recorded and Analyzed

- **In vehicle logger transmits data over cell modem to INL**

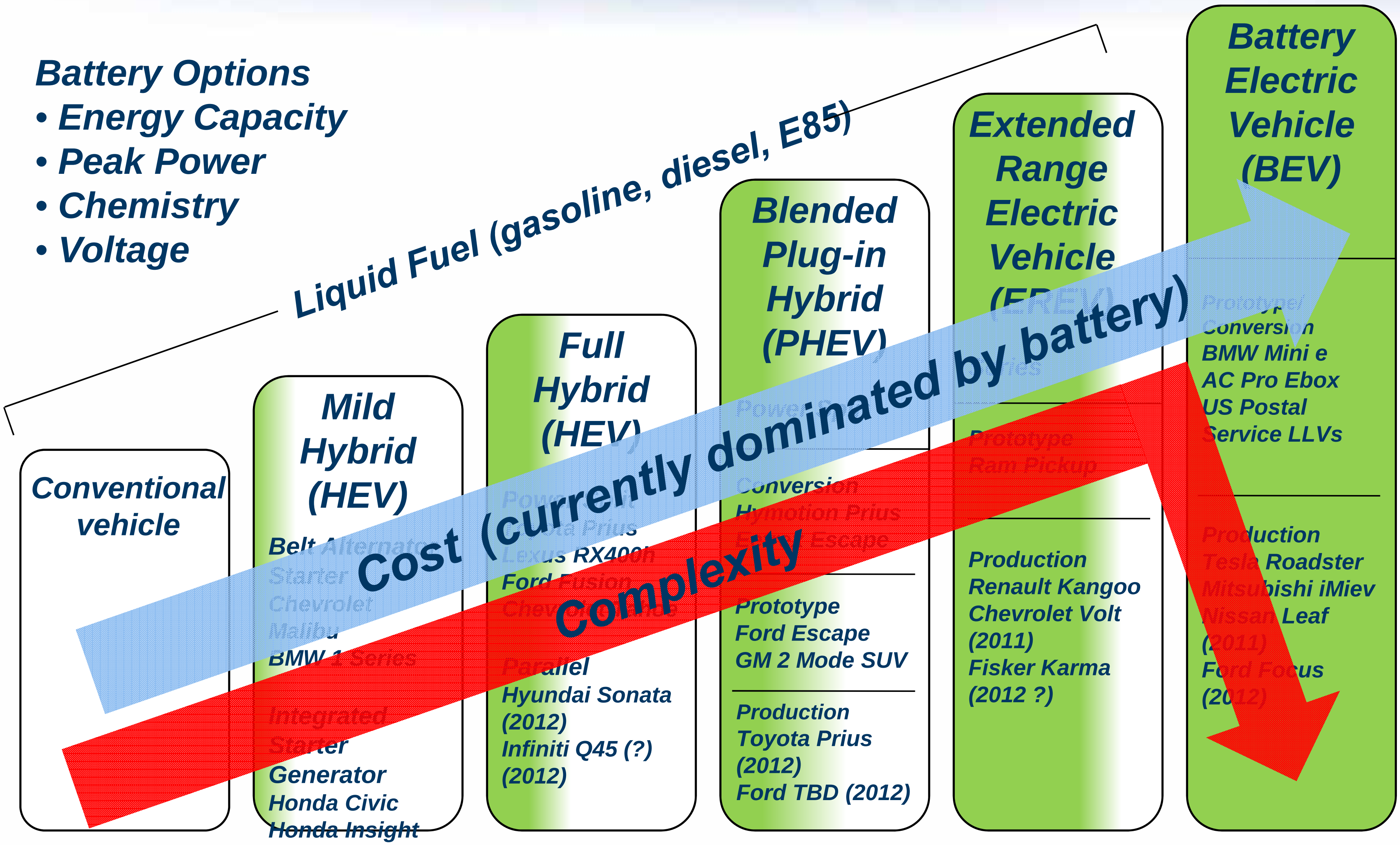




Conceptual Comparison of Vehicle Operation



Electrified Vehicle Powertrain Architectures



Dates given are announced target years for start of production

Grid-Connected Charging Infrastructure Overview

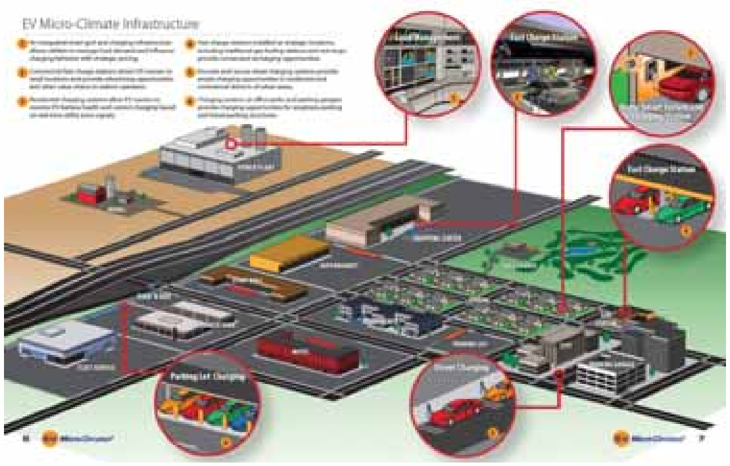
Vehicle Electrification: Grid Impacts

- **In the U.S., current grid capacity could supply electricity for 70% of our vehicles without adding capacity, but assumes:**
  - **Vehicles would only charge off-peak**
  - **"Perfect" distribution of electricity**
  - **No local impacts such as overburdening neighborhood transformers**

- **PEVs will not cause a grid "meltdown" but we clearly need to work to reduce vehicle rollout impacts**
- **Smart charging will be key to lowering costs and minimizing impacts**
- **Time of day pricing is important**
- **Administration Goal: 1 Million Plug-in Vehicles by 2015**

Build-out of Charging Infrastructure

- Key today: Home Charging
  - Need to get the cost and installation process right. Currently a significant barrier
- Work and Public Access Charging
  - Expensive if not well utilized
  - Expensive to fully cover full driving patterns
- Ideally need market pull to determine public infrastructure build-out
  - PHEVs may be key to help initiate market pull for public infrastructure



Innovative Approaches

- **Battery swapping (Project Better Place retrenchment)**
  - **Requires OEM buy-in**
- **Fast Charging (becoming less innovative)**
- **Innovative Financing**
- **Secondary use of batteries**
  - **Utility ancillary services**
  - **Bulk energy storage**
  - **Increase present value**
- **Vehicle to Grid (V2G)**

Charging Definitions

- Defined in Society of Automotive Engineers (SAE) J1772
  - AC (On-board vehicle charger)
    - Level 1: 120V AC (up to 16 Amps, ~ 1.92kW Max)
    - Level 2: 240V AC (up to 80 Amps, ~ 20kW Max)
    - Level 3: > 20kW (proposed)
  - DC Charging (Off-board vehicle charger)
    - Level 1: Up to 20kW (proposed)
    - Level 2: Up to 80kW (proposed)
    - Level 3: >80kW (proposed)
  - There may be other levels proposed
- What is called "fast charging" today is DC Level 2
- Most vehicles have onboard chargers that operate at 3.3 or 6.6 kW. Tesla charges at 10 kW. Energy is supplied to the vehicle via electric vehicle supply equipment (EVSE) at AC Level 2

Selecting the EVSE or DCFC Type & Rate

- **AC Level 1 (supplies electricity to on-board DC Charger)**
  - **110 VAC EVSE should be connected to commercial grade NEMA outlet and dedicated branch circuit**
  - **Convenience charge cord typically provided with PEV used for emergency purposes.**
  - **Charge times range from 6+ hours (PHEV) to 24+ hours (BEV) for a full recharge**
  - **Could be used to charge PHEV on a daily basis but dissatisfaction can occur if PHEV does not fully charge**
- **AC Level 2 (supplies electricity to on-board DC Charger)**
  - **240 VAC EVSE connected to dedicated branch circuit**
  - **Charge times range from 2 (PHEV) to 8 hours (BEV) for a full recharge**
  - **Good for malls, movie theatres, work place**

Selecting the EVSE or DCFC Type & Rate

- **DC (Off-board Charger, directly charges the vehicle battery pack. Does not use the onboard charger)**
  - **DC Level 2 (>20kW and up to 80kW)**
  - **50kW is the most commonly used power output today (Nissan Leaf)**
  - **Provides 2 to 4 miles range per minute of charge**
  - **Good for City corridors, convenience stores and fast food restaurants**

Examples of Level 1 EVSE

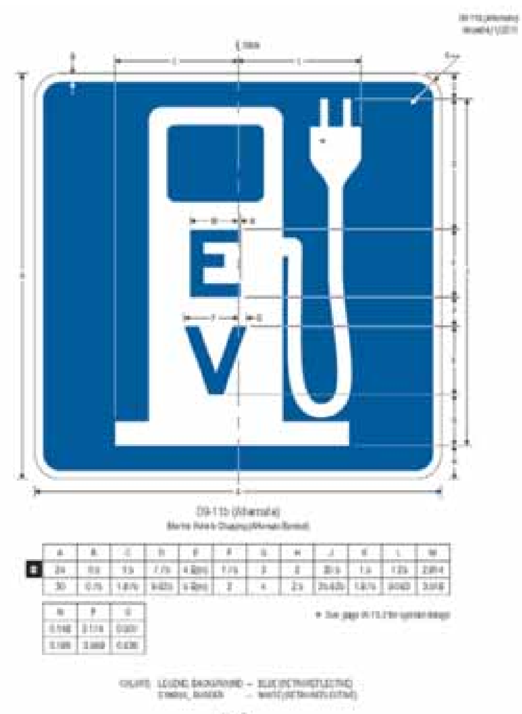
Examples of Level 2 EVSE Hardware

Examples of DC Fast Charging

Commercial Site Considerations

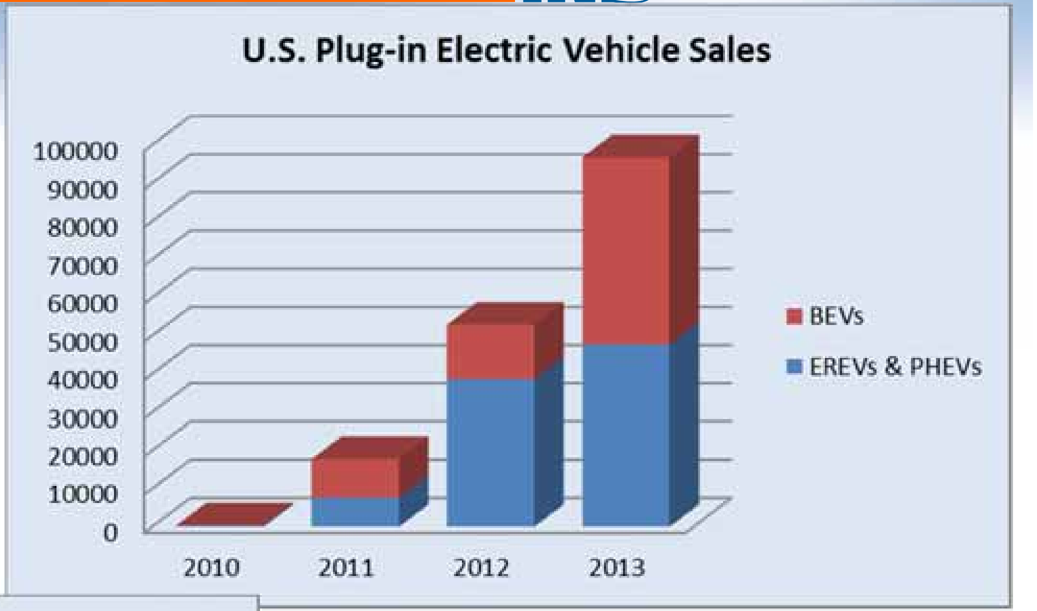
- **Geographic Coverage / Planning**
- **Local attraction(s)**
- **Proper charger level for location**
- **ADA Requirements**
- **Lighting / Security**
- **Signage**
- **Access**
- **Local Permitting Authority**

Signage Examples

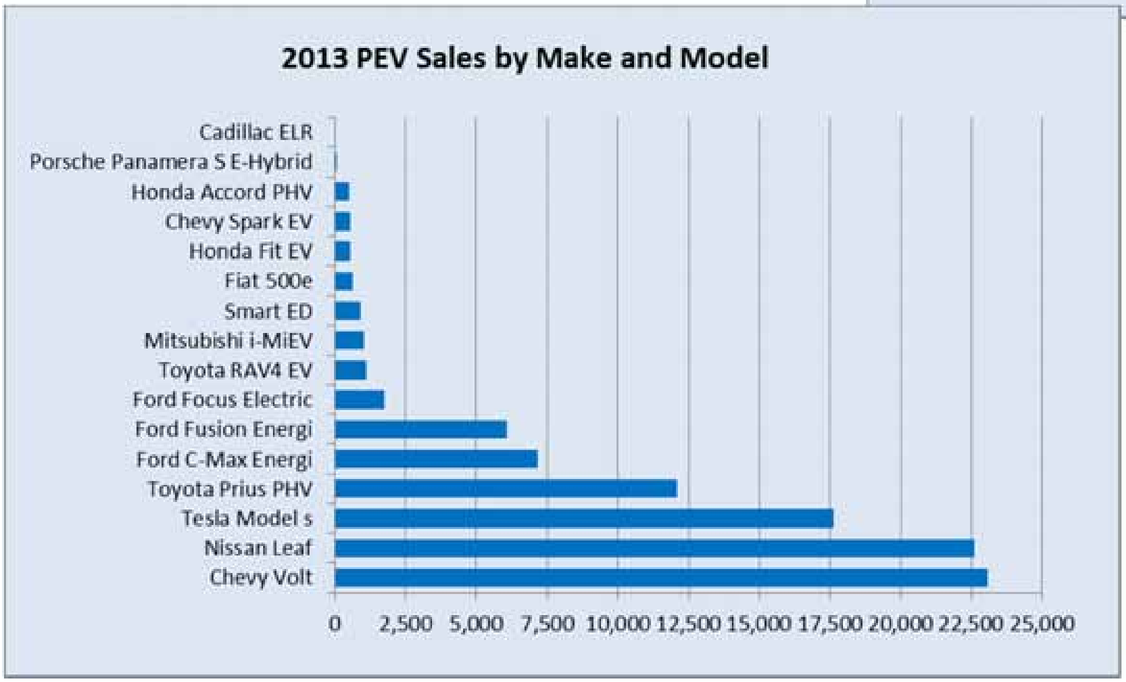


PEV Sales and Announcements

U.S. PEV Sales



Data obtained at:
http://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952



Data obtained at:
http://www.cars21.com/news/view/5720

Plug-in Electric Vehicle U.S. Production Status

MAKE	MODEL	POWER-TRAIN	ESTIMATED U.S. AVAILABILITY DATE	ELECTRIC/ TOTAL RANGE (MI) *EPA-rated value	BATTERY CAPACITY (kWh)	BATTERY SUPPLIER	EPA FUEL ECONOMY (Electric MPGe / Gasoline Only mpg)	BASE MSRP (PRIOR TO INCEN. & DEST. FEE)	TOTAL SALES (IF AVAILABLE)
Audi	A3 e-tron (sportback)	PHEV	early 2015	31 / 584	8.8	Cells supplied by Panasonic		$49,000	
	A6 e-tron	TBD	concept					TBD	
	A8 e-tron	TBD	concept					TBD	
	Q7 e-tron	PHEV	from 2014					TBD	
	Q8 e-tron (crossover)	BEV	2017	target of 370					
	R8 e-tron	BEV	2nd half, 2014	248.5	48.6			~$1.3 million	
	Allroad Shooting Brake	PHEV	concept	31 / 500+	8.8				
	Sport quattro	PHEV	concept						
BMW	Active Tourer	PHEV	concept			TBD		N/A	
	i3	BEVx	2nd quarter, 2014	136 (or 217 w/ range extender)	18.8	SB LiMotive (JV between Samsung and Bosch)		$41,350 (or $45,300 for range-extender model)	
	i8	E-REV	2014	20 / ?	10.8			~$125,000	
	X5 eDrive	PHEV	concept	18+					
Boulder	DV-500	BEV	in production, fleet only	40, 80, or 120	80 kWh (for 120 mi)			$100,000	
Buick	Riviera	PHEV	concept			TBD			
BYD Auto	e6	BEV	in production, fleet only	186	60	BYD (in house)		$42,000	
Cadillac	ELR	E-REV	early 2014	35	16.5	LG Chem	82 / 33	$75,000	105
Chevrolet	Spark	BEV	in production (MY2014)	82	21	A123 Systems	119	$26,685	724
	Volt	E-REV	in production (MY2014)	38/380*	16	LG Chem	98 / 37	$34,185	56,680
Chrysler	Town & Country	PHEV	demo only	30	24	Electrovaya		N/A	
Commuter Cars	Tango T600	BEV	in production (low volume)	80-200	32, 60 under development	Hawker Genesis G70EP lead acid or li-ion		$108,000	
Detroit Electric	SP:01	BEV	delayed	190	37	Will not use single supplier		$135,000	
Dodge	Ram	PHEV	demo only, no production plans	20	12	Electrovaya		N/A	
Fiat	500e	BEV	in production (MY2013)	87*	24	SB LiMotive (JV between Samsung and Bosch)	116	$31,800	370
Fisker	Atlantic	E-REV	TBD					~$50,000-60,000	
	Karma	E-REV	TBD	50				$102,000	
Ford	C-MAX Energi	PHEV	in production (MY2013)	21/620*	7.5	Panasonic	100 / 43	$32,950	10,407
	C-MAX Solar Energi	PHEV	concept				100 / 43		
	Focus Electric (sedan/hatchback)	BEV	in production (MY2014)	76*	23	LG Chem	105	$35,200	2,652
	Fusion Energi	PHEV	in production (MY2014)	21/620*	7.6	Panasonic	100 / 43	$38,700	7,401
Honda	Accord	PHEV	in production (MY2014)	13/570*	6.7	Blue Energy (JV between GS Yuasa and Honda)	115 / 46	$39,780	577
	Fit	BEV	in production (MY2014)	82*	20	Toshiba	118	$36,625, currently only leasing for $259/mo (3 yr)	725
Infiniti	LE	BEV	delayed indefinitely	100	24	Nissan JV AESC			
Jaguar	XJ_e	PHEV	concept	25	12.3	Axeon		N/A	
Kia	Venga	BEV	concept	112	24	LG Chem		N/A	
	Soul EV	BEV	3Q, 2014	124.3	27	SK Innovation		~$35,000	
Land Rover	Range_e (diesel)	PHEV	2014	22	14.2				
Lightning Car Company	GT	BEV	2014	150	44	Altairnano		$190,000	
Li-ion Motors	Inizio (R, RT and RTX models)	BEV	In production (low volume)	150, 200 or 250	40.3, 81 or 97	Superlattice Power		$139,000, $189,000, $249,000	
	Wave II (S and SE models)	BEV	In production (low volume)	150 or 200	33.6 or 40.3			$39,000	
	LiV Flash	BEV	In production (low volume)	120					
	LiV Harmony	BEV	In production (low volume)	120					
	LiV Wise	BEV	In production (low volume)	120					
Lotus	Evora 414E	E-REV	in testing	35	14.4				
Mazda	Mazda2 EV	BEV	2018		20				

Last Revised: 3/6/2014

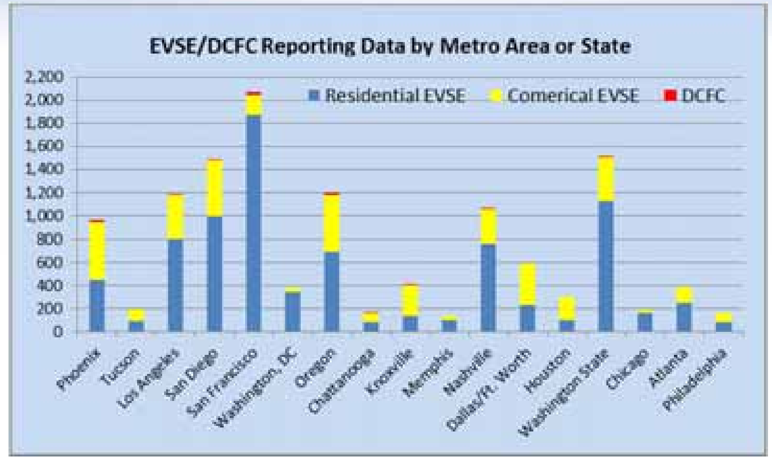
MAKE	MODEL	POWER-TRAIN	ESTIMATED U.S. AVAILABILITY DATE	ELECTRIC/ TOTAL RANGE (MI) *EPA-rated value	BATTERY CAPACITY (kWh)	BATTERY SUPPLIER	EPA FUEL ECONOMY (Electric MPGe / Gasoline Only mpg)	BASE MSRP (PRIOR TO INCEN. & DEST. FEE)	TOTAL SALES (IF AVAILABLE)
McLaren	P1	PHEV	in production (MY2013)	12	4.7			$1.35M	
Mercedes-Benz	B-Class E-Cell PLUS	PHEV	concept	62	18				
	B-Class Electric Drive	BEV	Summer 2014 to select markets, nationwide in 2015	124	28	Tesla Motors			
	C-Class	PHEV	TBD						
	SLS AMG Coupe Electric Drive	BEV	concept	130	60	SK Innovation		N/A	
Mitsubishi	CA	BEV	concept	~186	28			N/A	
	GC-PHEV	PHEV	concept						
	i-MiEV	BEV	in production (MY2012)	62*	16	Lithium Energy Japan (JV between GS Yuasa and Mitsubishi)	112	$22,995	1,701
	Outlander	PHEV	delayed until 2015	30	12	Lithium Energy Japan (JV between GS Yuasa and Mitsubishi)		TBD	
	XR-PHEV	PHEV	concept						
Navistar	eStar (fleet van)	BEV	in production, fleet only	100	80	A123 Systems		$150,000	
Nissan	LEAF	BEV	in production (MY2014)	84*	24	Nissan JV AESC	114	$28,980	44,799
	e-NV200	BEV	undergoing testing, 2017	73	24			N/A	
Phoenix Motorcars	SUT (sport utility truck)	BEV	concept	70+	35	Altairnano		N/A	
Porsche	918 Spyder	PHEV	early 2014	16	6.8			$845,000	
	Panamera S E-Hybrid	PHEV	in production (MY2014)	15	9.4			$99,000	249
Scion	iQ EV	BEV	in production, fleet and carsharing only	38*	12		121		
Smart	fortwo ED coupe/convertible	BEV	in production (MY2013)	68*	17.6	Deutsche ACCUmotive	107	$25,000 (coupe), $28,000 (convertible)	1,591
Tesla	Model S	BEV	in production (MY2013)	208 (60 kWh) or 265 (85 kWh)*	60 or 85	Cells supplied by Panasonic	95 (60 kWh) or 89 (85 kWh)	$72,070 (60 kWh), $81,070 (85 kWh)	22,200
	Model E	BEV	2016			Cells supplied by Panasonic		~$30,000	
	Model X (crossover)	BEV	late 2014		60 or 85	Cells supplied by Panasonic		$50,000-90,000	
Toyota	NS4	PHEV	concept					N/A	
	Prius Plug-in	PHEV	in production (MY2014)	11/540*	4.4	Primearth EV Energy (JV between Panasonic and Toyota)	95 / 50	$29,990	26,688
	RAV4 (2nd gen with Tesla)	BEV	in production (MY2013)	103*	37	Tesla Motors	76	$49,800	1,361
Velozzi	SOLO (crossover)	E-REV	TBD	200				TBD	
	Supercar	E-REV	in production (low volume)	200				upon request	
VIA Motors	Vtrux (truck, SUV, and cargo van)	E-REV	in production	40 / 300	24	A123 Systems		$79,000	
Volkswagen	CrossBlue (crossover)	PHEV	concept	13 / 570	9.8			N/A	
	E-Bugster	PHEV	concept	110	28.3			N/A	
	e-Golf	BEV	4th quarter, 2014	118	24.2	Volkswagen (in house)			
	Golf GTE	PHEV	first markets in autumn 2014	31 / ~580	8.8				
	Passat	PHEV	TBD						
Volvo	V60 Diesel	PHEV	2014	32	12				
	XC90	PHEV	concept	35				N/A	
Wheego	LiFe	BEV	in production	100	30			$32,995	

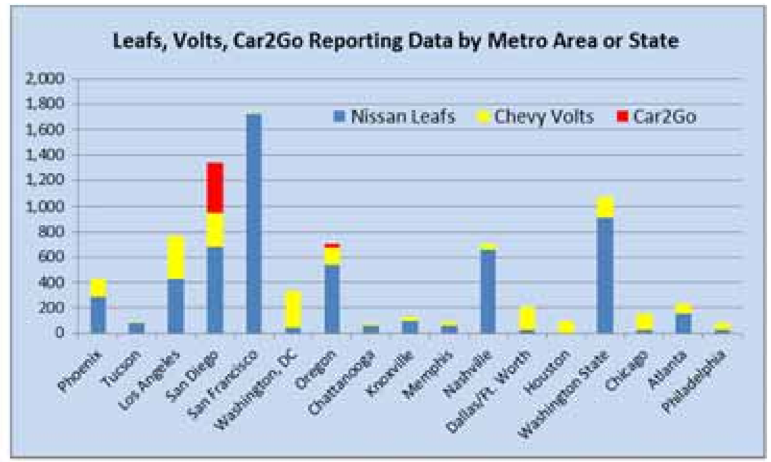
The U.S PEV production document was created for informational purposes only, using publicly available resources. It is not guaranteed to be 100% accurate,

EV Project Vehicle and Charging Profiles

EV Project Deployments

- **EVSE**
  - **8,251 Residential Level 2 EVSE**
  - **4,005 Public Level 2 EVSE**
  - **107 DCFC (DC Fast Chargers)**
  - **12,363 Total EVSE & DCFC**
- **Vehicles**
  - **5,788 Nissan Leafs**
  - **2024 Chevy Volts**
  - **416 Car2Go**
  - **8,228 Total vehicles**





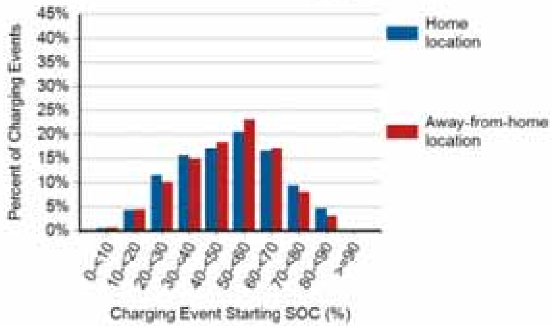
Vehicle Profiles *(4th quarter 2013 data)*

	Leafs	Volts
• Number of vehicles	*3,499*	*1,611*
• Number of Trips	*781,062*	*559,680*
• Distance (million miles)	*5.3*	*4.7*
• Average (Ave) trip distance	*6.7 mi*	*8.2 mi*
• Ave distance per day	*26.7 mi*	*39.8 mi*
• Ave number (#) trips between charging events	*3.6*	*3.3*
• Ave distance between charging events	*23.9 mi*	*27.2 mi*
• Ave # charging events per day	*1.1*	*1.5*

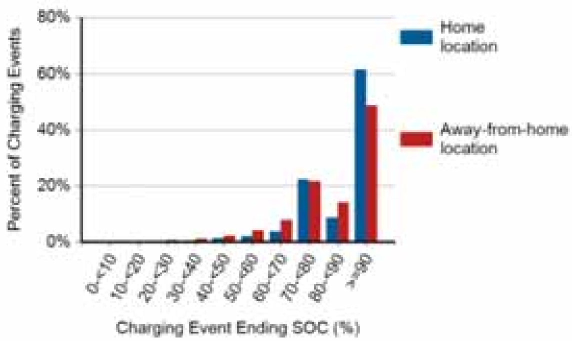
Vehicle Charging *(4th quarter 2013 data)*

Leafs

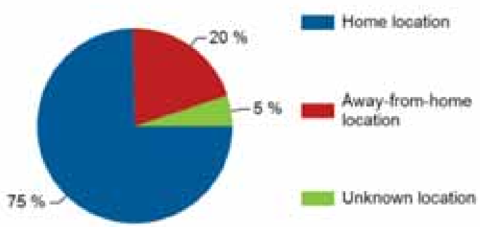
Battery State of Charge (SOC)
at the Start of Charging Events



Battery State of Charge (SOC)
at the End of Charging Events

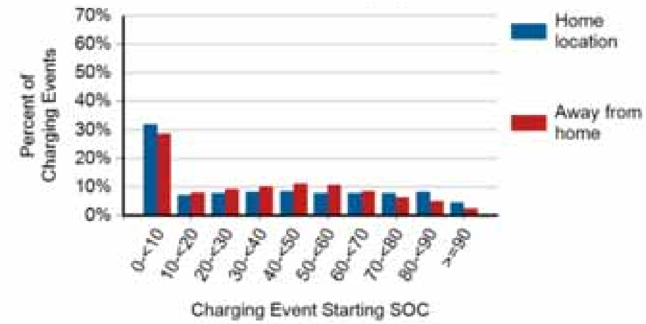


Frequency of Charging by
Charging Location



Volts

Battery State of Charge (SOC)
at the Start of Charging Events



Battery State of Charge (SOC)
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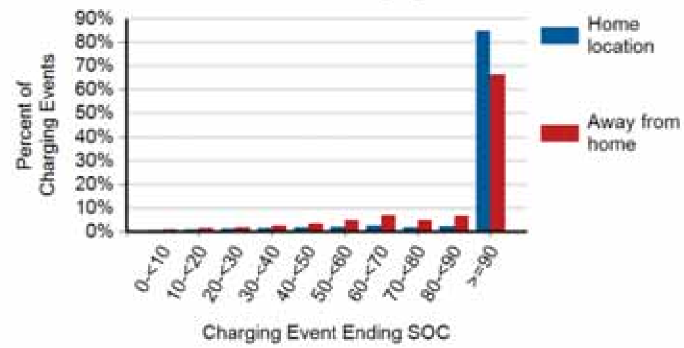
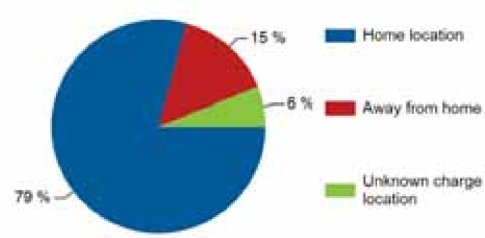


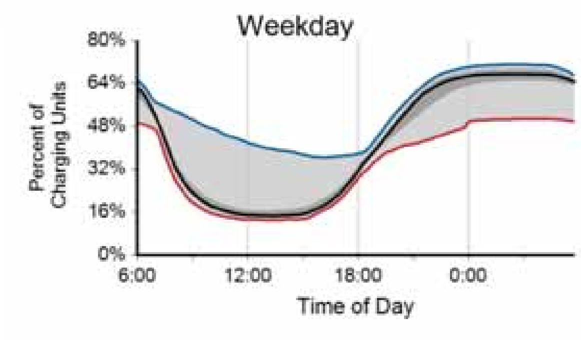
Frequency of Charging by Charging
Location and Type



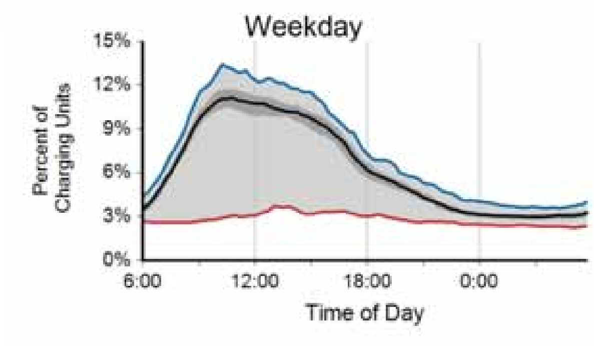
Level 2 EVSE Use *(4th quarter 2013 data)*

- **Residential and public connect time and energy use are fairly opposite profiles. Weekday data**

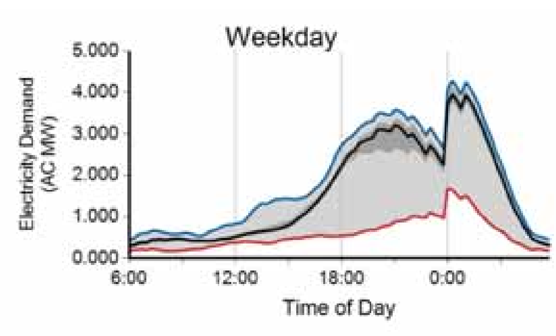
National Residential Connect Time



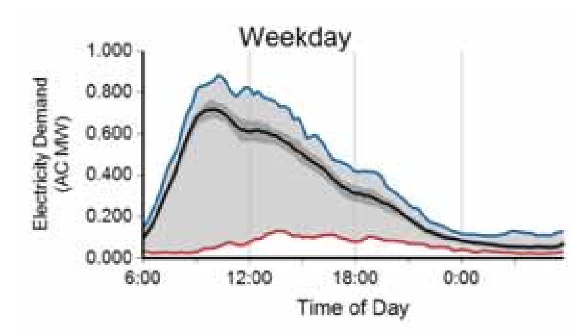
National Public Connect Time



National Residential Demand



National Public Demand

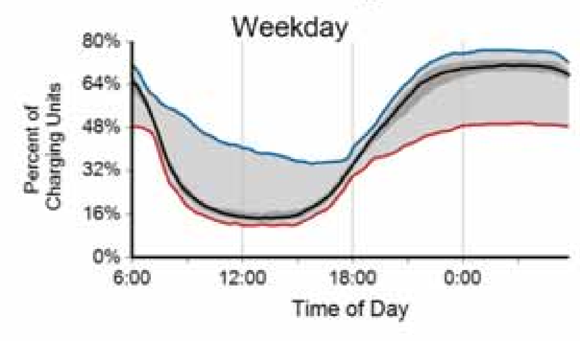


Legend: 92 day reporting quarter. Data is max (blue line), mean (black line) and minimum (red line), for the reporting period. Dark gray shaded is plus and minus 25% quartile.

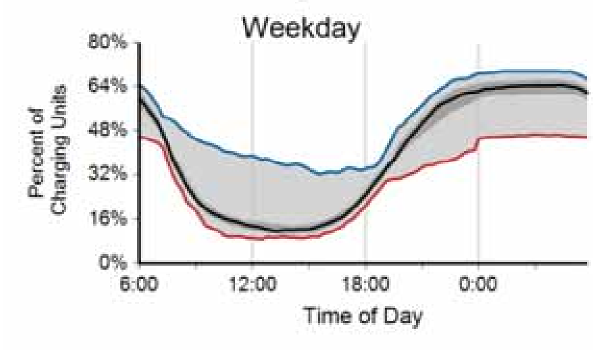
Residential Level 2 EVSE Connect *(4th quarter 2013)*

- **San Diego and San Francisco, with Residential L2 Time-of-Use (TOUI) rates, are similar to other regional EVSE connect profiles. Weekday data**

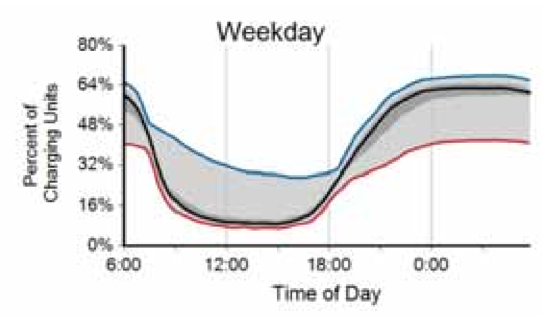
San Diego



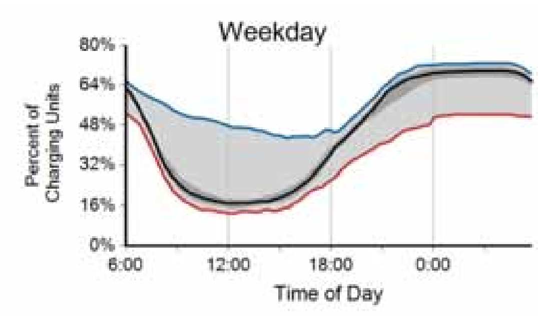
Los Angeles



San Francisco



Washington State

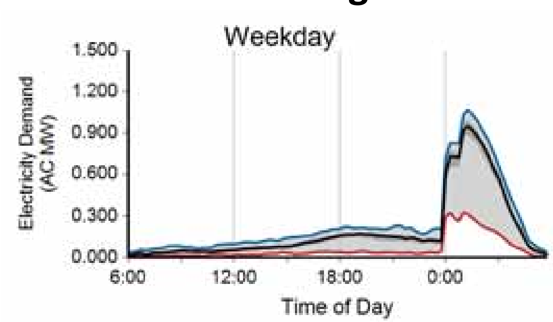


Legend: 92 day reporting quarter. Data is max (blue line), mean (black line) and minimum (red line), for the reporting period. Dark gray shaded is plus and minus 25% quartile.

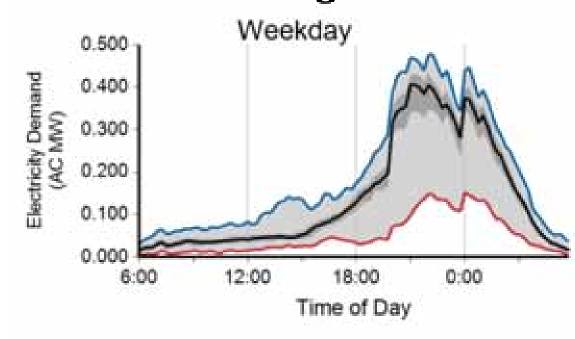
Residential Level 2 EVSE Connect (4th quarter 2013

- **Time of use rates in San Diego and San Francisco clearly impact when vehicle charging times are set. Weekly data**

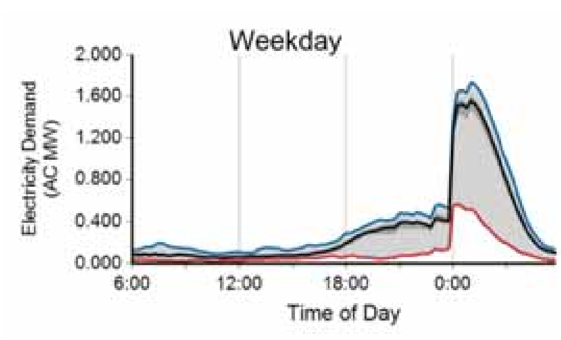
San Diego



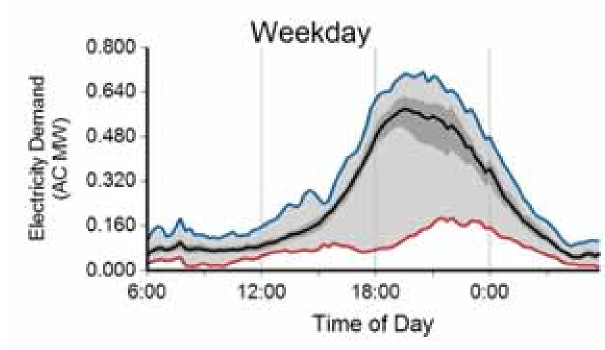
Los Angeles



San Francisco



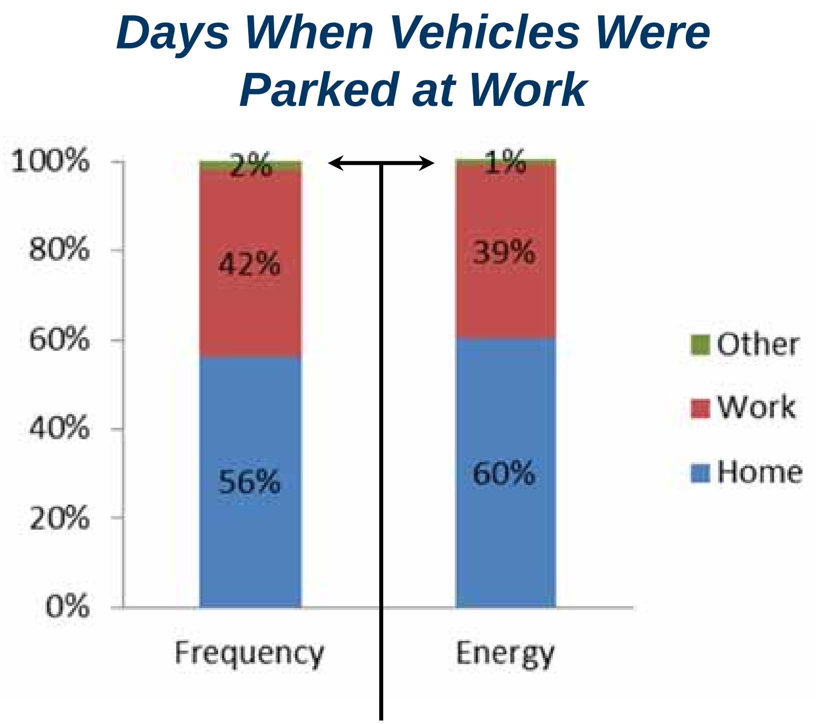
Washington State

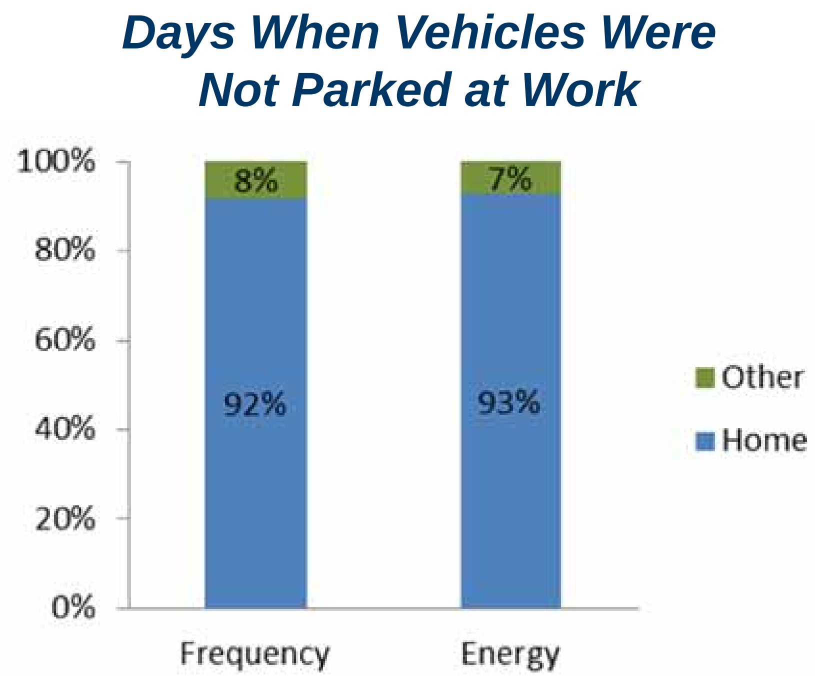


Legend: 92 day reporting quarter. Data is max (blue line), mean (black line) and minimum (red line), for the reporting period. Dark gray shaded is plus and minus 25% quartile.

Accomplishments - Charging Location Preference for Nissan Leaf drivers

Group of 707 Nissan Leafs with Access to Workplace Charging 2012 – 2013



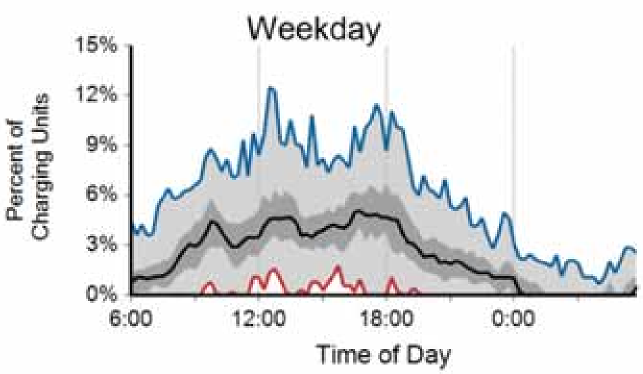


In aggregate, workplace vehicle drivers had little use for public infrastructure on days when they went to work

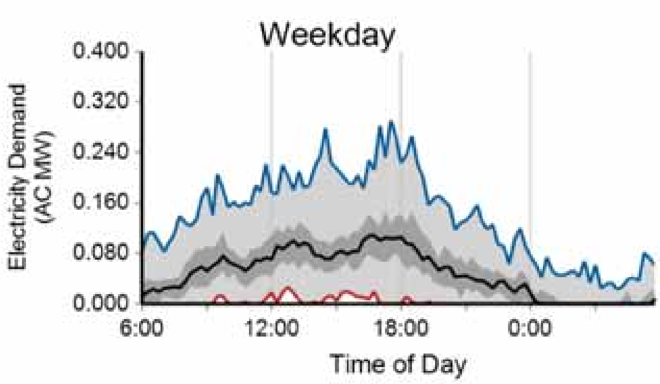
DC Fast Charger (DCFC) Use

- 4th quarter 2013, DCFC weekday use profiles
- 95 DCFC, 11,704 charge events, & 109 AC MWh

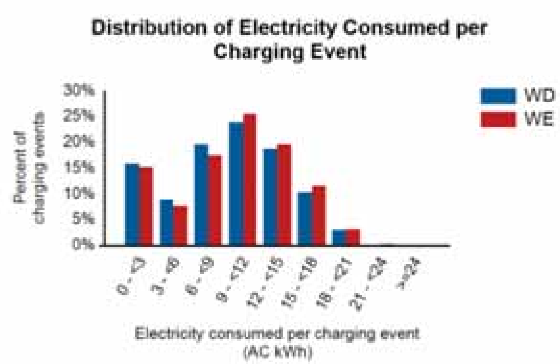
Weekday Connected Profile

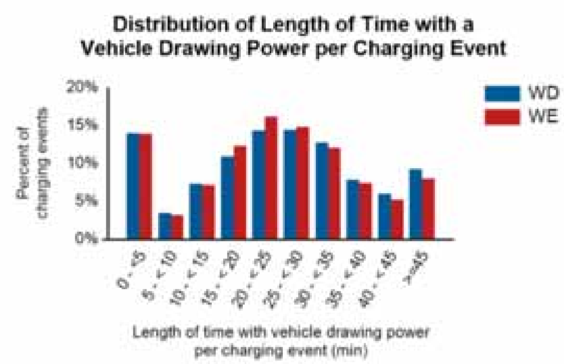


Weekday Demand Profile

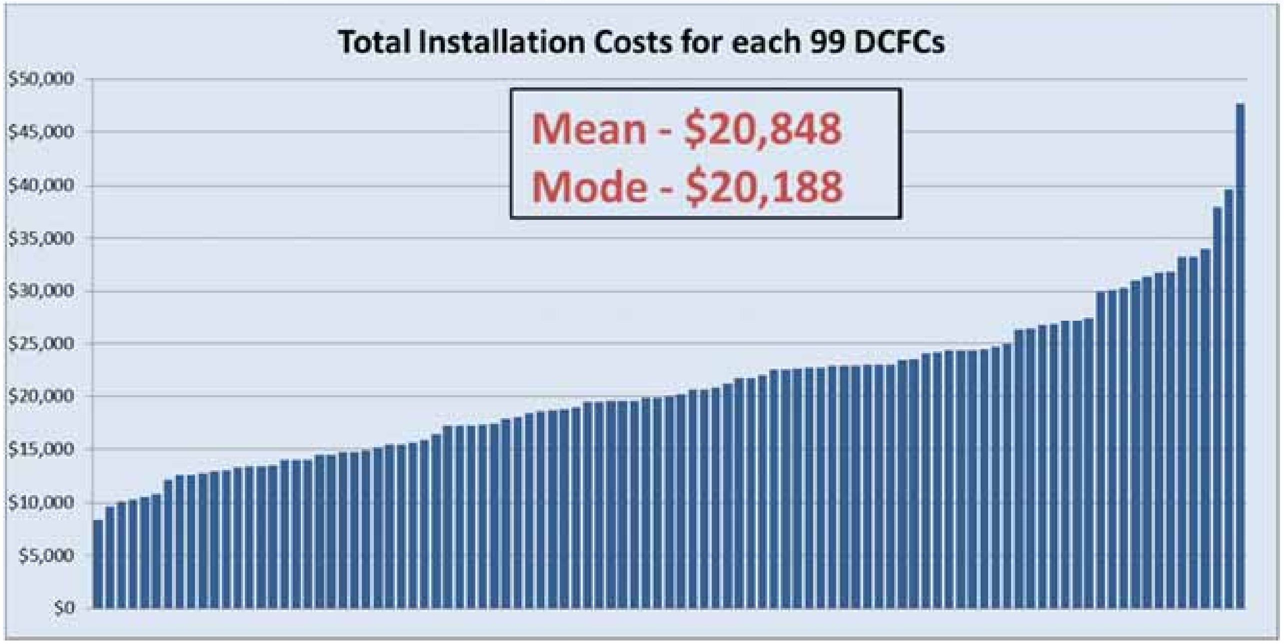


- EV Project Leafs 18% charge events and 16% energy used
- 1.3 average charge events per day per DCFC
- 24.6 minutes average time connected
- 24.6 minutes average time drawing energy
- 9.3 kWh average energy consumed per charge





DCFC Infrastructure Install & Demand Costs



	Utility Demand Charges - Nissan Leaf	Cost/mo.
CA	Glendale Water and Power	$ 16.00
	Hercules Municipal Utility:	$ 377.00
	Los Angeles Department of Water and Power	$ 700.00
	Burbank Water and Power	$ 1,052.00
	San Diego Gas and Electric	$ 1,061.00
	Southern California Edison	$ 1,460.00
AZ	TRICO Electric Cooperative	$ 180.00
	The Salt River Project	$ 210.50
	Arizona Public Service	$ 483.75
OR	Pacificorp	$ 213.00
WA	Seattle City Light	$ 61.00

- **DCFC installation costs do not include DCFC hardware costs**

Nissan Leaf – Onroad DCFC & Level 2 Charging Results

Advanced Vehicle Testing Activity

DC Fast Charge Effects on Battery Life and Performance Study – 50,000 Mile Update

Four model year 2012 Nissan Leaf battery electric vehicles were instrumented with data loggers and are being operated over a fixed on-road test cycle. Each vehicle is charged twice daily, with two vehicles charged at AC Level 2 (L2), and two DC fast charged (DCFC) with a 50kW charger. The traction battery packs are removed and tested when the vehicles were new, and at 10,000 mile intervals. Battery tests include constant current discharge capacity, electric vehicle power characterization, and low peak power tests[1]. The testing will continue to at least 50,000 miles at which point the battery testing results will determine if testing continues in additional 10,000 mile increments. This fact sheet summarizes the measured changes in capacity at 10,20,30,40, and 50 thousand miles relative to baseline test results.

	1011 L2	4582 L2	2183 DCFC	2078 DCFC
Baseline (New)	23.31	23.59	23.38	23.24
10,000 Miles	21.75	22.3	21.97	21.93
20,000 Miles	21.53	21.51	21.64	21.07
30,000 Miles	19.99	20.2	19.42	19.33
40,000 Miles	18.10	18.34	17.53	17.37
50,000 Miles	17.51	17.77	16.94	16.92

Table 1 - C_3 Energy capacity[2] (kWh)

		1011 L2	4582 L2	2183 DCFC	2078 DCFC
0-10k Miles	(Oct-Jan)	28.6	28.6	32.7	32.5
10-20k Miles	(Jan-Mar)	22.7	22.5	27.6	27.3
20-30k Miles	(Apr-Jul)	35.7	36.0	39.8	39.5
30-40k Miles	(Jul-Oct)	38.2	38.4	40.8	40.6
40-50k Miles	(Oct-Mar)	23.2	23.6	27.3	26.8

Table 2 – Average pack temperature during all charging through mileage accumulation interval (°C)

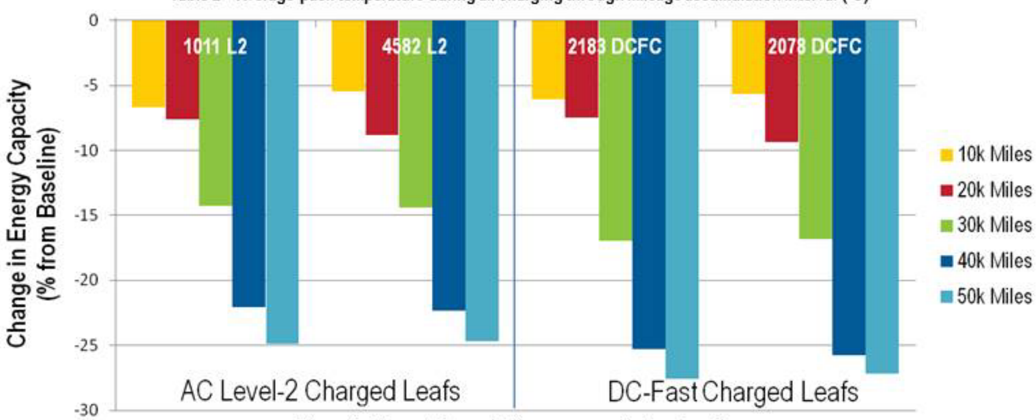


Figure 1 – Percent change in C_3 energy capacity from baseline

1. Capacity and Peak Power tests based on tests from USABC Electric Vehicle Battery Test Procedures Manual Revision 2. Electric Vehicle Power Characterization test adapted from the *Hybrid Pulse Power Characterization Test* from the FreedomCAR Battery Test Manual for Power-Assist Hybrid Electric Vehicles.
2. C_3 capacity reported is the mean value of 3 tests performed sequentially.

Intertek

4/15/2014
INL/MIS-13-29877

Commercial EVSE Level 2 Installation Costs

- Nationally, commercially sited Level 2 EVSE averaged $4,000 for the installation costs. EVSE cost excluded
- There is much variability by region and by installation
- Multiple EVSE at one site drive down per EVSE install cost
- Tennessee and Arizona have average installation costs of $2,000 to $2,500
- Costs driven by poor sitting requests
  – Example: mayor may want EVSE by front door of city hall, but electric service panel is located at the back of the building

Region	Count of Permits	Average Permit Fee	Minimum Permit Fee	Maximum Permit Fee
Arizona	72	$228	$35	$542
Los Angeles	17	$195	$67	$650
San Diego	17	$361	$44	$821
Texas	47	$150	$37	$775
Tennessee	159	$71	$19	$216
Oregon	102	$112	$14	$291
Washington	33	$189	$57	$590

Residential EVSE Level 2 Installation Costs

- **Nationally, 4,466 residential sited Level 2 EVSE averaged $1,300 for the installation costs. EVSE cost excluded**
- **Max $8,429, min $250, mean $1,414, medium $1,265**

- **High cost drivers**
  - **Replacing residential electrical service ($8,429) or not installing near the service panel**
  - **Desire to site away from the house**
  - **Cutting concrete or asphalt driveway, or other surfaces**
- **Low cost drivers**
  - **Existing 240 V outlet in the garage ($250)**
  - **Simple addition of a breaker and minimal conduit run**
  - **Space in the garage**

Couple of Slides on Safety and First Responders

Third Party Conversion of a HEV to a PHEV

Third Party Conversion of a HEV to a PHEV

PEVs Are Not Unique When it Comes to Vehicle Based Thermal Anomalies

- **According to the NFPA, between 1980 and 1982, there was an average of approximately 447,000 highway vehicle fires per year; between 2009 and 2011, there was an average of approximately 187,500 highway vehicle fires per year (http://avt.inel.gov/pdf/energystorage/FinalReportNFPA.pdf)**

Port of Newark, Sandy event
Impact of salt water flooding

Thermal Events Lessons Learned

- **Unintended battery discharging and resulting thermal events have not occurred in any production vehicle the AVTA has tested during 144 million test miles, with 11,700 electric drive vehicles**
- **Full battery thermal events can be suppressed or "finished" by:**
  - **Disassembling the pack (thus discharging) and applying water to the cool the pack to avoid in-pack and in-vehicle combustible materials from burning**
  - **Allowing the event to continue unsuppressed and ensuring personnel and facility safety. Will ultimately result in all combustible materials burned and vehicle destroyed (but the fire will be out!!!!)**
  - **Using trained electrical safety worker to discharge the pack while applying cooling water it to stop combustible materials from burning (INL's most recent experience)**
    - **However, this should only be undertaken by electric safety trained workers with large battery pack safety and equipment experience**
    - **Hours or days when the vehicle may not be in a safe location**

Thermal Events Lessons Learned

- The need for first responder training was recognized by U.S. DOE, U.S. DOT (NHTSA), and National Fire Protection Association (NFPA). DOE, DOT, NFPA, and INL developed a vehicle fire suppression lessons-learned program
  - OEMs, through the Alliance of Automobile Manufacturers, participated and contributed vehicle-sized lithium ion battery packs
  - Packs were used to demonstrate suppressed outcomes via the NFPA fire trainer vehicle
  - Target audience was first responders
  - Film is part of the education and training materials

NFPA Project - Goal

- Identify full-scale heat release rate (HRR) and fire suppression testing of PEVs with large format Li-ion batteries
- In particular, members of the emergency response community had questions regarding
  - Appropriate PPE to be used for responding to PEV fires
  - Tactics for suppression of fires involving PEV batteries
  - Best practices for tactics and PPE to be used during overhaul and post-fire clean-up operations
- One, laboratory test was conducted to determine HRR
- Six, full-scale fire suppression tests were conducted to collect data and evaluate any differences associated with PEV fires as compared to traditional ICE vehicle fires
  - Three of the Battery "A", 4.4 kWh lithium ion battery pack
  - Three of the Battery "B", 16 kWh lithium ion battery pack

NFPA HRR Test

- ***The objective of the HRR testing was to determine the amount of energy released from the battery alone when it was ignited by an external ignition source***
- ***Secondary testing objective was to verify the battery could be induced into thermal runaway with the external ignition source (propane fueled burners positioned beneath the battery) for use during the full-scale fire suppression tests and to collect data as to the indications that the battery was experiencing thermal runaway***
- ***Based on a review of NFPA data on vehicle fire risk, flammable or combustible liquids or gases were the first item ignited in 31% of U.S. highway vehicle fires, resulting in 70% of civilian deaths, 58% of civilian injuries, and 31% of the direct property damage. As such, a pool fire scenario under the PEV was selected as the likely ignition scenario where the batteries become near fully involved and "burning on their own."***
  (http://avt.inel.gov/pdf/energystorage/FinalReportNFPA.pdf)

NFPA PEV Fire Suppression Project

Figure 72 Off gassing of Battery A3 approximately 22 hours after the conclusion of the test

- ***22 hours after testing – self reignition***
- ***At the conclusion of testing, an OEM's procedure for soaking PEV batteries in a salt bath were followed before shipping the six damaged battery packs. This method requires a minimum of 24 hours of submersion***

NFPA - Best Practices

A small sample of findings are listed below

- **Use standard vehicle firefighting equipment and tactics in accordance with department SOPs/SOGs**
- **All personnel should wear and utilize full PPE and SCBA as required at all vehicle fires**
- **Use water or other standard agents for PEV fires**
- **The use of water does not present an electrical hazard to firefighting personnel**
- **If a PEV battery catches fire, it will require a large, sustained volume of water**
  - **Battery A required 275 to 1,060 gallons**
  - **Battery B required 1,165 to 2,639 gallons**
- **If a Lithium Ion (Li-Ion) HV battery is involved in a fire, there is a possibility that it could reignite after extinguishment. If available, use thermal imaging to monitor the battery. Do not store a vehicle containing a damaged or burned Li-Ion HV battery in or within 50 feet of a structure or other vehicle until the battery can be discharged**

NFPA Report

- *NFPA Final Report and Appendices*
  - *http://avt.inel.gov/energystoragetesting.shtml*
- *NFPA Final Report only*
  - *http://avt.inel.gov/pdf/energystorage/FinalReportNFPA.pdf*
- *NFPA Appendix A*
  - *http://avt.inel.gov/pdf/energystorage/AppendixBthruE1NFPA.pdf*
- *NFPA Appendix B*
  - *http://avt.inel.gov/pdf/energystorage/AppendixBthruE1NFPA.pdf*

The Other Blue Football Field

The Other Blue Turf - Barrow, Alaska High School Football – Home of the "Whalers"

Arctic Ocean in the Background *(08/01/10)*

Additional Questions?