FOREWORD

Recent forecasts indicate that almost one million Plug-in Hybrid Electric Vehicle (PHEV) or Plug-in Electric Vehicles (PEV) charge points will need to be installed in the United States by 2015, with approximately one-third of these being non-residential charging units. The National Electrical Code® addresses the safety of the built infrastructure wrt to charging and in 2011 a Task Force was established to explore this issue and its implications for the NEC. This project was undertaken in support of that Task Force.

This report presents the results of a project whose overall goal is to facilitate the safe integration of electric vehicles in the nation’s electrical safety infrastructure. It describes a review of technologies likely to impact electrical safety and presents an assessment of needed changes to codes and standards and a roadmap for needed research on this topic.

The content, opinions and conclusions contained in this report are solely those of the authors.
Electrical Vehicle Charging and NFPA Electrical Safety
Codes and Standards

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Executive Summary

A recent study by Pike Research\(^1\) forecasts that almost one million Plug-in Hybrid Electric Vehicle (PHEV) or Plug-in Electric Vehicles (PEV) charge points will need to be installed in the United States by 2015, with approximately one-third of these being non-residential charging units. According to Zpryme Reports\(^2\), the number of electric vehicle charging stations (with multiple charge points) is expected to grow by 40% annually within the next five years. The growth in charging units is projected to align with charging station level, with AC Level 1 charging stations expected to have the earliest growth, while the growth of DC Level 2 charging stations is expected to occur later in this five-year period.

Based upon the large growth forecast for EVs, the Fire Protection Research Foundation supported this report to assess the implications of electric vehicle charging for NFPA electrical safety codes and standards. As indicated in the Project Summary, the specific tasks of the report are to:

- Assess charging station specifications to determine the implications for electrical infrastructure
- Review NFPA standards and prepare a straw-man assessment of gaps and inconsistencies
- Present interim findings to the NEC EV task force and revise the straw-man based on this input
- Prepare and present a final report of all tasks at the NFPA/SAE Electric Vehicle Summit

Based upon the results of the study to-date, the following areas were identified as affecting safety principles embedded in the NEC and other NFPA standards.

- Dramatic increase in load relative to typical residential and commercial usage (customers and/or employees)
- Infrastructure upgrades necessitated by geographic grouping of PEVs and 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 70 articles which may be affected 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
Project Summary

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.

Scope
This focus of this project is the suite of electrical safety standards for the built environment that are promulgated by the National Fire Protection Association. They include:
- The National Electrical Code®, which contains provisions related to the service interface; electric load in-building data gathering and control; control of onsite generation sources (PV, fuel cells, generators, wind turbines, water turbines, etc.) used in distributed generation schemes
- NFPA 70E, Electrical Safety in the Workplace, which addresses worker safety issues
- Other NFPA safety standards and emergency responder standards which may be impacted.

Project Tasks
1. **Task 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. **Task 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 strawman assessment of gaps and inconsistencies will be prepared.
3. **Task 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. **Task 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.
1.0 Background
A recent study by Pike Research forecasts that almost one million Plug-in Hybrid Electric Vehicle (PHEV) or Plug-in Electric Vehicle (PEV) charge points will need to be installed in the United States by 2015, with approximately one-third of these being non-residential charging units. By comparison, the Electric Vehicle (EV) Charger Maps web site states that as of the end of 2010, California contained less than 400 non-residential charging stations. For convenient reference, a list of all acronyms is included in Appendix B.

According to Zpryme Reports, the number of electric vehicle charging stations (with multiple charge points) is expected to grow by 40% annually within the next five years. Annual new charging service users are projected to grow by 40.4% annually from 2011 to 2016, from 27,600 to 150,400. The growth in charging units is projected to align with charging station level, with AC Level 1 charging stations expected to have the earliest growth, while the growth of DC Level 2 charging stations is expected to occur later in this five-year period. The cumulative total number of charging service users is projected to grow from 39,800 in 2011 to 574,900 in 2016.

Another good resource for the current number of installed charging stations can be found at http://www.afdc.energy.gov/afdc/fuels/stations_counts.html. This is the US Department of Energy’s (DOE) Alternative Fuels and Advanced Vehicles Data Center (AFDC) website. The site counts stations that have AC Level 1 or 2 stations that conform to the NEMA 5-15, NEMA 5-20, or J1772 standards, and exclude residential stations. The data comes from the DOE’s National Renewable Energy Laboratory (NREL). Stations are contacted before they are added to the database initially, and the NREL contacts them once a year thereafter to verify the location is still a valid charging station. As of July 31, 2011, the AFDC reports that there are 3,154 installed stations.

This can be contrasted with the earlier figure of 13,600 installed public stations, as cited in the Zpryme report, to show the wide range of station numbers data. Some of this discrepancy is due to the different criteria by which stations are counted, and more rigorous sites such as ADFC will report fewer stations then a less rigorous, more user-driven site like http://www.evchargernews.com/.

The driver of charging station installations is PEV and PHEV sales, and projection estimates of these vary widely as well. Zpryme estimates 104,200 in 2011 and 730,700 in 2016. The DOE’s One Million Electric Vehicles status report estimates 45,600 EVs in 2011 and 1,222,200 by 2015. Finally, a report by the Center for Automotive Research (CAR) drew upon estimates by JD Power and HIS Global Insight to forecast 27,000 vehicles for 2011 and 496,000 for 2015.

The Pike Research estimates that there will be just fewer than 1 million charging locations in the US by 2015, and 1.5 million by 2017, and that 64% of these will be residential. This can be compared to the Zpryme estimate of 220,700 AC and DC Level 2 stations by 2016, about 57% of which are home-based. The data in the previous two paragraphs can be correlated by dividing the number of vehicles by the number of charging stations, yielding a range of 1.04 to 2.52 PEVs / station based on the Pike Research estimate of total charging locations. A report by Accenture estimates 2 stations per vehicle at full deployment. It is difficult to make this comparison to the AFDC or Zpryme data because they exclude residential and AC Level 1 stations, respectively. Table 1-1 uses the correlation to establish the range
boundaries for the number of charging stations forecast. The number of cars from each estimate is used as a base, and then multiplied by 2.5. The Pike Research data is used without modification.

**Table 1-1: Growth of US Electric Vehicle Charging Stations**

<table>
<thead>
<tr>
<th>Year</th>
<th>Zpryme</th>
<th>Zpryme 2.5</th>
<th>DOE</th>
<th>DOE 2.5</th>
<th>CAR</th>
<th>CAR 2.5</th>
<th>Pike</th>
<th>Linear (DOE 2.5)</th>
<th>Linear (CAR)</th>
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<td>200</td>
<td>200</td>
<td>200</td>
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<td>2013</td>
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<tr>
<td>2015</td>
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<td>375</td>
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<tr>
<td>2018</td>
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<td>400</td>
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</tr>
</tbody>
</table>

**1.1 Introduction**

Plug-in vehicles fall into one of two main categories: PHEVs or PEVs, which are sometimes referred to as Battery Electric Vehicle (BEVs). PEVs / BEVs are all-electric vehicles with no internal combustion engine (ICE). Collectively, all of these are more commonly referred to as Electric Vehicles (EVs). Both categories of electric vehicles differ from fossil fuel-powered vehicles in that they are able to consume electricity which could be generated from a wide range of sources, including fossil fuels, nuclear power, renewable sources (such as tidal, solar, or wind power) or any combination of these.

A plug-in hybrid's all-electric range is designated as PHEV-[miles] or PHEV [kilometers] km in which the number represents the distance the vehicle can travel on battery power alone. For example, a PHEV-20, also designated as a PHEV32km, can travel twenty miles (32 km) without using its combustion engine. The Energy Independence and Security Act of 2007 defines a plug-in electric drive vehicle as one that:

- draws motive power from a battery with a capacity of at least 4 kilowatt hours
- can be recharged from an external source of electricity for motive power, and
- is a light-, medium-, or heavy-duty motor vehicle or non-road vehicle.
This distinguishes PHEVs from regular hybrid cars mass marketed today, which do not use any electricity from the grid. The Institute of Electrical and Electronics Engineers (IEEE) defines PHEVs similarly, but also requires that hybrid electric vehicle have the ability to be driven at least ten miles (16 km) in all-electric mode (PHEV-10; PHEV16km), while consuming no gasoline or diesel fuel. General Motors is referring to its Chevrolet Volt series plug-in hybrid as an Extended-Range Electric Vehicle (EREV). These three types of vehicles are shown in Figure 1-1.

**Figure 1-1: Characteristics of PHEVs, EREVs, and BEVs**

The energy could be transmitted to the vehicle through the electrical grid, using wireless energy transfer such as inductive charging or more commonly via direct connection through an electrical cable. The electricity is stored onboard the vehicle using a battery, flywheel, or supercapacitors. The current infrastructure is based upon cable connections with battery storage. A list of manufacturers and car models (current and projected) for both PEVs and PHEVs is shown in Table 1-2.
### Table 1-2: Manufacturer Release of PEVs and PHEVs

<table>
<thead>
<tr>
<th>Manufacturer/Model</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plug-in Electric Vehicles (PEV)</strong></td>
<td></td>
</tr>
<tr>
<td>Mitsubishi i</td>
<td>X</td>
</tr>
<tr>
<td>Nissan LEAF</td>
<td>X</td>
</tr>
<tr>
<td>Ford TRANSIT connect electric</td>
<td>X</td>
</tr>
<tr>
<td>Tesla Motors Roadster Sport 2.5</td>
<td>X</td>
</tr>
<tr>
<td>Zero Motorcycles Zero S</td>
<td>X</td>
</tr>
<tr>
<td>Brammo Enertia</td>
<td>X</td>
</tr>
<tr>
<td>TH!NK City</td>
<td>X</td>
</tr>
<tr>
<td>Coda Automotive Sedan</td>
<td>X</td>
</tr>
<tr>
<td>Tesla Motors Model S</td>
<td>X</td>
</tr>
<tr>
<td>Ford Focus electric</td>
<td>X</td>
</tr>
<tr>
<td>BMW ActiveE</td>
<td>X</td>
</tr>
<tr>
<td>Fiat 500 minicar</td>
<td>X</td>
</tr>
<tr>
<td>Audi e-tron</td>
<td>X</td>
</tr>
<tr>
<td>Honda Fit EV</td>
<td>X</td>
</tr>
<tr>
<td>Audi R8 EV</td>
<td>X</td>
</tr>
<tr>
<td>Mercedes SLS E-Cell AMG</td>
<td></td>
</tr>
<tr>
<td>Volkswagen Golf Blue-e-motion</td>
<td></td>
</tr>
<tr>
<td>BMW i3</td>
<td></td>
</tr>
<tr>
<td>Tesla Motors EV</td>
<td></td>
</tr>
<tr>
<td><strong>Plug-in Hybrid Electric Vehicles (PHEV)</strong></td>
<td></td>
</tr>
<tr>
<td>Chevy Volt Extended Range EV</td>
<td>X</td>
</tr>
<tr>
<td>Toyota Plug-in Hybrid</td>
<td>X</td>
</tr>
<tr>
<td>BYD F3DM Plug-in Hybrid</td>
<td>X</td>
</tr>
<tr>
<td>Toyota Prius Plug-in Hybrid</td>
<td>X</td>
</tr>
<tr>
<td>Bright Automotive IDEA Plug-in Hybrid</td>
<td>X</td>
</tr>
<tr>
<td>Ford Escape Plug-in Hybrid</td>
<td>X</td>
</tr>
<tr>
<td>Ford C-MAX Energi</td>
<td>X</td>
</tr>
<tr>
<td>BMW Vision</td>
<td></td>
</tr>
<tr>
<td>BMW i8</td>
<td></td>
</tr>
<tr>
<td>Cadillac Converj</td>
<td></td>
</tr>
</tbody>
</table>
1.2 PEV and PHEV Charging Stations
Electric vehicles typically charge from conventional power outlets or dedicated charging stations. Depending on the voltage and current type available, the process may take only a fraction of an hour to several hours. Refer to Section 2.1.2 for current industry standards, charging voltages, and currents. Since residential service is typically provided at 120/240 VAC, the charging voltage is essentially limited to 240V for residential applications, and the process for this type of customer will usually occur overnight for many hours. If a large proportion of private vehicles were to convert to grid electricity it would increase the demand for generation and transmission, and consequent emissions; however, overall energy consumption and emissions would diminish because of the higher efficiency of electric vehicles. It is conceivable that the existing power plant generation and transmission infrastructure has sufficient capacity, assuming that most charging would occur overnight, using the most efficient off-peak base load sources. One concern, however, is that the distribution system, and specifically distribution system transformers, will be undersized to accommodate the needs of EV nighttime charging.

Due to the rapid charging capability projected for a DC Level 2 station - charging a typical electric car in under 30 minutes - a large growth is forecast for institutional organizations (city or county fleets, K-12 schools or universities, or federal post office within a city/county), rental car agencies, or retail facilities, including: hotels, supermarkets, restaurants, coffee shops, shopping malls, etc., as drivers will need locations to charge their vehicles.

1.3 Vehicle-to-Grid Distribution and Storage
Grid energy storage (or large-scale energy storage) lets energy producers send excess electricity via the grid to temporary electricity storage sites that become energy producers when electricity demand increases. Grid energy storage is particularly important in matching supply and demand over a 24 hour period of time. A proposed variant of grid energy storage is called Vehicle-to-Grid energy storage, where electric vehicles that are charged via the energy grid can also release their stored electrical energy in their batteries back into the grid during peak power demand. This assumes that vehicles will be connected to the grid and their power will be available when needed. However, many details need to be determined, such as where/when vehicles are charged/discharged (i.e., at home or work). Furthermore, the effect of providing energy back to the grid needs to be better understood (in particular to battery warranty) before becoming common place.

The Department of Defense plans to take advantage of early technology breakthroughs in grid scale energy storage, batteries for electric vehicles, and power electronics and develop an energy storage device that will provide future defense systems with long duration storage suitable for a variety of applications, including military bases and vehicles and eventually commercial grids. Vulnerability to energy supply disruption is a significant challenge for facilities dependent on the commercial power grid, and backup power is both limited and expensive. Onsite renewable electricity generation combined with grid scale storage would allow installations to maintain critical functions in the event of grid disruption and enhance installations' efforts to develop micro-grids for energy security.
1.4 Potential NEC Impact of Charging Stations and Vehicle-to-Grid Distribution
The potential impacts of these technologies on electrical safety principals embedded in the NEC could include:

- 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 AC Level 2 charging
- Maintenance that must be done for public charging stations to keep them safe for the public
- 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
- For Vehicle-to-Grid Distribution and Storage:
  - 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

2.0 Project Tasks

2.1 Task 1: Technology Review and Safety Assessment

2.1.1 Scope and Approach
Working with the automotive industry and battery and battery charging technology companies, current and emerging AC and DC Level 2 charging station technical specifications were assessed to determine the implications for electrical infrastructure including wiring, overcurrent protection, load management, etc.

2.1.2 Current Industry Specifications

2.1.2.1 Standards and Levels
In 1994, the Electric Power Research Institute (EPRI) defined three EV charging levels:

- Level 1 is 120 VAC, 12A or 16A,
- Level 2 is 240VAC, 40A, and
- Level 3 is 480 VAC.
Today, however, there is debate as to the definition of current charging “levels”. For example, the “Plug In Michigan” website lists specifications for AC and DC Levels 1 and 2, but claims Level 3 is TBD for both types of voltage. Other sources, such as an article from EVS24 indicate that Level 3 is DC up to 500A and 600V, however, the plugin cars web site contends that “today, Level 3 means proprietary DC charging hardware.”

The Society of Automotive Engineers (SAE) Standard J 1772, “Electric Vehicle Conductive Charge Coupler”, released January 2010, defines AC Level 1 as 120V single phase, 12A or 16A; AC Level 2 as 240V single phase up to 80A, and AC Level 3 as TBD. The SAE also has identified DC Level 1 charging as 200-450V DC up to 80A, DC Level 2 charging as 200-450V DC up to 200A, and DC Level 3 charging as 200-600V DC (tentative) up to 400A (tentative).

Another standard is the International Electrotechnical Commission (IEC) 61851. This standard defines 4 charging “modes” with VAC up to 690V and VDC up to 1,000V. Finally, there is also a DC charging system called “CHAdeMO” (an abbreviation of “CHArge de MOve", equivalent to “charge for moving”) which is the trade name of a quick charging method for battery electric vehicles that is in use in Japan. This system allows VDC up to 500V and 125A. CHAdeMO has suggested that SAE adopt their system as a DC Fast-Charging standard. These standards are summarized in Table 2-1.

**Table 2-1: Current Industry Specifications**

<table>
<thead>
<tr>
<th>Level</th>
<th>EPRI</th>
<th>SAE (AC)</th>
<th>SAE (DC)</th>
<th>IEC</th>
<th>CHAdeMO</th>
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<tr>
<td></td>
<td>120 VAC, 12A or 16A</td>
<td>120V single phase, Configuration current 12A ≥ 16A</td>
<td>200-450 V</td>
<td>4 charging “modes” with VAC up to 690V and VDC up to 1,000V</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>120 VAC, 12A or 16A</td>
<td>120V single phase, Configuration current 12A ≥ 16A</td>
<td>200-450 V</td>
<td>4 charging “modes” with VAC up to 690V and VDC up to 1,000V</td>
<td></td>
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<tr>
<td>2</td>
<td>240VAC, 40A</td>
<td>240V single phase, Rated current ≤ 80A</td>
<td>200-450 V</td>
<td>4 charging “modes” with VAC up to 690V and VDC up to 1,000V</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>480 VAC</td>
<td>Not Finalized**</td>
<td>Not Finalized**</td>
<td>Not Finalized**</td>
<td></td>
</tr>
</tbody>
</table>

* > 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

**2.1.2.2 Communication Standards**

SAE J 1772 compliant connectors and charging equipment have built-in safety features such as not supplying power to the connector unless it is coupled to the vehicle, and communicating with the vehicle to prevent driving while connected. SAE J2847/1 specifies requirements for communication between plug-in vehicles and the electric grid. Furthermore, there also will be communication between EV supply equipment and other wired or wireless interfaces, such as an Energy Management System (EMS)
or smart phone. One concern would be to ensure that a system failed-safe with regard to service providers and public workers.

2.1.2.3 Battery Capacity and Charging Speed

The Nissan Leaf is a PEV while the 2012 Prius is available as a PHEV\(^1\); the Chevy Volt is a PHEV, but configured more toward electric operation than the Prius. The Ford Transit Connect EV is a commercial utility van PEV. Battery sizing varies by size and type of vehicle:

- Transit Connect EV has the largest battery at 28 kWhr
- Leaf at 24kWhr
- Volt at 16kWhr, and
- Prius slated for 5.2kWhr\(^2\).

By comparison, a more limited production specialty car, such as the Tesla Roadster, might have a battery as large as 56kWhr\(^3\). By comparison, a representative street legal electric motorcycle, the Zero S, has a much smaller 4.4kWhr battery pack.

The range associated with the above electric-only vehicles, based on product literature, is as follows:

- 50 to 80 miles for the Transit Connect EV\(^2\)
- 62 to 138 miles for the Leaf\(^3\),
- 245 miles for the Tesla, and
- 43 miles for the Zero S\(^4\).

As stated in the Leaf’s specifications, the range can vary greatly depending on driving habits, use of accessories such as air conditioning, and environmental conditions. By comparison, ranges of 200 to 400 miles for combustion engine only cars and vans, and 100 to 200 miles for motorcycles, are typical.

The Leaf has a 3.3kW onboard charger for its first year of production, and the option to install a 50kW DC charging port that is compatible with CHAdeMO. The Leaf is scheduled to have a 6.6kW charger for its second year, and its home-installed charger - currently rated at 40A – is expected to remain the same for the second production year. For comparison, the Tesla has a 70A charger, the Transit Connect EV’s is 30A\(^5\), and the Volt’s is 16A.

Based on a stated charge time of about 7 hrs using the Leaf’s 3.3kW charger, the 6.6kW should charge a fully depleted battery in about 3.5hrs. This is similar to the stated charging time of 4 hrs for the Volt’s AC Level 2 charger, and 3.5 hrs for the Tesla’s AC Level 2 “High Power Wall Connector.” The Transit Connect EV takes 6 to 8 hours for a full charge\(^6\) with the AC Level 2 charger, while the Zero S takes 2.3 to 4 hours, depending on the vehicle options.

A summary of specific PEV vehicle specifications is shown in Table 2-2a and a summary specific PHEV vehicle specifications is shown in Table 2-2b. Table 2-3 lists AC Charging Power Levels per SAE J1772.
### Table 2-2a: Summary of PEV Vehicle Specifications

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

### Table 2-3b: Summary of PHEV Vehicle Specifications

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Battery Capacity (useable)</th>
<th>Charge Power [max rated capacity / stated charge time] (based on useable)</th>
<th>Charge Time (AC Level 1)</th>
<th>Total Range per Tank (Electric Only) [EPA]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volt Sedan</td>
<td>16 (10.4) kWhr</td>
<td>3.3 [4 (2.6)] kW</td>
<td>4 hrs</td>
<td>375 ([35]) mi</td>
</tr>
<tr>
<td>Prius Sedan</td>
<td>5.2 (3.8) kWhr</td>
<td>[3.47 (2.53)] kW</td>
<td>1.5 hrs</td>
<td>475 (14) mi</td>
</tr>
<tr>
<td>F3DM²⁷,²⁸ Sedan</td>
<td>16kWhr</td>
<td>[2] kW</td>
<td>(8) hrs</td>
<td>360 (40-60) mi</td>
</tr>
</tbody>
</table>

### Table 2-4: AC Charging Power Levels: SAE J1772

<table>
<thead>
<tr>
<th>Type</th>
<th>Expected Power Level</th>
<th>Est. Charge Time*</th>
<th>Vehicle Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>≤1.9 kW (16A)</td>
<td>4 – 11 hrs, 11 – 36 hrs</td>
<td>PHEVs (5 - 15 kWh) BEVs** (16 -50 kWh)</td>
</tr>
<tr>
<td>Level 2</td>
<td>≤19.2 kW (80A)</td>
<td>1 – 4 hrs, 2 – 6 hrs, 2 – 3 hrs</td>
<td>PHEVs (5 - 15 kWh) BEVs (16 – 30 kWh) BEVs (30 – 50kWh)</td>
</tr>
<tr>
<td>Level 3</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
2.1.2.4 Speculative Analysis

As noted above, with the exception of the Tesla, the current PEVs’ range is about one-quarter to one-half of what would probably be expected from an ICE counterpart. As electrical energy storage technology progresses, manufacturers may aim for ranges similar to those of ICE vehicles, to ease customers’ “range anxiety.”

Assuming efficiency does not increase significantly, this will require energy capacities of around 50 to 70 kWh. If these target capacities are met, AC Level 2 chargers will require approximately 6 to 12 kW of power to meet the common 6 to 8 hour charging time, and 12 to 24 kW to meet the more aggressive 3 to 4 hour times. The upper end of the latter power requirements exceeds the current SAE AC Level 2 rating. These increased charging requirements will impose a significantly higher load challenge on homes and the grid.

The CHAdeMO standard can provide 62.5 kW, which would require more than 1 hour to recharge a fully depleted battery at the upper end of the predicted scale. If manufacturers attempt to achieve recharging times comparable to ICE vehicle refueling, charging power greater than 100 kW may be necessary. JFE engineering claims to be developing a system that has a charging current of 500 to 600 A and will charge current PEVs to 50% of battery capacity in 3 minutes and 70% in 5 minutes. The system uses two batteries for charging; one that is capable of a rapid discharge, coupled with another high-capacity battery that continuously draws energy from the grid at a lower rate, reportedly 20 kW, and feeds this energy to the rapid discharge battery.

2.1.2.5 Energy Related Features

Both the Nissan Leaf and the Chevy Volt have the capability to be charged per a predetermined schedule to avoid charging during peak hours. This feature can be programmed from a computer or smart phone.

2.1.3 Electrical Infrastructure Implications

Load management will be a critical concern and will vary between geographical areas. For example, a comparison was made of the amount of PEV registration from 2004 to 2008 for two different locations served by the same utility. The towns are located less than 200 miles apart, however, the amount and percentage of registration indicate a significant variation, as shown in Table 2-4.

<table>
<thead>
<tr>
<th>Location</th>
<th>Amount of New Registrations</th>
<th>Amount of PEV Registrations</th>
<th>Percentage of PEV to new registrations</th>
<th>Median amount of PEV registrations within Zip Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresno, CA</td>
<td>83,000</td>
<td>2,000</td>
<td>2.4%</td>
<td>11</td>
</tr>
<tr>
<td>Berkeley, CA</td>
<td>14,000</td>
<td>2,500</td>
<td>18%</td>
<td>212</td>
</tr>
</tbody>
</table>

Furthermore, research has shown that when offered a choice, customers prefer a quicker, AC Level 2 charge at a greater ampacity, rather than an extended charge time, as shown in Figure 2-1. This figure indicates that while the typical AC Level 1 charge draws less than 50% of the typical power (1.5 kW) of
a Berkeley customer, a AC Level 2, 30A charge draws about the same amount of power (6.5 kW) as a customer located in Fresno.

**Figure 2-1: PEV Charging and Increase in Electrical Load for PG&E Customers**

![Chart showing PEV charging and increase in electrical load for PG&E customers](chart.png)

Assuming that EVs will be in located in geographical clusters (per Table 2-4), localized distribution stresses may occur. This situation will be compounded if customers elect to have quicker, AC Level 2 charging stations at a greater ampacity (per Figure 2-1). If the electrical grid is set up for two-way electricity exchange, then this impact may be mitigated. Charging habits also will be influenced by Time of Use (TOU) metering rates. If commercial stations with rapid charging (in excess of the current SAE AC Level 2 rating) adopt battery systems similar to the two battery system described in Section 2.1.2, and they are configured for two-way exchange of power, then this capacity may also help ease local electrical distribution problems.

Another factor of consideration is the implications of households with more than one EV. Will this increase the likelihood of both vehicles being charged from AC Level 2 stations? Since it takes most of the overnight hours to charge one vehicle using a AC Level 1 charging station, will two EVs drive most households toward back-to-back AC Level 2 overnight charging? Or would this scenario result in multiple single-family charging stations with the ensuing safety implications from the increased demand such situations would induce?

Finally, the type of rate structure allowed by the local utility is also a factor of consideration. Within the PG&E service territory, two electric vehicle rate options are available for PEV or PHEV customers:

- **E-9A**: Single meter option providing one baseline amount and rate that is shared by both the home and vehicle, as shown in Figure 2-2.
- **E-9B**: Two meter option providing two baselines, and two potentially different rates; one for the home and a second meter for the vehicle, as shown in Figure 2-3.

The single meter option is predominately preferred by the majority of customers due to the large initial expense ($2k-10k) required for an additional meter and support equipment.
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.
2.1.3.1 Gasoline vs. Electricity
A rough estimate of the additional power requirements imposed by PHEVs and PEVs on the grid is presented below. The estimate is projected for the year 2015, and assumes that 1,000,000 PHEVs and PEVs are in operation, which is the goal stated by the Obama Administration. The estimate does not account for charging and discharging efficiency or gasoline consumed for purposes other than transportation.

According to the US Energy Information Administration (EIA), approximately 378,000,000 gallons of gasoline were used per day in 2010, primarily in cars and light trucks\(^3\). In 2009, the US net electric generation averaged approximately 10,800,000 MW-hr per day. Assuming approximately 122 MJ per gallon of gasoline and 15% energy used\(^3\), yields approximately 1,920,000 MW-hr per day. The EIA further states that there are approximately 249 million vehicles on the road, which yields a rough estimate of approximately 7.7 kW-hr per vehicle per day.

2.2 Task 2: Standards Review and Gap Assessment

2.2.1 Methodology

2.2.1.1 Background
The potential impact from increased deployment of PEVs, PHEVs, and their associated charging systems were determined from the information included in Task 1. These impacts were analyzed for overlaps with the safety principles embedded in the NEC and other NFPA standards. The following areas were identified:

- 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 and 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 (located in the vehicle for AC charging or the EVSE for DC charging)
- Voltage flicker due to charging station load
- DC charging installations, especially where DC generation or storage, such as where Photovoltaic Cells (PV) are present

2.2.1.2 Scope and Approach
A preliminary assessment of gaps or inconsistencies within the U.S. fire and electrical safety regulatory framework was prepared. The NFPA standards that were reviewed included the following:
Electrical Vehicle Charging and NFPA Electrical Safety Codes and Standards

- NFPA 70, The National Electric Code
- NFPA 70E, Electrical Safety in the Workplace

Some of the identified gaps or inconsistencies are the same as those cited in a previous Fire Protection Research Foundation study, “Smart Grid and NFPA Electrical Safety Codes and Standards”, and are reproduced for completeness.

2.2.2 Review of NFPA Standards

2.2.2.1 NFPA 70

Based upon an assessment of the Task 1 findings concerning current and emerging technologies related to PHEVs and PEVs, a review of the 2011 edition of the NFPA 70 was performed. This review identified the following code articles as potential candidates for revision.

2.2.2.1.1 Article 210 Branch Circuits

- **210.2 Table 210.2 Specific-Purpose Branch Circuits**
  - Recommendation: add EV and PHEV Charging Stations.
  - Substantiation: dedicated branch circuits should be used for these receptacles.

- **210.19(A) Informational Note**
  Reference The Fire Protection Research Foundation 1/30/2011 Interim Report\textsuperscript{36} 210.19(A)
  Informational Note No. 4:
  “Informational Note No. 4: Conductors for branch circuits as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, provide reasonable efficiency of operation. See Informational Note No. 2 of 215.2(A)(3) for voltage drop on feeder conductors.”
  - Recommendation: Add Informational Note No. 5 in 210.19(A):
    - Where the major portion of the load consists of nonlinear loads, harmonics currents may increase the resistivity of the conductor leading to higher voltage drops.
  - Substantiation: High harmonic penetration might cause temperature increase in the conductor, which increases the resistance and the voltage drop (Sankaran 2002 and De La Rosa 2006).”
    EMS switching of loads may generate additional harmonics.

- **210.52 Dwelling Unit Receptacle Outlets**
  “(E) Outdoor Outlets. Outdoor receptacle outlets shall be installed in accordance with (E)(1) through (E)(3). [See 210.8(A)(3).]”
  - Recommendation: consider adding a note to 210.52 (E) for EV and PHEV receptacles.
  - Substantiation: adding a dedicated receptacle for EVs and PHEVs would accommodate future charging requirements.
2.2.2.1.2 Article 215 Feeders

- **215.2(A)(4) Informational Note**
  
  
  “(4) Individual Dwelling Unit or Mobile Home Conductors.
  
  Feeder conductors for individual dwelling units or mobile homes need not be larger than service conductors. Paragraph 310.15(B)(6) shall be permitted to be used for conductor size.
  
  Informational Note No. 1: See Examples D1 through D11 in Informative Annex D.
  
  Informational Note No. 2: Conductors for feeders as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, will provide reasonable efficiency of operation.
  
  Informational Note No. 3: See 210.19(A), Informational Note No. 4, for voltage drop for branch circuits.”
  
  - Recommendation #1: Add Informational Note No. 4 in 215.2(A)(4):
    
    Where the major portion of the load consists of nonlinear loads, harmonics currents may increase the resistivity of the conductor leading to higher voltage drops.
  
  - Substantiation #1: High harmonic penetration might cause temperature increase in the conductor, which increases the resistance and the voltage drop (Sankaran 2002 and De La Rosa 2006).”
    
    EMS switching of loads may generate additional harmonics.
  
  - Recommendation #2: Consider impact of two meter residential option; one for the home and a second meter for the vehicle
  
  - Substantiation #2: Refer to as Figure 2-3

2.2.2.1.3 Article 220 Branch Circuit, Feeder, and Service Calculations

- **220.3 Table 220.3 Additional Load Calculation References**
  
  - Recommendation- add EV and PHEV charging stations.
  
  - Substantiation- other specialty devices and equipment are currently listed.

- **220.14 Other Loads - All Occupancies**
  
  “(L) Other Outlets. Other outlets not covered in 220.14(A) through (K) shall be calculated based on 180 volt-amperes per outlet.”
  
  - Recommendation- add 220.14 (M) EV and PHEV Receptacles Outlets. An outlet for EV and PHEV shall be calculated based on the ampere rating of the EV and PHEV equipment served.
  
  - Substantiation- minimum load requirements should be specified.

- **220.44 Receptacle Loads - Other Than Dwelling Units**
  
  - Recommendation- consider adding Commercial EV and PHEV charging stations to Table 220.44.
  
  - Substantiation- this will address load demand factors for equipment.
2.2.2.1.4 Article 230 Services

- 230.82 Equipment Connected to the Supply Side of Service Disconnect
  - Recommendation: consider adding EV and PHEV vehicle-to-grid configuration as power providers, and refer to all of these systems as “alternate power sources.”
  - Substantiation: code section currently lists new generation systems and vehicle-to–grid is a potential source of generation

2.2.2.1.5 Article 240 Overcurrent Protection

- 240.3 Table 240.3 Other Articles
  - Recommendation: add EV and PHEV charging stations (625).
  - Substantiation: other specialty devices and equipment are currently listed.

2.2.2.1.6 Article 250 Grounding and Bonding

- 250.3 Table 250.3 Additional Grounding and Bonding Requirements
  - Recommendation: add EV and PHEV charging stations.
  - Substantiation: other specialty devices and equipment are currently listed.

2.2.2.1.7 Article 625 Electric Vehicle Charging Stations

- 625.26 Interactive Systems
  “Electric vehicle supply equipment and other parts of a system, either on-board or off-board the vehicle, that are identified for and intended to be interconnected to a vehicle and also serve as an optional standby system or an electric power production source or provide for bi-directional power feed shall be listed as suitable for that purpose. When used as an optional standby system, the requirements of Article 702 shall apply, and when used as an electric power production source, the requirements of Article 705 shall apply.”
  - Recommendation: Provide clarity as to whether a PEV, when connected to its charging system, can be considered an electric power production source, as opposed to an energy storage device.
  - Alternate recommendation: Add code provisions, such as ceasing to supply power upon loss of the primary source, for the system when providing for bi-directional power feed.
  - Substantiation: Both articles 702 and 705 refer to generation rather than storage. 702.2 states “Optional standby systems are intended to supply on-site generated power to selected loads…”, and 705.1 states “This article covers installation of one or more electric power production sources…”. A PEV connected to its charging station would probably be identified as a storage device, but not a generation device. If bi-directional power feed is allowed as separate from the requirements of either article 702 or 705, then some provisions similar to those in 702 and 705 should be added. This may just be an issue of clarity.

2.2.2 NFPA 70E

2.2.2.2.1 Article 120 Establishing an Electrically Safe Work Condition

- 120.1 Process of Achieving an Electrically Safe Work Condition
  - Recommendation: add (7): Disconnecting means to be provided to disconnect/isolate electrical equipment and the potential personnel hazards from equipment that may be operated remotely.
Substantiation- on-site generation may be remotely controlled to power-up or -down depending upon the kW-hr cost of electricity.

2.2.2.2 Article 320 Safety Requirements Related to Batteries and Battery Rooms

- 320.3 (H) (1) (1) Abnormal Battery Connections for vented batteries
  - Recommendation- add (e): Alarm condition for overcharging.
  - Substantiation- Frequent charging/discharging of batteries due to increased supply of power to the grid may result in overcharging conditions.

2.2.3 Identification of Other Standards

2.2.3.1 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

2.2.3.2 The Society of Automotive Engineers (SAE)
- J1772™ – SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler

Acknowledgements

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This work was made possible by the Fire Protection Research Foundation (an affiliate of the National Fire Protection Association). The authors are indebted to the project technical panel members for their valuable suggestions.
EV Charging and Electrical Safety Standards

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
## Appendix B Glossary of Acronyms

- Battery Electric Vehicle (BEV)
- Electric Power Research Institute (EPRI)
- Electric Vehicle (EV)
- Energy Information Administration (EIA)
- Energy Management Systems (EMS)
- Extended-Range Electric Vehicle (EREV)
- Institute of Electrical and Electronics Engineers (IEEE)
- Internal Combustion Engine (ICE)
- International Electrotechnical Commission (IEC)
- Photovoltaic Cells (PV)
- Plug-in Electric Vehicle (PEV)
- Plug-in Hybrid Electric Vehicle (PHEV)
- Society of Automotive Engineers (SAE)
- Time of Use (TOU)
- Underwriters Laboratories, Inc (UL)
## APPENDIX C TASK 1 COMMENT RESOLUTION FORM

<table>
<thead>
<tr>
<th>No.</th>
<th>Task 1 Location</th>
<th>Comment</th>
<th>Commenter’s Suggestions</th>
<th>Commenter</th>
<th>Date Received</th>
<th>Disposition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General</td>
<td>To my knowledge in the US charging levels and corresponding charge rates are defined by SAE J1772 (I chair that committee). Level 3 (DC fast charge) was defined as such in the 1996 version of J1772. The term Level 3 was removed from J1772 in the 2001 release of the document. Old habits die hard and many still refer to DC fast charging as Level 3.</td>
<td>I suggest that the document use the new terminology in this attached slide.</td>
<td>Gery Kissel</td>
<td>8/15/11</td>
<td>Agreed</td>
<td>Table 2-1 has been revised to reflect current SAE information</td>
</tr>
<tr>
<td>2</td>
<td>General</td>
<td>I suggest defining these terms near the beginning of the document instead for referring to a later section.</td>
<td>It may be helpful to just have a list of definitions up front.</td>
<td>Gery Kissel</td>
<td>8/15/11</td>
<td>Agreed</td>
<td>An Executive Summary has been added at the beginning of the report, with reference to new App B Glossary of Acronyms</td>
</tr>
<tr>
<td>3</td>
<td>1.3</td>
<td>Section 1.3 discusses projections for charge station growth.</td>
<td>I do not see a reference to the data to support these projections. I am especially concerned about the projections for DC Level 2 (referred to as Level 3 in table 1-2). These assets will be very expensive to install and to purchase. I would be cautious to not over estimate.</td>
<td>Gery Kissel</td>
<td>8/15/11</td>
<td>Agreed</td>
<td>The reference to the Zpymne research report has been cited. Also, refer to the references in Section 1.0.</td>
</tr>
<tr>
<td>4</td>
<td>1.4</td>
<td>Section 1.4 jumps directly to vehicles providing energy back to the grid to help support the grid when needed.</td>
<td>I suggest adding information to the more likely, especially in the near to mid term, of charge rate control where charge rate is reduced or terminated completely during grid events. The effect of providing energy back to the grid needs to be understood, in particular to battery warranty, before becoming common place.</td>
<td>Gery Kissel</td>
<td>8/15/11</td>
<td>Clarified</td>
<td>Section 1.4 has been revised to reflect some of the concerns associated with vehicle-to-grid power production</td>
</tr>
<tr>
<td>No.</td>
<td>Task 1 Location</td>
<td>Comment</td>
<td>Commenter's Suggestions</td>
<td>Commenter</td>
<td>Date Received</td>
<td>Disposition</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----</td>
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<td>---------</td>
<td>-------------------------</td>
<td>-----------</td>
<td>---------------</td>
<td>-------------</td>
<td>---------</td>
</tr>
<tr>
<td>5</td>
<td>2.1.2.1</td>
<td>Section 2.1.2.1 states that SAE is supposedly considering adoption of the CHAdeMO system for DC Level 2 charging.</td>
<td>I think it is more accurate to state that CHAdeMO has suggested their system to be adopted for DC Level 2 charging.</td>
<td>Gery Kissel</td>
<td>8/15/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
</tr>
<tr>
<td>6</td>
<td>2.1.2.3</td>
<td>Table 2-2 is a summary of PEV vehicle specifications.</td>
<td>I suggest adding a table for PHEVs as these vehicles will probably be more prevalent in the near to mid future.</td>
<td>Gery Kissel</td>
<td>8/15/11</td>
<td>Agreed</td>
<td>A Summary of PHEV Vehicle Specifications Table has been added</td>
</tr>
<tr>
<td>7</td>
<td>General</td>
<td>The background jumps right into types of cars and I’m not sure where this report is headed – what am I to expect in this report (executive summary maybe)</td>
<td>Suggest the Project Summary and Scope be placed at the front of the report.</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>An Executive Summary and Project Summary have been added at the beginning of the report</td>
</tr>
<tr>
<td>8</td>
<td>1.3</td>
<td>Note that Level 3 does not exist – the SAE standard was released without a Level 3 and most likely the fast charge will be defined as a Level 2 DC charging. So there are 3 levels of AC charging proposed with on the Level 1 and 2 agreed upon in the US.</td>
<td></td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Table 2-1 has been revised to reflect current SAE information. Also, refer to comment #1</td>
</tr>
<tr>
<td>9</td>
<td>1.3</td>
<td>Residential is NOT limited to 240, however the current infrastructure in a way limits it but NFPA codes do not limit it.</td>
<td></td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Reference rephrased</td>
</tr>
<tr>
<td>No.</td>
<td>Task Location</td>
<td>Comment</td>
<td>Commenter's Suggestions</td>
<td>Commenter</td>
<td>Date Received</td>
<td>Disposition</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----</td>
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<td>-----------</td>
<td>---------------</td>
<td>-------------</td>
<td>---------</td>
</tr>
<tr>
<td>10</td>
<td>1.3</td>
<td>“If a large proportion of private vehicles were to convert to grid electricity it would increase the demand for generation and transmission, and consequent emissions; however, overall energy consumption and emissions would diminish because of the higher efficiency of electric vehicles.” This is an interesting assumption. At night when electrical demand is lower, it is possible to delay the charging of EVs that would give utilities the ability to level their loading across the entire day and create a storage source as noted in the following sentences, so not sure this is an appropriate assumption.</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Clarified</td>
<td>The concern is that the utility distribution system (i.e., distribution system transformers) will be undersized to accommodate the needs of EV nighttime charging</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1.3</td>
<td>Claims rapid growth of Level 3 – may I suggest the source of this be footnoted so this is not an opinion –</td>
<td>I might suggest that Level 3 be more appropriate for fleet use for say a town or even the postal service or maybe campus vehicles (my opinion).</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Additional institutional fleet management applications have been added to Section 1.3</td>
</tr>
<tr>
<td>12</td>
<td>1.4</td>
<td>Agree with your paragraph. Does it warrant a conclusion statement: “V-2-G implementation assumes the vehicles population will be connected to the grid.” If I’m charging at home and driving to work and not charging at work then V-2-G is a long way away until charging stations are at my work location.</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Clarified</td>
<td>Additional wording has been added</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1.5</td>
<td>Other considerations might include: Energy management systems</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
<td></td>
</tr>
</tbody>
</table>
### Electrical Vehicle Charging and NFPA Electrical Safety Codes and Standards

<table>
<thead>
<tr>
<th>No.</th>
<th>Task 1 Location</th>
<th>Comment</th>
<th>Commenter's Suggestions</th>
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<th>Date Received</th>
<th>Disposition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>1.5</td>
<td>Other considerations might include:</td>
<td>Cord and Plug connection of the supply equipment (not the car connection)-- should there be a limit on the amperage (50A, 100A,...)</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
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<td>15</td>
<td>1.5</td>
<td>Other considerations might include:</td>
<td>“EV Ready” – EV Ready is a term used to convey infrastructure has been put in place to facilitate the ease of installation of a charging station (maybe conduit from panel to parking location or the branch circuit installed from the panel to the parking location (electrical box). If the speculation is that battery capacity will grow and push Level 2 charging to the upper end than an EV Ready Home with a 20A branch circuit is hardly thinking ahead to be able to address the EV of 2015.</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
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<td>16</td>
<td>1.5</td>
<td>Other considerations might include:</td>
<td>NFPA 70B address electrical equipment maintenance – is there a role this document or possibly a section that might be added to NFPA 70B to address the maintenance that must be done for public charging stations to keep them safe for the public</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
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<td>17</td>
<td>1.5</td>
<td>Other considerations might include:</td>
<td>Interconnection with the Utility – vehicle back-feeding the electrical system – not typical scenario in residential or retail electrical systems. Should a V-2-G configuration permit cord and plug connection between the utility source and the EVSE (the male end of the plug would be hot)? What are the implications of public safety and electrical worker safety in the V-2-G configuration when working on other parts of the electrical system? Have all the appropriate isolation switches been placed in the system to ensure safety?</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
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<td>18</td>
<td>1.5</td>
<td>Other considerations might include:</td>
<td>Charging of the EV whether at home, at work, or at the mall could be an active smart grid component through Demand Response to remove the charging load and then turn it back on. Does this have implications to worker safety? Public safety? Is there a requirement to have indication for DR for the public to understand the EVSE in being called upon for DR?</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
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<td>19</td>
<td>2.1.2.2</td>
<td>Communication – there is also communication with the EVSE. Could be an energy management system in the facility, DR, your I-Phone,… Is it wired? If wireless are there safety concerns? Might a worker test the EVSE and determine it to be without power and a signal energize it? (70E)</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
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<td>20</td>
<td>2.1.2.4</td>
<td>Excellent Discussion! I think the NEC does need to consider the fact that battery technology will continue to improve which points to the upward creep of the amperage demands for Level 2 beyond the typical 30A. The point being that even moving this to a 50A charger imposes significantly more of a load challenge on homes and the grid.</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Noted</td>
<td>Additional text has been added to the section to emphasize the increase in load to residences and the grid</td>
<td></td>
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<td>21</td>
<td>2.1.2.5</td>
<td>Energy Related Management – This discussion should anticipate energy management well beyond the car. Facility energy management system from simply ones on the home to avoid a service upgrade, to sophisticated systems where multiple EVSE are installed and can monitor the EVSE to understand those that are no longer charging and switch to others on the system. This permits a reduction in the infrastructure size in order to accommodate the same charging need. Also may be used to manage peak demand when a penalty is imposed on the utility customer. There is also a lot of discussion around using “diversity” in the load calculation for a service with multiple EVSEs similar to say multiple dryers. The difference is that dryers cycle and EVSEs are a continuous load when they are connected and charging.</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>This subject is addressed in section 2.2.2.1.3 Article 220 Branch Circuit, Feeder, and Service Calculations</td>
<td></td>
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<tr>
<td>22</td>
<td>2.1.3</td>
<td>Do the NEC requirements in Article 230 address additional services and potential configurations?</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
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### Electrical Vehicle Charging and NFPA Electrical Safety Codes and Standards

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<tr>
<td>23</td>
<td>General</td>
<td>I would encourage a Summary that captures potential issues or topics for NEC, NFPA 70E and NFPA 70B – that can then be directly assessed in Task 2.</td>
<td>Alan Manche</td>
<td>8/18/11</td>
<td>Agreed</td>
<td>An Executive Summary has been added to the beginning of the report</td>
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<td>24</td>
<td>General</td>
<td>I would ask again that Level 3 not be used to describe DC Fast Charging. I understand that we only have working definitions for DC charging at this time but to continue to use Level 3 will add confusion in the future. As a compromise I would like to suggest replacing &quot;Level 3&quot; with DC Fast Charging. I would also like to suggest that &quot;Level 1&quot; be replaced with &quot;AC Level 1&quot; and &quot;Level 2&quot; be replaced with &quot;AC Level 2&quot;.</td>
<td>Gery Kissel</td>
<td>9/7/11</td>
<td>Clarified. This comment is in conflict with comments 1 and 8. Levels 1 and 2 include both AC and DC charging (per SAE). Level 3 includes AC charging (per IEC)</td>
<td>Table 2-1 has been revised to reflect current industry information on AC and DC charging</td>
<td></td>
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<td>25</td>
<td>General</td>
<td>I think it would be beneficial to explain someplace in the document that for AC charging (AC Level 1 or AC Level 2) that the charger is in the vehicle and not the EVSE. This is a common misunderstanding especially since the term “charging station” implies to many that the charger itself is located in the EVSE. This came to mind because in areas where areas were identified as affecting safety principles in the NEC, harmonics induced by charging stations is noted. Since the charger is located in the vehicle for AC Level 1 &amp; 2, it is the on-board charger creating these harmonics, not the EVSE or “charging stations” as noted. Harmonics are induced by DC charging stations (fast or slow) because the power conversion is in the EVSE.</td>
<td>Gery Kissel</td>
<td>9/7/11</td>
<td>Agreed</td>
<td>Comment incorporated</td>
<td></td>
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<td>2.2.1.1</td>
<td>Finally in 2.2.1.1 the substantiation noted in a couple places indicates that dedicated branch circuits will be required for each Charging Station. This is not true in all cases. An example being if I have 2 15 amp EVSEs in my garage, there would be no reason that I could not feed them from a single 40 amp branch with a receptacle for each EVSE</td>
<td>Gery Kissel</td>
<td>9/7/11</td>
<td>Clarified</td>
<td>Paragraph revised to state that dedicated branch circuits should be used for each charging station. Feeding two 15 A EVSEs from a 40 A breaker would not protect the 15 A devices from overloads &gt;15 A but &lt; 40A.</td>
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APPENDIX D END NOTES

1 http://www.pikeresearch.com/newsroom/64-percent-of-electric-vehicle-charge-points-in-the-united-states-to-be-residential-units
2 http://www.4evriders.org/2010/12/electric-vehicle-charging-station-us-market-to-exceed-4b-by-2016-zpryme-reports/
4 http://www.evchargermaps.com/
5 http://www.4evriders.org/2010/12/electric-vehicle-charging-station-us-market-to-exceed-4b-by-2016-zpryme-reports/
6 http://www1.eere.energy.gov/vehiclesandfuels/pdfs/1_million_electric_vehicles_rpt.pdf
7 http://www.pikeresearch.com/research/electric-vehicle-charging-equipment
8 http://www.goelectricdrive.com
9 http://www.electricdrive.org
10 http://www.doe.gov/articles/energy-and-defense-departments-announce-new-steps-enhance-cooperation-clean-energy-and

12 ibid
13 “Fast Charging vs. Slow Charging: Pros and cons for the New Age of Electric Vehicles” by Charles Botsford et al.
14 http://www.plugincars.com/fast-vehicle-charging-goes-many-names-49817.html
15 “Plug-In Power” by Mark Venables. Engineering and Technology, February 2011
16 http://www.sae.org/smartgrid/chargingspeeds.pdf
21 http://www.teslamotors.com/roadster/technology/battery
23 http://www.nissanusa.com/leaf-electric-car/index#/leaf-electric-car/theBasicsRange/index
24 http://www.zeromotorcycles.com/zero-s/specs.php
26 http://www.fordinthenews.com/ford-delivers-first-transit-connect-electric-vehicle/
30 http://techon.nikkeibp.co.jp/english/NEWS_EN/20100621/183598/
31 http://www.nissanusa.com/leaf-electric-car/faq/view/3#/leaf-electric-car/specs-features/index
32 http://www.chevrolet.com/volt/#technology
33 http://www.nissanusa.com/leaf-electric-car/#/charging, August 14, 2009
34 http://www.eia.gov/energyexplained/index.cfm?page=gasoline_use
35 http://www.fueleconomy.gov/feg/atv.shtml

36 Evaluation of the Impact on Non-Linear Power on Wiring Requirements for Commercial Buildings, Jens Schoene, EnerNex Project Number 1092

37 ibid