Electrical Vehicle Charging

Alternative Energy Technologies and Electrical Safety Standards

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Project Background

In 2010, NFPA and SAE held a joint Summit on the safety aspects of the widespread introduction of electric vehicles to the marketplace. A critical outcome of that Summit was the identification of the need to assess the implications of electric vehicle charging for NFPA electrical safety codes and standards and to communicate that to the inspection community and other audiences.

NFPA technical committees are currently addressing these impacts and will benefit from additional information from the EV community on emerging technologies which may impact safety.

Project Tasks

1. Technology Review and Safety Assessment: Working with the automotive industry and battery and battery charging technology companies, assess the current and emerging charging station technical specifications (Level 2 and 3 charging) to determine the implications for electrical infrastructure including wiring, overcurrent protection, load management, etc.
2. Standards Review and Gap Assessment: using the outcome from Task 1, the NFPA standards identified above will be reviewed in the context of these safety impacts and a straw-man assessment of gaps and inconsistencies will be prepared.
3. Workshop Presentation: The contractor will present interim findings to the NEC EV task force and other stakeholders at a ½ day meeting at an east coast location. The strawman will then be revised based on this input.
4. Report of all Tasks: A final report of all tasks will be prepared and a presentation made at the NFPA/SAE Electric Vehicle Summit in Detroit.

Project Technical Panel

Panel Members

Gery Kissel	General Motors Corporation
John Kovacik	Underwriters Laboratories
Alan Manche	Schneider Electric
Gil Moniz	NEMA
Frank Tse	Leviton
Mark Earley	NFPA Staff Liaison

Growth of US Electric Vehicle Charging Stations

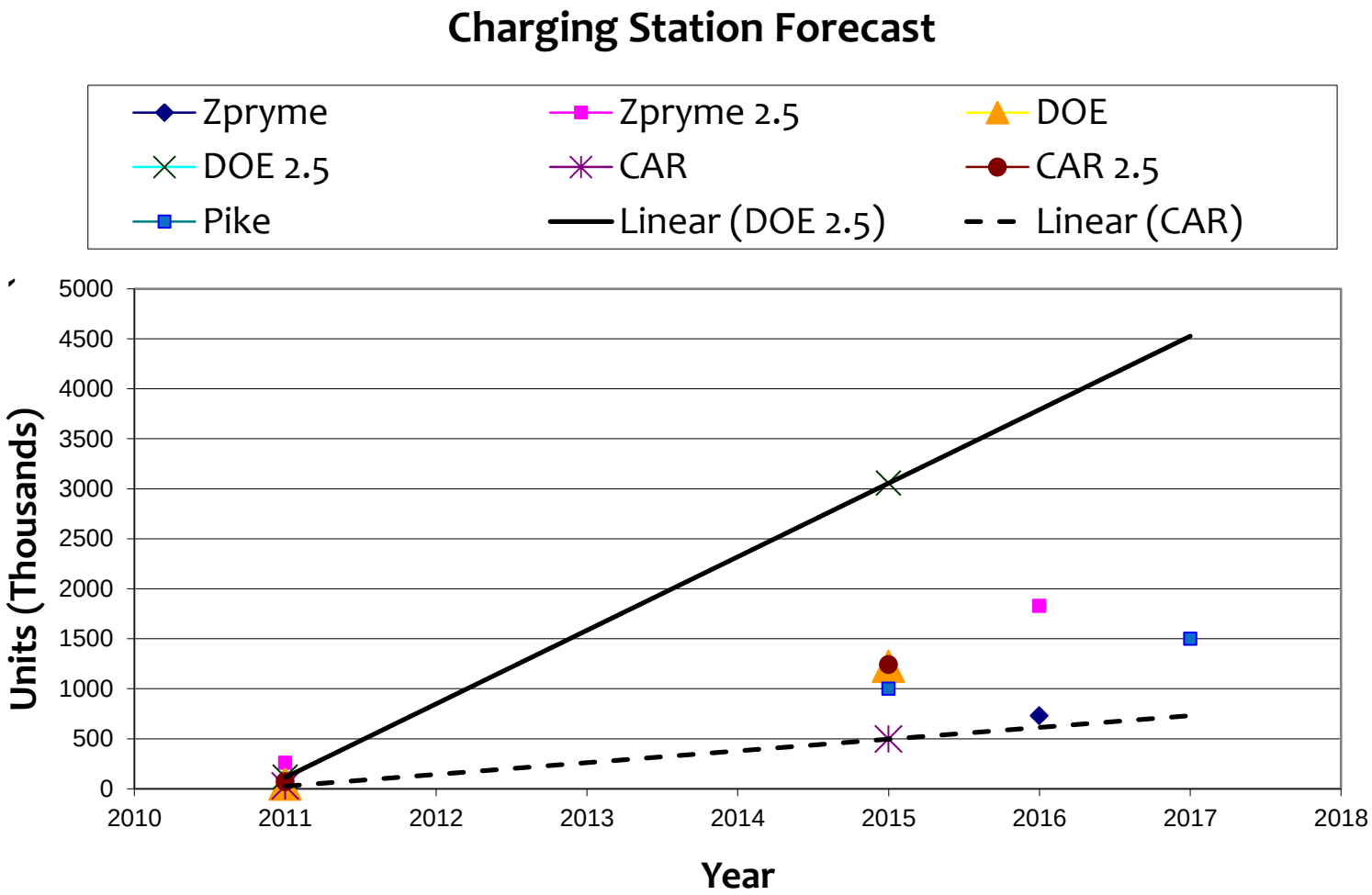
Projections for the amount of growth of US Charging Stations varies widely, as do the forecasting entities:

- US Department of Energy's (DOE) Alternative Fuels and Advanced Vehicles Data Center (AFDC) website has data DOEs National Renewable Energy Laboratory (NREL)
- Zpryme is an independent research and consulting firm which provides market research in developing industries
- The Center for Automotive Research (CAR) is a nonprofit organization focused on trends and changes related to the automobile industry
- Pike Research is a market research and consulting firm that provides analysis of global clean technology markets

Growth of US Electric Vehicle Charging Stations

- Using data from these sources, along with their projections for the total amount of charging stations, yields a range of 1.04 to 2.52 Plug-in Electric Vehicles (PEVs) per station based on the Pike Research estimate of total charging locations
- This range is validated by Accenture, a global management consulting, technology services and outsourcing company, which projects 2 stations per vehicle at full deployment
- Using the number of cars from each organization as a base, and then multiplying this by 2.5 charging stations per vehicle establishes an upper boundary for the number of charging stations
- The Pike Research data is used without modification

Growth of US Electric Vehicle Charging Stations



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Characteristics of PHEVs, EREVs, and BEVs[1]

Plug-in hybrid electric vehicle (PHEV)	Extended range electric vehicle (EREV)	Battery electric vehicle (BEV)

Wheels powered by	Gasoline engine and/or electric motor	Electric motor	Electric motor
In-car electricity source	Battery	Battery and/or generator	Battery

1 http://www.goelectricdrive.com

Manufacturer Release of PEVs and PHEVs[1]

Manufacturer/Model	Year				
	2010	2011	2012	2013	2016
Plug-in Electric Vehicles (PEV)					
• Mitsubishi i	X				
• Nissan LEAF	X				
• Ford TRANSIT connect electric	X				
• Tesla Motors Roadster Sport 2.5	X				
• Zero Motorcycles Zero S	X				
• Brammo Enertia	X				
• TH!NK City		X			
• Coda Automotive Sedan		X			
• Tesla Motors Model S		X			
• Ford Focus electric		X			
• BMW ActiveE		X			
• Fiat 500 minicar			X		
• Audi e-tron			X		
• Honda Fit EV			X		
• Audi R8 EV			X		
• Mercedes SLS E-Cell AMG				X	
• Volkswagen Golf Blue-e-motion				X	
• BMW i3				X	
• Tesla Motors EV					X

Manufacturer Release of PEVs and PHEVs[1]

Manufacturer/Model	Year				
	2010	2011	2012	2013	2016
Plug-in Hybrid Electric Vehicles (PHEV)					
• Chevy Volt Extended Range EV	X				
• Toyota Plug-in Hybrid	X				
• BYD F3DM Plug-in Hybrid		X			
• Toyota Prius Plug-in Hybrid			X		
• Bright Automotive IDEA Plug-in Hybrid			X		
• Ford Escape Plug-in Hybrid			X		
• Ford C-MAX Energi			X		
• BMW Vision				X	
• BMW i8					X
• Cadillac Converj					X

1 http://www.electricdrive.org

Potential NEC Impact of Charging Stations

- Battery meter (for charging rate and voltage) installation requirements
- Meters for power consumption
- Protection against overcharging energy storage systems to prevent failures
- Charging and discharging of PHEVs, PEVs, and other on-site energy storage systems
- Energy management systems
- Cord and Plug connection of the supply equipment (not the car connection) – should there be a limit on the amperage (50A, 100A, etc.)
- EV Ready building infrastructure for a charging station (including conduit/wiring from the electrical panelboard to the charging location); this may include a larger branch circuit capacity to support Level 2 charging
- Maintenance that must be done for public charging stations to keep them safe
- Worker and public safety during charging/discharging (whether at home, work, or a public charging station) could be an active smart grid component through Demand Response; requiring some form of public indication

Potential NEC Impact of Vehicle-to-Grid Distribution

Charging and discharging of Vehicle-to-Grid storage systems

Cord and plug connection between the utility and the EVSE (i.e., the male end of the plug would be hot)

Public and electrical worker safety when working on other parts of the electrical system

Placement of appropriate isolation switches in the system to ensure safety

Current Industry Specifications

Lvl	Standard				
	EPRI	SAE (AC)	SAE (DC)	IEC	CHAdeMO
1	120 VAC, 12A or 16A	120V single phase, Configuration current 12A≥16A Configuration power 1.44≥1.92 kW	200-450 V Rated current ≤ 80A Rated power ≤ 36 kW	4 charging "modes" with VAC up to 690V and VDC up to 1,000V	VDC up to 500V and 125A
2	240VAC, 40A	240V single phase Rated current ≤ 80A Rated power ≤ 19.2 kW	200-450 V Rated current ≤ 200A Rated power ≤ 90 kW		
3	480 VAC	Not Finalized*	Not Finalized**		

* > 20 kW, single phase and 3 phase proposed

** the current standard has the potential for 200-600 VDC at a maximum of 400 amps and 240 kW

Summary of PEV Vehicle Specifications

Vehicle	**Type**	**Battery Capacity**	**Charge Power (max rated capacity / stated charge time)**	**Charge Time**	**Range**
Zero S	Motorcycle	4.4kWhr	(1.9) kW	2.3 hrs	43 mi
Leaf	Sedan	24kWhr	3.3 to 6.6 (3 to 6.8) kW	3.5to 8hrs	62 to 138 mi
Transit Connect EV	Van	28kWhr	(3.5 to 4.7) kW	6 to 8 hrs	50 to 80 mi
Tesla	Sports Car	56kWhr	(16)kW	3.5 hrs	245 mi

Summary of PHEV Vehicle Specifications

Vehicle	Type	Battery Capacity (useable)	Charge Power [max rated capacity / stated charge time] (based on useable)	Charge Time (AC Level 1)	Total Range per Tank (Electric Only) [EPA]
Volt	Sedan	16 (10.4) kWhr	3.3 [4 (2.6)] kW	4 hrs	375 ([35]) mi
Prius	Sedan	5.2 (3.8) kWhr	[3.47 (2.53)] kW	1.5 hrs	475 (14) mi
F3DM[1,2]	Sedan	16kWhr	[2] kW	(8) hrs	360 (40-60) mi

[1] http://www.nytimes.com/2011/02/20/automobiles/autoreviews/byd-f3-dm-review.html?pagewanted=1&_r=1

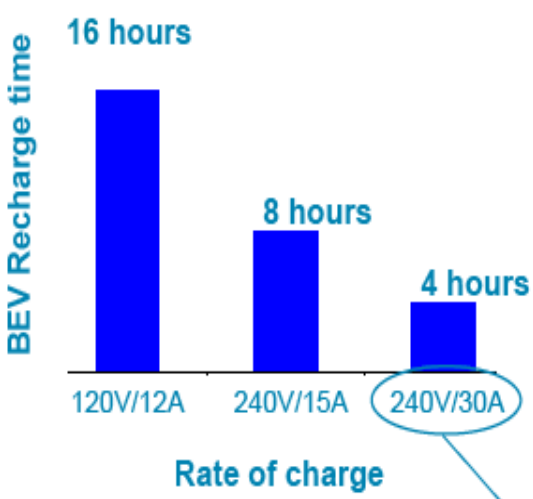
[2] http://en.wikipedia.org/wiki/BYD_F3DM

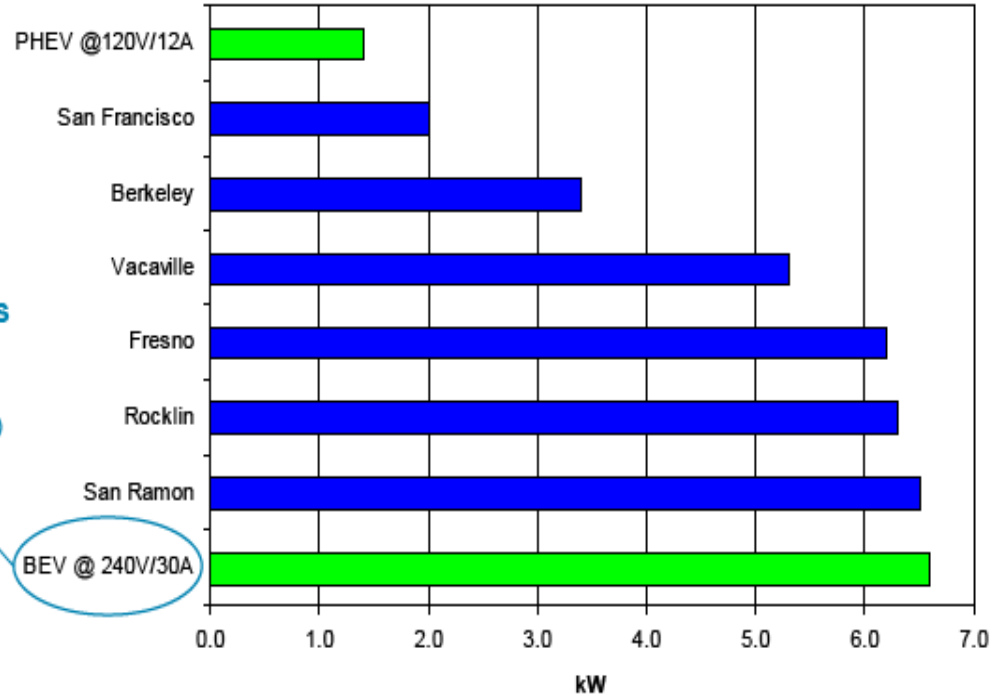
Comparison of PEV Registration in Two Locations

Location	Amount of New Registrations	Amount of PEV Registrations	Percentage of PEV to new registrations	Median amount of PEV registrations within Zip Code
Fresno, CA	83,000	2,000	2.4%	11
Berkeley, CA	14,000	2,500	18%	212

PEV Charging and Increase in Electrical Load for PG&E Customers[1]

Customers will prefer a 240V charge to shorten recharge times → **PEV charging at 240V is a large load for PG&E customers, comparable to average peak summer load of a single home**

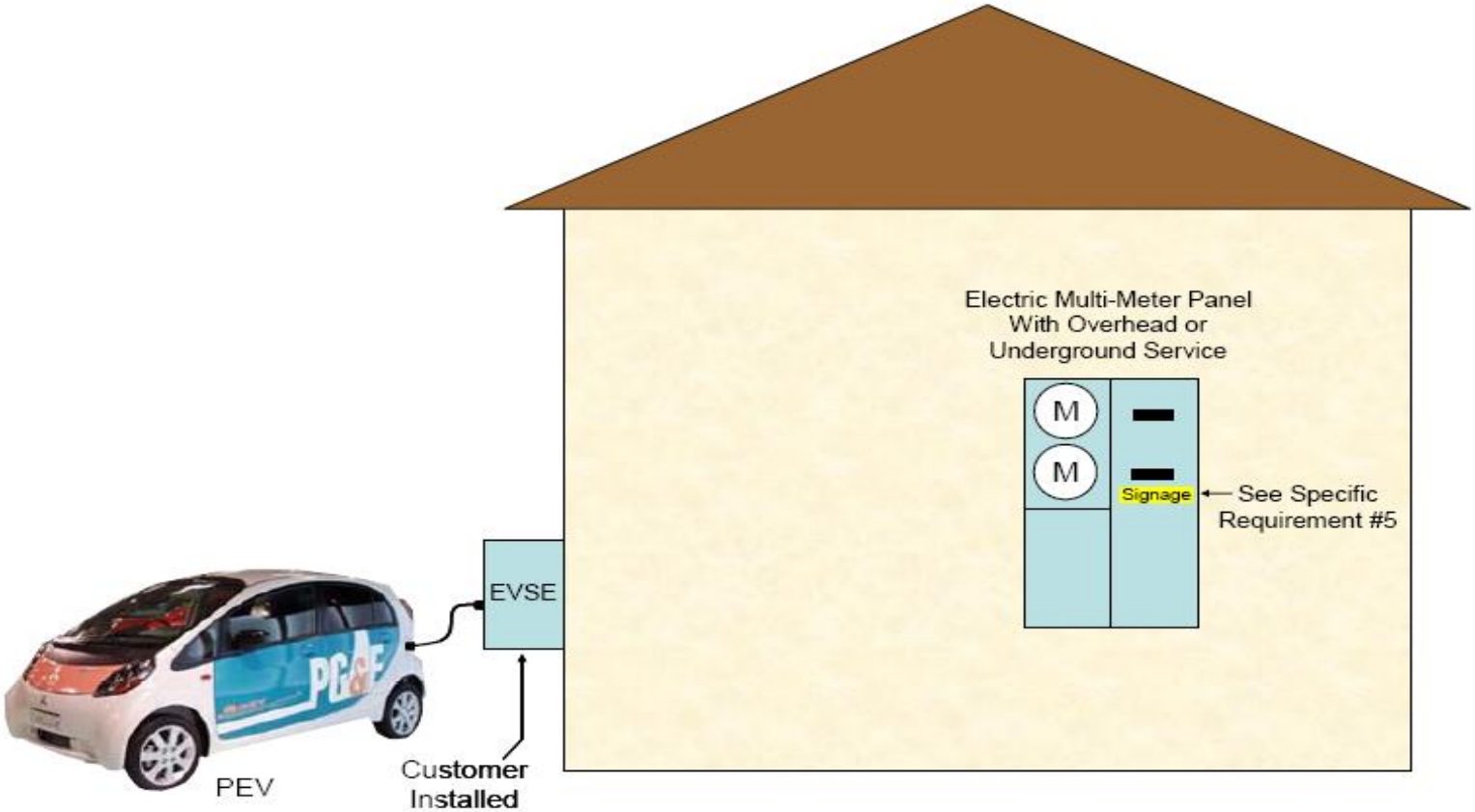




1 http://www.electricdrive.org

Residential Single Meter Option

Residential: E-9B Time Of Use (TOU) rate
Multi-Meter Panel option for House and Electric Vehicle Load.



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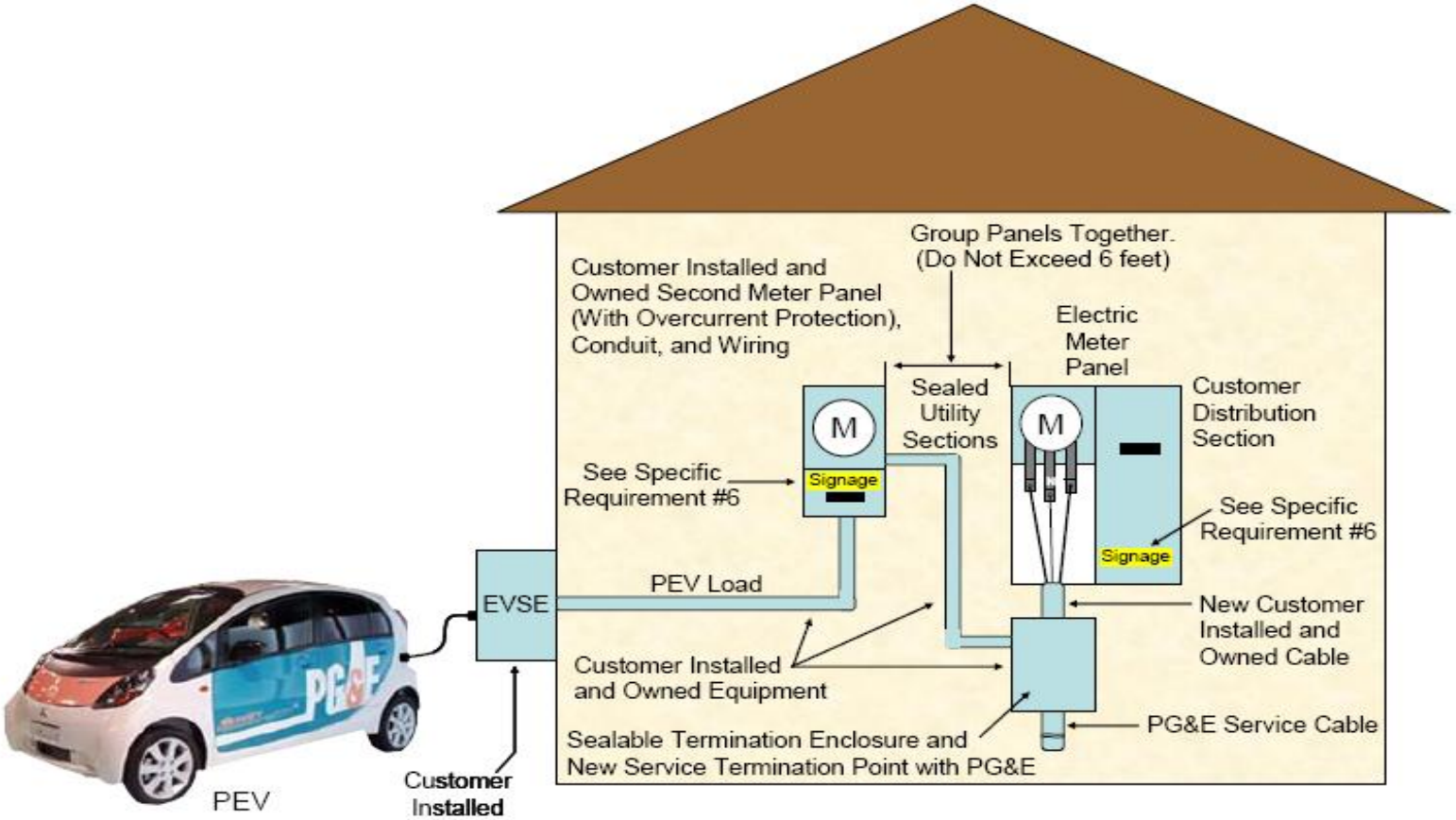
Residential Two Meter Option

Residential: E-9B Time Of Use (TOU) rate
Second-Meter Panel Option Connected to Existing Meter Panel; Underground Service



Effect of Increased Deployment of PEVs & PHEVs

The geographical clustering of charging stations, charging voltage/duration preferences, single versus multiple EV charging, and rate structure/metering options collectively result in the potential for a wide range of implications for electrical infrastructure wiring, overcurrent protection, and load management

Hopefully, clarity will develop as battery technology improves, utility costs are determined, and customer desires become more defined

Impact of Increased Deployment of PEVs & PHEVs

- Dramatic increase in load relative to typical residential usage
- Dramatic increase in load relative to typical commercial usage in some cases, such as where charging is offered to customers and/or employees
- Infrastructure upgrades necessitated by geographic grouping of PEVs & PHEVs
- Increased communication wiring, especially if two-way power exchange becomes common
- Interface between charging stations and smart meters or EMS
- Revised venting requirements due to different battery chemistries
- Overcurrent protection
- Load management
- Harmonics induced by charging stations
- Voltage flicker due to charging station load
- DC charging installations, especially where DC generation or storage, such as where Photovoltaic Cells (PV) are present

Specific NFPA Articles Which May Be Affected

- NFPA 70 articles include:
  - Article 210 Branch Circuits
  - Article 215 Feeders
  - Article 220 Branch Circuit, Feeder, and Service Calculations
  - Article 230 Services
  - Article 240 Overcurrent Protection
  - Article 250 Grounding and Bonding
  - Article 625 Electric Vehicle Charging Stations

- NFPA 70E articles include:
  - Article 120 Establishing an Electrically Safe Work Condition
  - Article 320 Safety Requirements Related to Batteries and Battery Rooms

Identification of Other Standards

- Underwriters Laboratories, Inc. (UL)
  - UL 2202 Standard for Electric Vehicle (EV) Charging System Equipment
  - UL 2231, Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits
  - UL 2251 Standard for Plugs, Receptacles and Couplers for Electric Vehicles
  - UL 2271 Batteries for use in Light Electric Vehicle (LEV) Applications
  - UL 2594 Electric Vehicle Supply Equipment
- The Society of Automotive Engineers (SAE)
  - J1772 – SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler

Research in Support of NFPA Technical Committees

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