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Vehicle-to-Grid (V2G) Power Flow Regulations and Building Codes Review by the AVTA

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EXECUTIVE SUMMARY

The current availability of plug-in electric vehicles (PEVs), and their projected penetration of the private transportation market in the coming years, introduces the possibility of feeding the energy stored in vehicle batteries back to the electrical grid. This energy storage potential supports the objective of possibly providing additional financial incentives and opportunities for the PEV owner and by supporting emissions reduction by facilitating renewable energy integration and electric grid stability.

The Idaho National Laboratory (INL) and ECOtality North America (ECOtality) conducted a study of governmental regulations and building code requirements impacting the introduction and use of vehicles with vehicle-to-grid (V2G) capability which could influence future activities to:

- Develop a common set of regulations, standards, and building codes that would apply in broad geographic areas that would allow for widespread use of V2G vehicles
- Identify regulations, standards, and building codes requiring modification to allow for a single, national regulatory framework.

This project was divided into the following three phases:

- Phase 1 – Potential V2G Operating Modes and Functionality
- Phase 2 – Existing Codes, Regulations, and Business Models
- Phase 3 – Requirements for a Common Set of Regulations, Standards, and Codes

All three phases are summarized in this report.

Phase 1 provides the background for V2G systems so that a full understanding of the issues can be obtained. There are three basic system components involved that define the environment for recharging a vehicle or discharging energy from the vehicle to the electrical grid: (1) the location where the vehicle connects with the electrical grid, (2) the electric vehicle supply equipment to which the vehicle connects, and (3) the electric vehicle (or more specifically the battery management system) that manages the energy storage system state of charge. Various PEV configurations and charger levels will impact V2G potential. Different segments of the market (e.g., utilities, fleets, or general consumer) will be motivated by different incentives, including grid reliability, monetary payments, and emissions reductions. To realize the benefits that motivate customers, the industry first must address impacts (i.e., energy storage system life and warranty) and operational issues (i.e., ease of use, software programming, and automation).

Phase 2 includes an assessment of the existing codes and standards in several metropolitan areas as they relate to V2G to identify commonalities or conflicts. Local utility and codes experts were surveyed in Phoenix, Orlando, Boston, Detroit, Raleigh, Maui, San Diego, Dallas, Seattle, Portland, New York, and Washington D.C. The local contacts were queried on topics such as regulatory barriers (identifying the designated authority having jurisdiction and the version of the National Electric Code that is adopted locally), the electric utility

environment (whether the local electric utility electric service rules address V2G, electric vehicles, and renewable energy), implementation barriers (permitting and testing issues), and market barriers (incentives such as feed-in-tariff programs or time-of-use rates). A summary of findings is presented in Table E1. With the structure of local government control and the number of electric utilities reaching over 3,000 in the United States, there are variations to the way that resources are connected to the grid. Although codes and standards specific to V2G have yet to be developed, it is assumed that the same variation will be encountered on a local level and present implementation challenges to companies in the industry.

Phase 3 provides recommendations relating to a set of regulations, standards, and codes that would allow for widespread use of V2G operations. In an ideal world, codes and standards would be the same in every target implementation region for V2G. In actuality, there are many nuances that will cause challenges for customers and vendors.

Moving forward, authorities having jurisdiction and electric utilities should be encouraged to share best practices and information with other agencies in order to work toward common practices and quick adoption of nationally approved standards. The vehicles and electric vehicle supply equipment will be mostly standardized through the Society of Automotive Engineers proceedings and regulatory areas that the automotive manufacturers must follow. It is recommended that local authorities having jurisdiction and electric utilities follow the National Institute of Standards and Technology, Institute of Electrical and Electronics Engineers, and Society of Automotive Engineers proceedings and participate in standards development when feasible to understand and follow the guidelines that will support V2G technology. Also, authorities having jurisdiction and electric utilities should take care in preparing any customer-facing programs and language as more and more connected resources are moving from commercial entities to everyday consumers.

The INL is the lead United States Department of Energy (DOE) laboratory for the light-duty vehicle portion of the Advanced Vehicle Testing Activity (AVTA). ECOtality supports DOE, INL and the National Energy Technology Laboratory in the benchmarking of advanced technology vehicles, energy storage systems, PEV charging infrastructures. These new technologies are mostly the products of DOE research funding and the AVTA singularly provides field use feedback to researchers, technology developers and target setters.

The primary objective of the AVTA is to reduce the United States light-duty vehicle sector’s dependence on foreign oil while increasing the overall energy security of the United States. For more information about the AVTA and benchmarking results, see: http://avt.inl.gov

Table E1. Regional conditions related to codes and standards.

Region	Authority Having Jurisdiction	NEC	IBC	IRC	Online Permit	Utility							
						Utility	V2G Policy	EV-Only Rate	Solar/ PV Policy	[1]DG Policy	Net Metering Policy	Feed In Tariffs	TOU Rate
Phoenix	City of Phoenix	2008	2006	2006	Yes	SRP/APS	No/ No	No/ No	Yes/ Yes	No/ Yes	Yes/ Yes	No/No	Yes/ Yes
Orlando	Florida Building Commission	2008	2006	2006	Yes	Progress Energy	No	No	Yes	Yes	Yes	Yes	Yes
Boston	Board of Building Regulations and Standards	2011	2009	2009	Yes	NSTAR	No	No	No	Yes	Yes	No	Yes
Detroit	State of Michigan	2008	2009	2009	Yes	DTE Energy	No	Yes	Yes	Yes	Yes	No	Yes
Raleigh	City of Raleigh Inspections Department	2011	2009	2009	No	Progress Energy	No	No	Yes	Yes	Yes	No	Yes
Maui	Hawaii County Council	2008	2009		Yes	MECO	No	Yes	Yes	No	Yes	Yes	Yes
San Diego	California Building Standards Commission	2008	2009	2009	No	SDG&E	No	Yes	Yes	Yes	Yes	Yes	Yes
Dallas	City of Dallas	2011	2006	2006	Yes	Oncor/TX U Energy	No	No	No	Yes	Yes	No	Yes
Seattle	State Building Code Council	2008	2009	2009	No	SCL	No	No	Yes	No	Yes	No	No
Washing-ton, D.C.	Construction Codes Coordinating Board	2005	2006	2006	Yes	Pepco	No	No	No	Yes	Yes	No	Yes
Portland	Residential Structures Board	2011	2009	2009	Yes	PGE	No	No	Yes	Yes	Yes	Yes	Yes
New York	Division of Code Enforcement and Administration	2011	2006	2006	No	ConEd	No	No	Yes	Yes	Yes	Yes	Yes

[1]Distributed generation is electricity that is generated from small energy sources, typically renewable energy resources, and generally is used near its generation site, thereby reducing lost energy through transmission.

APS = Arizona Public Service
ConEd = Con Edison
DG = distributed generation
DTE = Detroit Edison
EV = electric vehicle
IBC = International Building Code
IRC = International Residential Code
MECO = Maui Electric Company
NEC = National Electric Code
Pepco = IBC = International Building Code
PGE = Portland General Electric
PV = photovoltaic
SCL = Seattle City Light
SDG&E = San Diego Gas and Electric
SRP = Salt River Project
TOU = time of use

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ACRONYMS

AC	alternating current
ANSI	American National Standards Institute
AMI	advanced metering infrastructure
APS	Arizona Public Service
AVTA	Advanced Vehicle Testing Activity
BEV	battery electric vehicle
BMS	battery management system
ConEd	Con Edison
DC	direct current
DER	distributed energy resource
DG	distributed generation
DOE	United States Department of Energy
DR	demand response
DTE	Detroit Edison
EPS	electrical power system
EREV	extended Range Electric Vehicle
ESS	energy storage system
EVSE	electric vehicle supply equipment
EVSP	electric vehicle service provider
FIT	feed-in tariff
IBC	International Building Code
ICE	Internal combustion engine
IECC	International Energy Conservation Code
IEEE	Institute of Electrical and Electronics Engineers
IGCC	International Green Construction Code
INL	Idaho National Laboratory
IOU	investor-owned utility
IRC	International Residential Code
ISO	independent system operator
kW	kilowatt
kWh	kilowatt hours
MECO	Maui Electric Company
MW	megawatt

NEC	National Electric Code
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
OEM	original equipment manufacturer
Pepco	Potomac Electric Power Company
PEV	plug-in electric vehicle
PGE	Portland General Electric
PHEV	plug-in hybrid electric vehicle
PV	photovoltaic
SAE	Society of Automotive Engineers
SCL	Seattle City Light
SDG&E	San Diego Gas and Electric
SOC	state of charge
SRP	Salt River Project
TMS	thermal management system
TOU	time-of-use
U.K.	United Kingdom
UL	Underwriters Laboratory
V	volt
V2B	vehicle-to-building
V2G	vehicle-to-grid
V2H	vehicle-to-home
VAC	volt alternating current
VDC	volt direct current

Vehicle-to-Grid (V2G) Power Flow

1. INTRODUCTION

Major automotive manufacturers began launching plug-in electric vehicles (PEVs) in 2010 and the future of transportation is being propelled by a fundamental shift to more efficient electric drive systems, and consumer interest in ownership of PEVs has grown. The first automotive manufacturers are not alone, as every major manufacturer has outlined plans to introduce PEVs in the next few years and most projections of the penetration of PEVs into the automotive market show at least 2.5 million PEVs by 2020 (Becker, Sidhu, and Tenerich 2009).

The PEV typically has a higher-capacity onboard energy storage system (ESS) than a hybrid electric vehicle, and the pure battery electric vehicle (BEV) utilizes the highest capacities to provide the longest range.

When considering the quantity of PEVs in the coming years and the capacities of the ESSs, there are possible additional advantages and uses for this source of stored energy. Most light-duty vehicles spend significant time not being operated and there maybe opportunities to utilize their stored energy. However, there are questions as to what additional hardware and software would be required to deliver the stored energy outside the vehicle, what communications systems would be required, can this be done without affecting the needs of the driver, what would the impact be on battery life and warranties, and what motivations exist to accomplish this and who benefits.

The above unknowns are explored in the following sections of this report. First, a common understanding of the existing PEVs and their battery systems is required. Then, the concept and technical details of vehicle to grid (V2G) are introduced and the motivation for this system is investigated. Next, the regulatory and implementation barriers to V2G are listed. Current V2G projects are described, and the codes and standards of specific areas in the United States are discussed. Finally, the commonalities and conflict between the regulatory codes and standards around the United States are explored before recommendations for how these conflicts can be resolved and a national standard is achieved.

This report was prepared for the U.S. Department of Energy Vehicle Technologies Program's Advanced Vehicle Testing Activity by the Idaho National Laboratory (INL) and ECOtality North America in order to report on a study of governmental regulations and building code requirements impacting the introduction and use of vehicles with vehicle-to-grid (V2G) capability.

The INL is the lead United States Department of Energy (DOE) laboratory for the light-duty vehicle portion of the Advanced Vehicle Testing Activity (AVTA). ECOtality supports DOE, INL and the National Energy Technology Laboratory in the benchmarking of advanced technology vehicles, energy storage systems, PEV charging infrastructures. These new technologies are mostly the products of DOE research funding and the AVTA singularly provides field use feedback to researchers, technology developers and target setters.

The primary objective of the AVTA is to reduce the United States light-duty vehicle sector's dependence on foreign oil while increasing the overall energy security of the United States. For more information about the AVTA and benchmarking results, see: http://avt.inl.gov

1.1 Plug-in Electric Vehicles

In order to introduce the V2G application, the types of vehicles that are expected to participate in the application also must be introduced.

1.1.1 Battery Electric Vehicle

BEVs are powered 100% by the ESS onboard the vehicle. The Nissan LEAF™ is an example of a BEV. The BEV battery is recharged by connecting it to the electrical grid through a connector system that is designed specifically for this purpose. A typical BEV design is shown in the Figure 1 block diagram.

The Nissan LEAF (Figure 2) has an advertised battery capacity of 24 kilowatt hours (kWh). This provides an advertised range of 100 miles, which varies with vehicle usage and conditions, including geographic topography, driver aggressiveness, operating speed, weather, vehicle occupancy, and so forth.

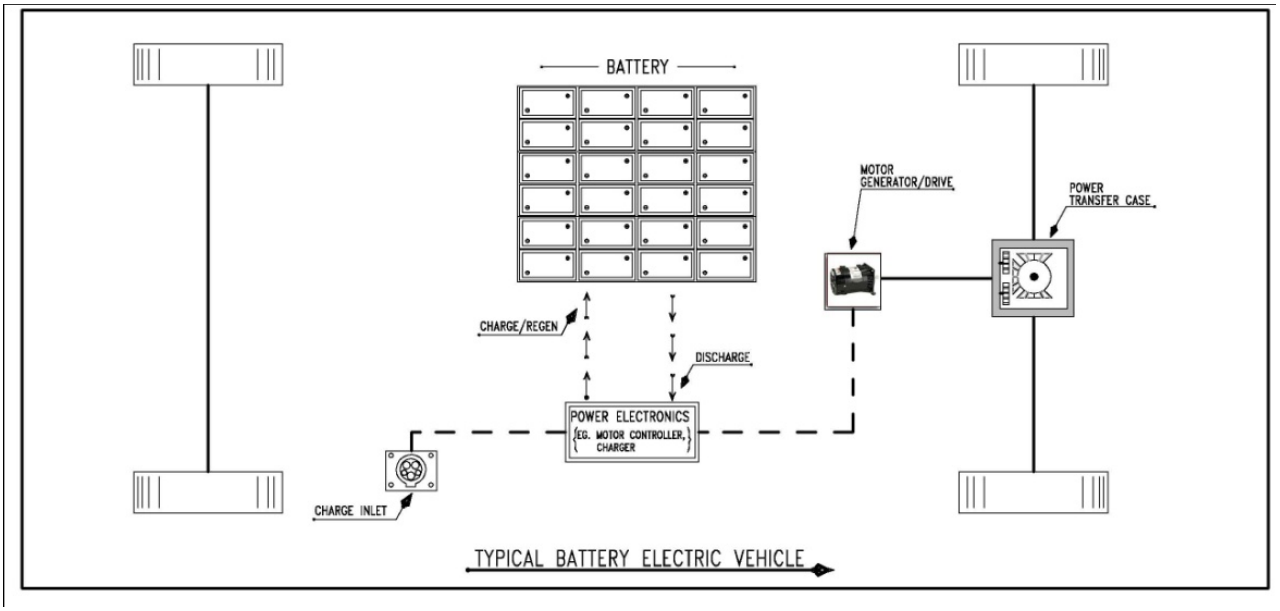

Figure 1. Battery electric vehicle.

Figure 2. Nissan LEAF battery electric vehicle (source: http://www.nissanusa.com).

1.1.2 Extended Range Electric Vehicle

Another type of PEV is the extended range electric vehicle (EREV). EREVs are powered by two energy sources: electricity stored in the battery ESS and combustible liquid fuel burned by an internal combustion engine. EREVs differ from hybrid vehicles in that they utilize a higher-capacity battery to allow for an all-electric range and they must plug into the electrical grid to fully recharge the battery. The internal combustion engine can provide the motive force for the vehicle, but also maintains the charge of the onboard battery above a minimum state of charge. EREVs typically have a smaller battery than BEVs because the vehicle has the gasoline engine/generator for backup power. The Chevrolet Volt, for example, is a type of EREV with a reported battery capacity of 16 kWh, with an advertised all-electric range of approximately 40 miles (Figure 3).

Figure 3. Chevrolet Volt plug-in hybrid electric vehicle (source: http://www.chevrolet.com/volt).

Manufacturers of EREVs use different strategies in balancing propulsion power from the electric drive system and internal combustion engine (ICE). For example, the Chevrolet Volt normally only uses the battery for propulsion until the battery reaches a minimum state of charge (SOC), after which the ICE generates electricity for the duration of the vehicle range. It should be noted that some in industry group the Volt as a PHEV and that other PHEV manufacturers blend electric and ICE power differently to meet driver demands for speed and acceleration. Frequently, PHEVs use a naming convention such as “PHEV-20” to indicate that the all-electric range is 20 miles.

Battery capacity is an important consideration for V2G operations. Other factors to consider for V2G and the differences between PHEVs and BEVs will be explored in Section 2.

1.1.3 Vehicle Energy Storage System Design

The ESS for contemporary PEVs is largely electrochemical in nature (some solid-state vehicle ESSs using ultra capacitors exist but have yet to be commercialized). The ESS consists of cells, modules, packaging, a thermal management system (TMS), and a battery management system (BMS). The various components are shown in Figure 4 (the TMS is not shown in its entirety; components such as fans, pumps, heat exchangers, and radiators are omitted for simplicity).

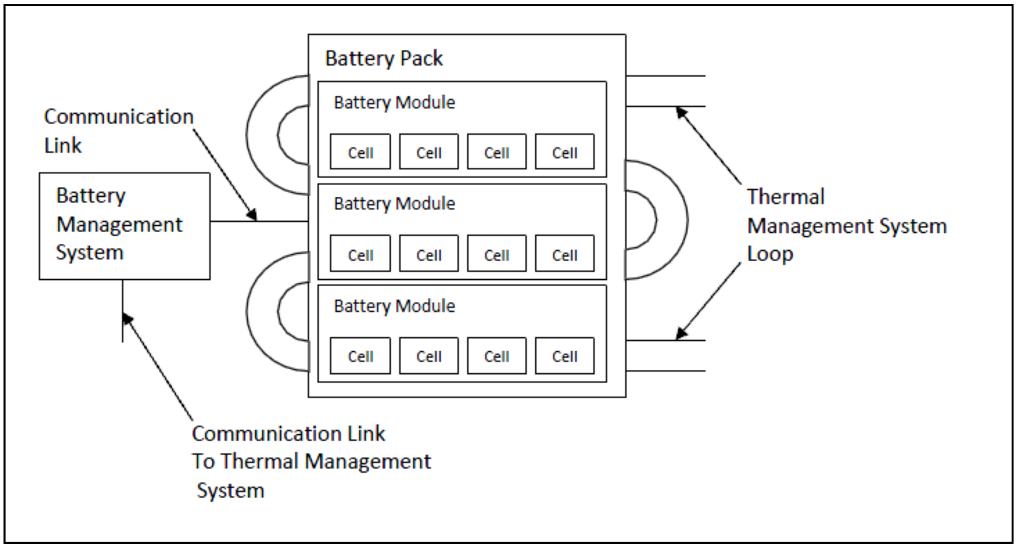

Figure 4. Schematic of an energy storage system.

A battery pack is built from hundreds to thousands of cells that are assembled into modules by connecting them electrically in a series to increase the voltage. The modules are then electrically connected in series or parallel (to increase the voltage or the energy capacity, respectively) to form the battery pack. The three most common types of cell packaging are cylindrical, prismatic, and pouch cells; at present, the industry appears to be favoring prismatic cells for ease of manufacturing and pouch cells because the lack of a casing allows for a higher energy density.

The most advanced ESS cells use lithium-based chemistries (i.e., Li-ion and Li-polymer). These chemistries have proven to contain higher energy and power densities, along with higher specific energies and densities, than previous chemistries such as nickel-metal hydride and lead-acid. These advanced chemistries also allow for lower self-discharge rates (approximately 5% per month for Li-ion batteries versus approximately 30% per month for nickel-metal hydride batteries) and less significant memory problems that hampered the longevity of previous chemistries (Electronics Lab 2011).

The packaging of the modules and pack depends on the manufacturer and application (i.e., the specific vehicle model). Because traction ESSs are usually voluminous, heavy, and subject to large physical forces, as well as vibrations and severe environments, rigorous structure and fastenings are required. This protection is particularly necessary for ESSs consisting of pouch cells that are vulnerable to physical damage. The packaging is usually a metal casing that protects not only the pack components, but also the outside environment from any thermal events occurring during pack failure.

The BMS is the control center of the ESS. It manages the physical state of the pack, modules, and individual cells, and ensures that the ESS provides the required function. The BMS is responsible for keeping track of the state of charge (SOC) of the ESS and will control the current flow both into (during a charge event such as regenerative braking or normal recharging) and out of (during a discharge event such as normal driving) the ESS. The SOC must be calculated using a model because it is not directly measurable. Most BMSs monitor the energy flow (in amp-hours) and use formulae based on the cumulative energy throughput, voltage, and temperature values to calculate the ESS SOC. Basic BMSs will sample, without retention, pack physical states. In more advanced BMSs, the voltage and temperature values of individual cells are monitored and the total energy delivered and the total operating time of the ESS since manufacture is tracked. The BMS also must equalize the charge in the battery cells to prolong the lifetime of the pack and prevent premature cell failure. Finally, the BMS manages the TMS.

The TMS ensures the temperature range of the ESS and of the individual cells is not exceeded and that temperature gradients within the pack are minimized. This function is crucial because ESS temperature influences the availability of discharge power and of charge acceptance and also is a significant factor in ESS longevity. TMSs can have thermal fluids of either air or liquid; these thermal fluids can be either actively or passively circulated through the system. Liquid fluids generally provide superior thermal management due to higher thermal conductivities and smaller boundary layers. Active systems are generally defined as systems where the thermal fluid, either the primary fluid through the pack or the secondary fluid that receives or provides heat to the primary fluid via a heat exchanger, is actively pumped. In a passive system, the thermal fluid(s) flows passively through the system. Finally, TMSs can provide cooling only or heating and cooling, depending on the complexity of the system.

There are communication paths between the BMS and the pack and between the BMS and the TMS. Communication is generally accomplished via controller-area network links for vehicles; these communications are essential to proper ESS function. The BMS communicates with the pack contactors, which are the connectors (or gateway) to the vehicle high-voltage bus. When power flow to or from the battery is desired, the BMS signals the contactors to close, and when no power flow to or from the battery is desired, the BMS signals the contactors to open. The communication link between the pack and the BMS also sends measured parameters (such as voltage, temperature, and amp-hour information) to the BMS for control purposes. The communication link between the BMS and the TMS allows for the former to turn the thermal management on/off and control the amount of thermal management to achieve the desired temperature (i.e., maintain the temperature within the specified pack and cell range).

1.2 Vehicle-to-Grid Definition

V2G technology can be defined as a system in which there is capability of controllable, bi-directional electrical energy flow between a vehicle and the electrical grid. The electrical energy flows from the grid to the vehicle in order to charge the battery. It flows in the other direction when the grid requires the energy, for example, to provide peaking power or “spinning reserves.” It should be noted that this is the way V2G would work if a vehicle had such capability, but there are currently no original equipment manufacturer (OEM) vehicles available to the general public with V2G in the United States.

Studies indicate that vehicles are not in use for active transportation up to 95% of the time (Letendre and Denholm 2006) and the underlying premise for V2G is that during these times, the battery can be utilized to service electricity markets without compromising its primary transportation function. Subsets of V2G technology include vehicle-to-home (V2H; when the electric vehicle is at a residence) or vehicle-to-building (V2B; when the electric vehicle is at a commercial building). In these cases, the battery power is used to supplement the local building electrical load without transfer to the electrical grid. Note that this still effectively displaces building load from the grid, which effectually provides a load-shed function. Alternatively, if there is a power outage from the grid, this permits emergency backup power to continue building processes.

1.3 Motivations for Vehicle-to-Grid

Significant interest exists in exploring the possibilities for V2G operations. The parties that would be involved in any V2G operation include the vehicle battery supplier, the vehicle supplier, the vehicle owner, the electric vehicle supply equipment (EVSE) owner, the business/home, the aggregation/ curtailment services provider, and the electrical utility or independent system operator (ISO). The U.S. Department of Defense also has significant interest in V2G, as will be noted in a following subsection. As we trace the flow of power during interaction between the battery and the grid, each of these plays a role. In some cases (such as a residential application), the EVSE owner, vehicle owner, and home owner are the same. For commercial operation, there are likely more stakeholders involved. Regulatory and governmental agencies also have particular motivations for investigating V2G. A review of the motivation of each of these entities is provided in the following subsections.

1.3.1 Utility Motivation

The electric utility has two primary obligations: (1) for its customers, it must reliably supply electricity and (2) for its owners/stockholders, it must maintain profitability. Increasingly, utilities also are called on to provide “cleaner” power through higher usage of renewable energy. These goals intersect with the need for load control to cost effectively manage periods of peak load.

Utilities typically respond with innovation when driven by economic impacts or regulatory mandates (which are a form of potential economic impact). Utilities are likely to find bi-directional power flow of PEVs in a V2G system attractive for two main reasons: (1) as a storage medium and load-leveling sink for intermittent renewable energy and (2) as a means of fulfilling their grid support/ancillary services obligations. The following sections expand on the specific rationale for embracing V2G from the perspective of electrical utilities.

1.3.1.1 Renewable energy storage. Lack of cost-effective electricity storage is seen as one of the barriers currently inhibiting faster adoption of renewable energy. In addition, power produced from an intermittent renewable source (such as wind or solar) is not a consistent source and its production may not coincide with daily peak usage. This intermittent nature can destabilize the electrical grid and lead to low wholesale prices for renewables. This reduces the corresponding impact to the return on investment needed to make the project feasible. However, if the ESSs in PEVs could be used as an electrical energy storage medium, and if sufficient numbers of PEVs eligible for V2G operation were connected to the grid at the right times, it would allow for optimized electricity production and deferred sale.

The unpredictability of renewable resources (such as wind generation) on its own may be problematic. In certain locations (such as Denmark, where 20% of the electricity needs can be met by wind energy), there are instances where the grid may be overwhelmed by a surge in wind power. Likewise, because of its unpredictability, a lack of wind will cause a shortage of available energy. By leaving PEVs plugged into the power grid during times when the vehicle is not being driven, the vehicle batteries can act as distributed storage to these states of surplus/deficit renewable energy. If PEVs with surplus energy capacity are left connected to the grid during daily peak energy demand periods, this stored renewable energy can be supplied to the grid at a rapid rate, potentially reducing the need for incremental peaking power plants. If the power is stored during periods of low usage, such as at night, the energy consumption can be deferred to offset periods of higher demand, thus flattening the system load curve. The hope is that V2G will enable synergistic operation of both PEVs and renewable energy sources, thereby assisting both PEVs and renewable energy in increasing market penetration.

1.3.1.2 Grid support. There are two main categories of grid support for which V2G might be useful. The first is providing peak power, because meeting the demands of peak power currently is a very expensive obligation for utilities. If vehicle ESSs could be charged during off-peak times and then discharged selectively to “shave the peak,” the utility could potentially forego the need to start up a peaking plant, which would save on operation and maintenance costs and yield significant environmental benefits. Peaking power plants are sometimes used only for several hours per year. Utilities have strong predictive capability for peak load planning (mostly during the summer due to air-conditioning load). The ability to activate distributed storage, along with traditional demand response (DR) assets, provides a cost-effective and clean alternative to expensive and capital-intensive spinning “peaking plant” generators. Therefore, the cost-benefit of a V2G system as a substitute for a peaking plant will depend on the utility, region, power plant mix, and demand (Kempton et al. 2001). The very need to build peaking plants could potentially be avoided, thereby saving millions of dollars in deferred infrastructure spending.

The second category is the V2G system providing the operating reserve. The operating reserve is the generating capacity that is available to come online within a short time in cases of generator failure or other disruptions to the electricity supply. Operating reserve plants require quick response times, accurate power supply, and are typically used for short durations; these criteria match the capabilities of vehicle ESSs exactly. Utilities must have access to operating reserve plants for all 8,760 operating hours of the year (Letendre and Denholm 2006). There are two types of services, known as ancillary services, which apply to V2G systems and operating reserve – regulation and spinning reserve:

- Regulation service (voltage or frequency response) is provided by generators on automatic generation control that measure the instantaneous difference between load supply and load demand. Regulation can be "up" or "down," meaning that there is higher demand than supply and vice versa, respectively. These regulation services must typically respond in 4 to 10 seconds.
- Spinning reserves are power plants that are already "spinning," or ready to provide power to the grid quickly. They must be able to be ramped up to full power in 10 minutes. Although spinning reserves must remain operational at all times, they are rarely used and, when used, they are only in operation for short durations. For example, in 2005, one regional transmission organization (PJM Interconnect, which serves Atlantic coastal states and parts of the Midwest) experienced 105 events requiring spinning reserve deployment. The average duration of the events was only 12 minutes (Letendre 2009).

Services that are potentially available from V2G would have the effect of reducing the electrical utilities' capital costs of building power plants and reducing the operating costs of these plants. A February 2010 report from Sandia National Laboratories (SAND2010-0815) outlined the benefits and market potential estimates for using aggregate energy storage with the electrical grid generation, transmission, and distribution. The energy storage applications identified in the Sandia report are identified as follows (with appropriate V2G applications indicated in bold italic):

- ***Electric energy time shift***
- ***Electric supply capacity***
- ***Load following***
- ***Area regulation***
- Electric supply reserve capacity
- ***Voltage support***
- Transmission support
- Transmission congestion relief
- Transmission and distribution upgrade deferral
- Substation onsite power
- ***Time-of-use energy cost management***
- ***Demand charge management***
- Electric service reliability
- Electric service power quality
- ***Renewables energy time shift***
- ***Renewables capacity firming***
- ***Wind generation grid integration.***

The above list of potential applications of V2G illustrates the concept attractiveness for electrical utilities (Eyer and Corey 2010).

1.3.2 Aggregator Service Providers

Participation in V2G services is primarily a function of minimum required storage capacity, vehicle ESS SOC, scheduled lead time for next operation of vehicle, electricity rates, and market signals (e.g., price, renewable mix, and regulation). A single vehicle battery has little impact on grid operations, but when a large number of vehicles are available, the aggregate battery storage capacity increases to the point that it may have a significant impact. The role of the aggregator service provider would be to manage groups of battery sources to provide the overall service to the electrical utility or regional ISO. The aggregator provides a single point of contact to manage the entire load/source and to guarantee and certify the participation level. The aggregator enrolls and integrates participants, assures sufficient availability, passes through control signals, validates participation, and reconciles payment streams for the market services.

The aggregator service providers also will need to have a certain level of predictive capability to properly oversize the participant pool so that sufficient committed resources can be guaranteed. The system needed for this requires that sophisticated device communication and messaging protocols be implemented to ensure that the energy transfer to and from the ESS can be programmatically controlled and optimized by both the vehicle owner and the grid operator. The ESS SOC and PEV owner preferences for timing and level of minimum SOC are communicated to the aggregator for control strategy decision for all vehicles participating in the V2G system.

In some cases, the unregulated utility may choose to develop and deliver aggregation service to the regional market, although it is expected that this will typically fall to an independent third party with expertise in communication networks and customer application deployment.

Specifically, the following storage applications as identified (and grouped) in the Sandia report can be implemented through aggregated PEV storage using V2G systems, and these will be further delineated and assessed in the following phases of this report. The following, which contains elements that are applicable to V2G, appear as a subset of the list available in the Sandia report:

- Electricity supply
  - Electric energy time shift
  - Electric supply capacity
- Ancillary services
  - Load following
  - Area regulation
  - Voltage support
- End user demand side services
  - Time-of-use energy cost management
  - Demand charge management
- Renewable generation integration
  - Renewables energy time shift
  - Renewables capacity firming
  - Wind generation grid integration.

1.3.3 Business/Home Owner Motivation

In some situations, a building owner may wish to make use of bi-directional power flow capability in order to provide emergency backup power, offset or supplement the building electricity grid supply, or to act as a conduit and sell the stored energy and power capacity to the utility. In this sense, the flow from the vehicle is similar to photovoltaic (PV) systems, although of course the latter does not have bi-directional capabilities. As mentioned previously, this situation is known as V2B. It is important to note that the benefits to the utility of bi-directional charging would be different for V2G and V2B functionality. In a V2B scenario, the utility may not be directly involved in the bi-directional electricity flow and the building owner uses the bi-directional capability to reduce the building demand during on-peak times. The reduction in the building owner's peak demand and total electrical kilowatt hour usage can be an attractive motivator to induce the owner's participation. The attractiveness of V2B is less than V2G for a utility because only peak demand is reduced and no electricity storage is made available to the utility. On the other hand, the complexity of the system is reduced because coordination of, and communication between, the vehicle chargers and electricity grid is no longer necessary. In either case, the safety requirements of Institute of Electrical and Electronics Engineers (IEEE) 1547 dictate that anti-islanding isolation is provided to ensure complete isolation from the electrical distribution system when utility workers are restoring outages. V2B or V2H capability could serve as a power source backup for the business or home, but the evaluation of V2B or V2H systems are outside of the scope of this investigation.

1.3.4 Electric Vehicle Supply Equipment Owner Motivation

The EVSE provides the connection between the vehicle's battery and the building electrical services that connect to the electrical grid. The EVSE and vehicle must be designed for this bi-directional flow and provide for the communications flow paths to allow the access and control of both the charge and discharge of the vehicle battery. The EVSE owner purposefully will have purchased this highly functional EVSE with these capabilities in mind because of the potential financial benefit of participating in the aggregator services offering. This selection requires a well-informed EVSE buyer, along with specific access and management tools provided by the aggregator/utility.

1.3.5 Vehicle Owner Motivation

In a V2G system, a PEV will be plugged into the grid when not in use and electric utilities, ISOs, or third-party electric vehicle service providers (EVSPs) will have direct access to, and control of, both the charge and discharge of the vehicle batteries for a variety of electric system reliability and economic recharging decisions. In a V2G system, the vehicle owner or fleet manager becomes both a consumer and seller of electrical energy and capacity. Because the vehicle owner controls the source of the V2G capability, the informed owner may be in a position to benefit from the bi-directional flow. Reduced electrical rates in exchange for the V2G power flow or direct compensation may be the motivator to enlist the vehicle owner's support.

There are three interests for the vehicle owner and they are conflicting:

1. The vehicle is the owner's mode of transportation and needs to be charged to a sufficient SOC so that it meets the driving needs of the owner when the owner wants to use it. At a minimum, the owner needs to understand the terms and conditions of his/her contract with the electrical utility so that he/she is not surprised with an unexpectedly depleted battery when he/she wants to drive the car. (Note that EVSE designed for this function will likely have customer over-rides or programming available to ensure that a minimum SOC is maintained in the battery to satisfy the owner's needs.)

2. The vehicle owner will want to earn revenue through energy arbitrage from every kWh of electricity that is discharged from their vehicle's ESS to the electrical grid or for simply making its capacity to discharge available for such action.

3. Each cycle undergone by the battery will contribute to battery degradation and will reduce the useful life of the battery. The rate of degradation will be of utmost concern to the vehicle owner (and the auto OEM as a warranty obligation), because battery replacement is expected to be expensive in the foreseeable future.

The vehicle owner will likely worry less about net SOC depletion for their battery when it is used for near real-time frequency regulation services. Unlike the peak shifting application described above, the use of the batteries for these ancillary services can be coordinated with a bias toward a net-positive recharge cycle to replenish the battery energy. The vehicle owner may be able to set a specific required SOC for his/her battery and allow the car to charge and discharge harmoniously with the expressed grid need.

To increase acceptance of V2G, consumers must be properly educated and consent to deploying the technology. Information must be readily available for individuals that pertain to off-peak charging and its positive effect on load stabilization. Additional education in regard to the way energy will be supplied from the battery to the grid will be required. Skeptics immediately assume that if one participates in V2G, the battery in the vehicle will be depleted each time (Levitan 2010). In reality, the use of shallow cycles, instead of deep cycles, will cause less battery degradation. As a result, grid regulation and spinning reserves are functions that best utilize V2G resources (Letendre 2009). The State of Illinois had a program in place designed to educate consumers on smart grid technology, DR programs, and alternative rate structures (Schwartz 2009). If consumers are provided complete information on V2G technology plans, benefits, and risks, they will be able to make thoughtful decisions about whether participation in a V2G program is right for them.

This segment of stakeholders has much to gain from a strong outreach and education effort. These early adopters have paid a significant investment premium for the battery storage capacity and may be willing to participate in easily accessed and understood programs that can be adopted to earn grid service revenue streams.

1.3.6 Vehicle Original Equipment Manufacturer Motivation

V2G demands additional charge and discharge cycles from a vehicle battery, which may reduce its longevity. It also adds complexity to the vehicle’s design and operation and increases vehicle cost. For example, the OEM would have additional costs for a bi-directional charger. V2G system development is costly for automakers and requires unprecedented levels of collaboration with electric utilities, EVSE suppliers, and other organizations. Reduced battery life due to V2G could increase automotive OEM warranty costs. V2G also puts automotive OEMS at risk of liability. Finally, widely varying codes and standards for V2G-capable vehicle design and operation across market regions make it difficult for automakers to produce a product that complies with all codes and standards. Presently, it is not apparent that customer demand for V2G will be sufficient to outweigh the risks involved and costs required.

Implementing V2G does not help auto OEMs meet regulatory requirements. Current environmental regulations on automakers are aimed at reducing vehicle greenhouse gas emissions by regulating vehicle fuel economy. The automaker does not receive credit for any reduction in greenhouse gas emissions from the electric grid that might be brought about by V2G. As noted previously, however, utilities are under increasing pressure to incorporate a higher mix of renewables into the generation supply mix. The benefits of the stabilizing function that V2G offers could become monetized and flowed to the OEMs as an enabling contributor to this clean energy value chain.

1.3.7 Vehicle Battery Manufacturer Motivation

Like the OEM, the battery manufacturer understands that the primary function of the battery is to provide the motive power for the vehicle. Battery manufacturers are under pressure to increase battery performance (for increased range and motive power) and battery life (longer warranty service). Increased capacity and life lead to greater public acceptance of the PEV to meet the daily needs of the consumer. Activities that may reduce the battery life will be contrary to the interests of the battery supplier unless other motivations exist. While the frequency regulation services may have little effect on battery life, deeper cycles of charge and discharge, supporting energy arbitrage and peak shaving, are anticipated to have an effect. Battery suppliers to automotive OEMs that allow V2G operations will need to consider these effects in meeting the required vehicle specifications. Such factors may affect the battery size and cost to the OEM.

The secondary use market for post-electric vehicle redeployment into community energy storage or other distribution system support is a potential field that may offer the promise of additional life (and therefore offsetting revenue sources). This could help justify a more aggressive use of the battery as a grid reliability service.

V2G must compete with stationary battery storage. These batteries operate in less rigorous environments and can be of significantly greater weight. This is serious competition to V2G. However, the V2G ESS usage is a secondary application for vehicle ESSs, while stationary ESSs will have just the single application, making the initial expenditure more difficult to justify.

1.3.8 Regulatory/Government Motivation

Utility regulators are under pressure from rate payer advocates and state/municipal governments to maintain reasonable electric rates and reliable electric service delivery. This is their primary focus. V2G falls far ahead on the curve of radical change to existing policies and conventions. This may lead to a bias toward "business as usual" and consequently deferring hearings/rulings.

Another disincentive for action on these issues can come from vested interest groups (typically utilities or energy companies) who do not want to move too quickly on establishing requirements that may place some uncompensated financial and technology burdens on them. Another area of disincentive is the natural tendency for bureaucracies to create jurisdictional walls between themselves that prevent action where coordinated resolution is required. This may lead to conflicting codes and standards created by the separate groups.

There is some motivation among the more forward-looking regulators to promote policies that will support rapid advancement of the V2G business models. At the national level, the Federal Energy Regulatory Commission is a strong champion for creating market-driven systems that incent participants to provide the needed energy and capacity services to keep the grid cost effective and reliable. For example, Jon Wellinghoff, current Federal Energy Regulatory Commission Chairman, has the opinion that V2G is a viable mechanism to help promote the wider adoption of both EVs and renewable generation and that PEV owners could make as much as $3,000 a year in income for providing ancillary services. Wellinghoff further believes that V2G systems will be in place in 3 to 5 years in the United States (LaMonica 2010).

At the state regulatory level, these motivations include alignment with politically supported state environmental agencies and initiatives and association with initiatives that drive economic or energy concerns. California, for example, has issued Legislative Order 626, which directs the California Public Utilities Commission to lower adoption barriers to widespread adoption of PEVs, which includes empowering third-party providers to deliver innovative business models such as V2G.

1.3.9 Department of Defense

The Department of Defense has identified that a significant portion of the military bases in the United States depend on the local electrical utility for their electrical supply. The vulnerability of bases in the event of an electrical failure (i.e., loss of a substation transformer for a significant period of time) or act of terrorism is then a matter of national security. As a result, defense agencies have established goals for being able to isolate from the local grid to power critical systems. The resulting base electrical system is then a "microgrid."

"A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode" (Ton 2011). The U.S Navy has among its goals that by the year 2020, 50% of all installations will be net-zero (i.e., energy taken from the local grid and energy provided to the local grid through base generation will be equal) and 50% of total Department of Defense energy consumption will come from alternative sources (Hicks 2011). The increased use of renewables to support the energy independence of installations also leads to the search for solutions to provide voltage and frequency control of this microgrid through ancillary services.

While microgrid support is a long-term goal, providing ancillary services is a near-term goal. There is a significant fleet of non-tactical vehicles on any military base used for a variety of missions. Assuming that PEVs can perform the same mission as vehicles with an ICE, replacement of these vehicles with ICEs serves two purposes. The mission of the vehicle can be augmented to provide ancillary services through V2G and at the same time assist in meeting the goals to reduce petroleum consumption. The motivation of the Department of Defense is strong enough to demonstrate increasingly complex micro-grids, often with V2G components.

The motivations discussed above are strong enough to continue to drive development and demonstration projects, proving the technical feasibility of V2G. Then much of the continuing motivation will result in the need to split benefits (and any revenue generated) between all the stakeholders (except military) listed above. Each stakeholder will want to see a financial reward for the expense and risk they incur. There are many hands to cross with V2G and the economics must be proven. The path of least resistance may be through fleet owners with the fewest hands to cross to economic sense. Once proven, the V2G benefits can be expanded to greater markets. Stationary storage has many fewer stakeholders and a much more direct business model. The stationary storage, on the other hand, cannot provide the additional vehicle services.

2. VEHICLE-TO-GRID OPERATING MODES AND FUNCTIONALITY

The methods and opportunities used to recharge a PEV from the grid are important to identify because any V2G power will flow through these same means. The device used to deliver electrical energy from the utility grid to the electric vehicle is the EVSE.

Three basic system components are involved that define the environment for recharging a vehicle or discharging energy from the vehicle to the electrical grid: (1) the location where the vehicle connects with the electrical grid, (2) the EVSE to which the vehicle connects, and (3) the electric vehicle (or more specifically the BMS/ESS) that manages the SOC. As seen below, the environment may be a person’s residence, the employer workplace, fleet vehicle parking lots, or a publicly available charging station. The EVSE can be designed to provide alternating current (AC) or DC power to the vehicle. In addition, the EVSE may be designed at several different power levels. The vehicle has several important components that control and regulate the battery charging rates, as well as the battery itself. All of these components play a role in determining the operating modes and functionality discussed in the following subsections.

2.1 Electric Vehicle Supply Equipment Design and Power Levels

There are some changes ongoing over designations of EVSE power levels. Some designations used in the 1990s are no longer accurate. The Society of Automotive Engineers (SAE) and National Electric Code (NEC) recently have established the AC and DC charging levels noted in Figure 5 and Table 1.

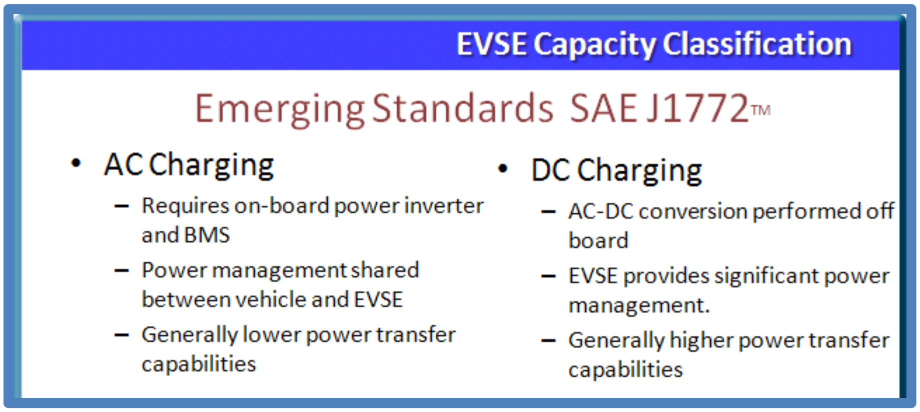

Figure 5. Alternating current and direct current charging comparison.

Table 1. Alternating current and direct current power levels.

AC Charging	DC Charging
AC Level 1: 120 volts alternating current (VAC), single-phase, maximum 16 amps (A), maximum 1.9 kilowatt (kW)	DC Level 1: 200 to 450 volts direct current (VDC), maximum 80 A, maximum 19.2 kW
AC Level 2: 240 VAC, single-phase, maximum 80 A, maximum 19.2 kW	DC Level 2: 200 to 450 VDC, maximum 200 A, maximum 90 kW
AC Level 3: to-be-determined, may include AC three-phase	DC Level 3: to-be-determined, may cover 200 to 600 VDC, maximum 400 A, maximum 240 kW

Many in the industry still use the term Level 3 to indicate DC fast charging (which is now more correctly called DC Level 2). This paper will use the Figure 5 definitions.

Utility power is delivered as AC to the premise where the EVSE is installed. The battery stores DC power; therefore, the conversion from AC to DC is required to complete the charge. Conversely, when V2G power is required, the DC in the battery must be converted to AC to deliver back to the grid.

In AC charging, the AC to DC conversion occurs in the vehicle's onboard charger. In DC charging, the AC to DC conversion occurs in the EVSE off board the vehicle.

2.1.1 Alternating Current Level 1

AC Level 1 is the most basic level of PEV charging and most of the public has easy access to the type of electricity required for AC Level 1 charging at home or at work. Typical voltage ratings found in both residential and commercial buildings in North America is between 110 and 120 VAC rated for a maximum current flow of 16 A.

AC Level 1 charging typically uses a standard three-prong electrical outlet (NEMA 5-15R/20R; Figure 6). The three-prong outlet is attached to a cord set, which also contains a charge current-interrupting device, located in the power supply cable within 12 in. of the plug in accordance with the NEC Section 625 code requirement. The vehicle connector at the other end of the cord set is typically the design approved by the SAE in their Standard J1772 connector. This connector will properly mate with the vehicle inlet, which also is defined by J1772 (Figure 7). SAE J1772 specifies the general physical, electrical, functional, and performance requirements of the electrical connector between a PEV and the EVSE (Figure 8). Most automotive suppliers will use this specific standard in the United States as the connector design for AC Level 1 and 2 charging. Tesla Motors has developed the J1772 Mobile

Connector, which is an adapter specifically designed to be compatible with both the Roadster vehicle's charge port and any J1772 connector. The Mobile Connector was developed because the J1772 standard was not complete when the Roadster was introduced to the marketplace (Tesla Motors 2011).

Figure 6. Typical 110/120-V, 15-A plug; 20-A plug; and 20-A receptacle.

Figure 7. Alternating current Level 1 cord set.

Figure 8. J1772 standard connector.

The J1772 connector is built for 10,000 connections/disconnections and to withstand exposure to dust, salt, water, and being driven over by a vehicle.

Level 1 charging will not offer a particularly fast charge, because the 1.9-kW maximum charge rate would require over 12 hours to fully charge a 24-kWh pack (such as the pack in the Nissan LEAF) and over 8 hours to fully charge a 16-kWh pack (such as the pack in the Chevrolet Volt). Likewise, the discharge capability of 1.9 kW might be marginally capable of powering the emergency backup needs of a small home, without air conditioning or major electrical appliance loads. Because charge times with Level 1 will be significantly longer, it is anticipated that most PEV owners will use Level 2 charging. Some PEV providers suggest that their Level 1 cord set should be used only during unusual circumstances when the Level 2 EVSE is not available, such as when parked overnight at a non-owner's home or in an emergency travel situation.

The cord set provides the basic functions of delivering AC power to the vehicle. Because of the very low level of power transfer capable with this level of charging and its total lack of controls or monitoring capabilities, V2G applications will not be practical or available with this unit.

2.1.2 Alternating Current Level 2

AC Level 2 is typically described as the primary and preferred method for EVSE both for private and public facilities. This level specifies a single-phase current with typical voltage ratings from 220 to 240 V. The higher voltage allows for a much faster charge in PEVs, with a maximum current rating of 19.2 kW. However, currently onboard chargers are the limiting factor, with maximum power capabilities much lower than the maximum charge rate. AC Level 2 charging is intended to support vehicle refueling modes that are coincident with destination locations. The J1772-approved connector allows for current as high as 80 amps AC (100-amp rated circuit). However, current levels that high are rare; a more typical rating would be 40 amps AC, which allows a maximum delivered current of 32 amps.

When connected, the vehicle BMS determines the charge required and draws the current from the EVSE accordingly. Thus, an EVSE that is capable of delivering 30 amps will deliver 20 amps if that is required by the BMS. The EVSE cannot deliver more than its rating; therefore, if a Level 2 EVSE is rated to deliver 20 amps and the BMS requests 30 amps, only the 20 will be delivered. A schematic of an AC Level 2 charging configuration is shown in Figure 9.

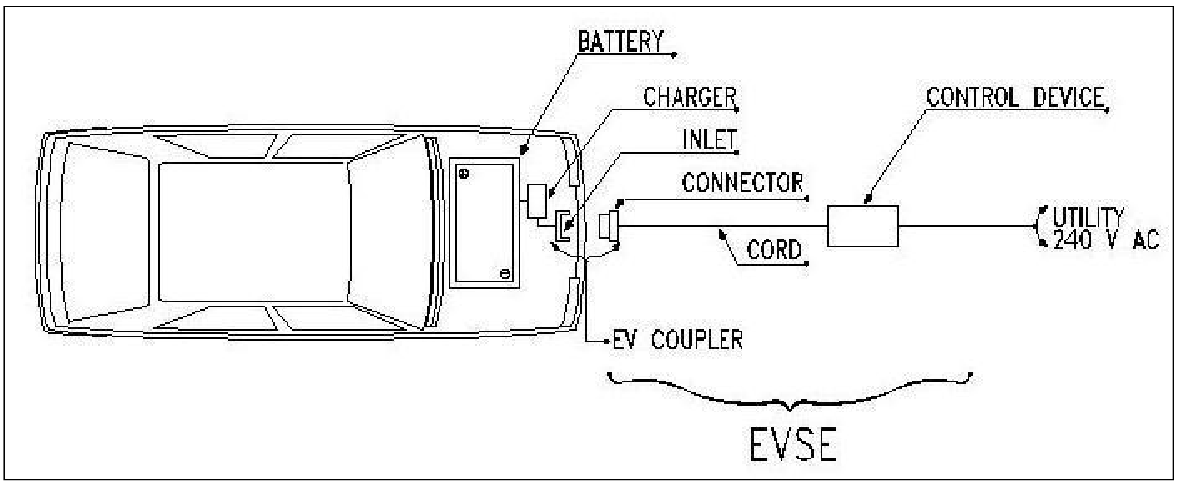

Figure 9. Alternating current Level 2 charging schematic.

There is significant interest in implementing AC Level 2 charging infrastructure around the United States, with the two largest deployments being DOE-funded infrastructure deployment projects called *The EV Project* and *ChargePoint America*. The EV Project is the largest world-wide deployment of EVSE, with more than 8,000 installed (as of September 2011) in 18 strategic markets in six states and the District of Columbia. In the ChargePoint project, Coulomb has installed approximately 3,000 EVSE in eleven states and the District of Columbia.

AC Level 2 charging is expected to be the preferred method for vehicle recharging and for V2G capabilities (if V2G is implemented), because of commonly available input power, and compatibility with applications that allow users to control charging. A typical publicly accessible commercial application for ECOtality Blink AC Level 2 units is shown in Figure 10.

Figure 10. Typical alternating current Level 2 public charging station.

AC Level 2 will factor considerably in the V2G environment because vehicles are expected to be connected to the electrical grid for relatively long periods of time, whether at the employer's workplace, in public, or at home. The power transfer capacity from these connections offers significant functional benefit for facility or grid support services. The planned widespread deployment of publicly available Level 2 EVSE to encourage PEV adoption also will contribute to the capacity of the connected vehicle load source.

2.1.3 Direct Current Charging

DC Level 2 charging, or DC fast charging, is used in commercial and public applications and is intended to perform in a manner similar to a commercial gasoline service station, in that additional range is rapidly restored to the vehicle. Typically, DC fast charging could provide an 80% recharge in 30 minutes for 85 to 100-mile range PEVs (approximately 24-kWh capacity) that are similar to the LEAF (Nissan 2011). DC fast charging typically uses an off-board charger to provide the AC to DC conversion. The vehicle's onboard BMS controls the off-board charger to deliver DC directly to the battery. The off-board charger is served by a three-phase circuit at 208, 240, 380, 480, or 575 VAC. Most suppliers of DC Level 2 equipment plan to provide DC Level 2 charging of 40 to 60 kW peak power, although the maximum power output for DC Level 2 charging is 90 kW. This unit would have an output voltage range of 200 to 450 VDC and a maximum current of 200 A. A schematic of a DC Level 2 charging configuration is shown in Figure 11. It also is possible that a vehicle manufacturer may choose not to incorporate an onboard charger for AC charging and use an off-board DC charger for all power levels. In this case, the PEV would only have a DC charge port.

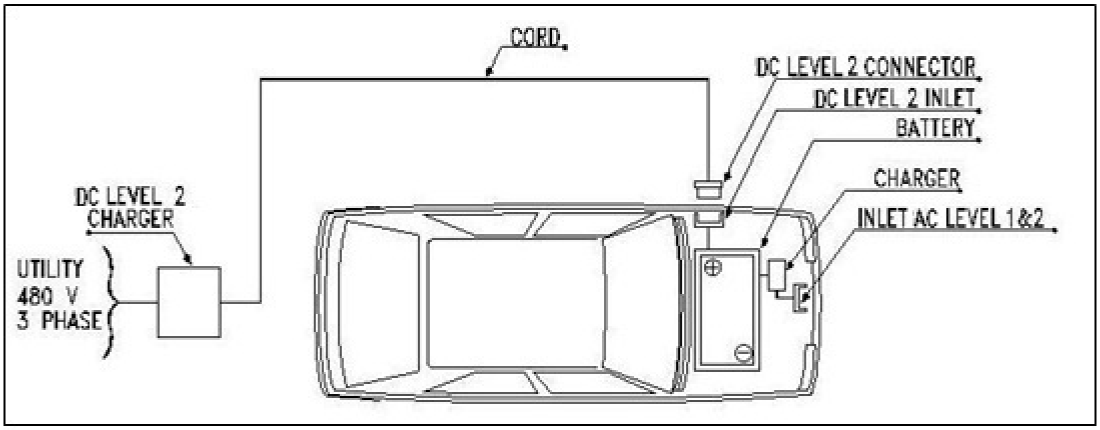

Figure 11. Direct current Level 2 charging schematic. Note that the DC Level 2 Inlet can also be located on any of the other three sides of vehicle, and this is a design decision. For the LEAF, it is located on the front of the vehicle by in AC Level 2 Inlet.

As batteries continue to increase in capacity, it is anticipated that DC charger power will increase as well to maintain short recharge times for these extended range or higher occupancy vehicles. Electric buses for school district and city uses also are being designed for charging by DC Levels 2 and 3. As larger delivery electric vehicles are produced, it is likely that DC charging will play an important role in their charging activities.

In Japan, the CHAdeMO standard has been introduced and adopted by a consortium of Asian PEV OEMs, including Mitsubishi, Nissan, Toyota, and Fuji Heavy Industries (Subaru). In fact, the Nissan LEAF and Mitsubishi i-MiEV are the only vehicles sold today with a DC fast charge inlet. These inlets use the CHAdeMO design, allowing a charging rate of 50 kW (Tepco Association 2010). SAE currently is considering a fast-charge connector design for its U.S. standard, which is expected to be approved in 2012 and will be used for both AC and DC charging. The CHAdeMO design connector and inlet for DC Level 2 charging are shown in Figure 12 and Figure 13. The ECOtality Blink DC Level 2 charger is shown in Figure 14. The SAE recommended “combo connector” is shown in Figure 15. Ford, General Motors, Chrysler, Audi, BMW, Daimler, Porsche, and Volkswagen have all committed to adopting the “combo connector” (Ponticel 2012).

Figure 12. Direct current Level 2 charging CHAdeMO connector.

Figure 13. Nissan LEAF Level 2 inlets (direct current on left, alternating current on right).

Figure 14. Direct current Level 2 charger.

Figure 15. Society of Automotive Engineers-recommended J1772 combo connector.

There is a widely recognized view that the availability of Level 2 public access EVSE infrastructure (both AC and DC) will significantly lower PEV adoption barriers. SAE currently is developing the standard for Level 3 charging for both AC and DC. As shown in Table 1, AC Level 3 charging is expected to involve three-phase power, while DC Level 3 charging is expected to have a voltage range of 200 to 600 VDC and a maximum current of 400 A, with a maximum power of 240 kW. Similarly, DC Level 1 standards are still being developed and will likely offer significant energy transfer capability (current proposed levels are up to 19 kW) through relatively small couplers and perhaps delivered through the same connector that is utilized for the J1772 AC standard. The voltage, current, and power of AC Level 3 charging is yet to be determined and would more likely be implemented in the future with heavier duty commercial vehicles and industrial equipment. This configuration requires dedicated charging equipment that will be non-compatible with typical public infrastructure.

Commercially hosted DC Level 2 EVSE most commonly will be found in metropolitan areas as a “safety net” for range anxiety. One study (Botsford 2009) found that the availability of DC Level 2 allowed the BEV driver to gain range confidence and utilize more of the battery capacity, simply by knowing that those stations existed. Because of the higher cost for this EVSE, the quantity of DC Level 2 is expected to be much lower than commercially hosted AC Level 2 EVSE in a metropolitan area. DC Level 2 also will be found on transportation corridors to enable PEVs to travel between the metropolitan areas. Some interesting shared applications may emerge for DC Level 2 charging at multi-family residential facilities, where individual dedicated AC Level 2 chargers, or even assigned parking spaces, are not practical.

The challenge for V2G using DC Level 2 EVSE for passenger or fleet vehicles will be that although there is the capability for significant power transfer, vehicles are going to be connected for a short period of time and will generally be used only because the PEV driver needs significant power restored to his/her battery quickly. The driver will likely be reluctant to allow two-way power flow or any significant reduction in battery SOC. On the other hand, off-duty buses (or other fleet vehicles) parked overnight may be an excellent resource for V2G aggregation.

2.2 Charging Station Environment

The abundance of gasoline stations usually precludes the conventional internal combustion engine vehicle driver from feeling anxiety over running out of gas. However, the same is not yet true for BEV drivers. This “range anxiety” for the BEV driver presents the characteristic chicken-and-egg dilemma: Will people buy a BEV without having a substantial charging infrastructure and will any host install a charging station if there are no BEV drivers? PHEVs and EREVs are not as susceptible to this as are BEVs, because of the dual-fuel design of PHEVs and EREVs. Nevertheless, it is likely that most PHEV and EREV drivers will desire to utilize their battery as much as possible to reduce liquid fuel consumption for both economical and environmental reasons.

Establishing a comprehensive system of charging infrastructure will provide PHEV drivers with more options for ad-hoc “top off” destination recharging. This should encourage an increase in PEV drivers by satisfying their anxiety over range restrictions.

There are four locations where vehicle owners will likely be able to charge their vehicles: (1) at their residence or primary overnight parking location, (2) at their place of employment, (3) at fleet vehicle charging locations, and (4) at commercial stations. The following sections discuss the four locations in detail.

2.2.1 Residential Charging

Most residential charging is expected to be accomplished through AC Level 2 charging due to the availability of AC Level 2 power from the grid in the residence and the much shorter charge times compared to AC Level 1. Suppliers of AC Level 2 EVSEs provide a variety of features, from very basic to advanced; therefore, depending on the features provided, some form of this equipment will be within the financial reach of most PEV purchasers. Some of these optional features include communications modules, revenue-grade meters, and touch-screen functionality. Forward looking utilities who realize the benefit of advanced controllable EVSEs for enabling/expanding their DR programs may offer subsidies for those homeowners who would consider participating in these programs.

While AC Level 1 charging requires much longer recharge times because of its lower power delivery, some may find that vehicle range requirement and usage is low enough that available recharging time (such as overnight) is sufficient to restore the battery capacity. Most PEV suppliers will provide an AC Level 1 cord set with the vehicle. It should be noted that these AC Level 1 cord sets are fairly simple devices to deliver power only. None are known to contain special features for communications with the vehicle or the utility grid. As with all EVSE, AC Level 1 cord sets are required to meet the safety requirements of NEC and should comply with the SAE J1772 standard for compatibility with vehicles. Both of these requirements will be explored in more detail later.

DC Level 1 (when available) adds too much load for all but the largest residential service panels (i.e., 600 A), and DC Level 2 is completely impractical for single family residences unless the home owner is will to spend significant dollars to upgrade the micro utility grid.

A substantial segment of the public lives in multi-family dwellings (such as condominiums or apartments), where dedicated parking areas may not exist. For this segment, PEV charging may require the use of publicly available EVSEs or other solutions, such as employer-provided EVSE stations.

It is generally believed that PEV drivers will conduct most of their charging at their residence if the infrastructure is installed. The PEV is parked for a significant amount of time and utility rates can be lower during the off-peak evening and early morning hours, and during weekend periods. In fact, many utilities are planning or implementing special electric vehicle-only rates to encourage PEV charging during these off-peak times.

Many electric utilities are implementing advanced metering infrastructure (AMI). This refers to the system of components and communication networks that allow for measurement and analysis of energy use and power demand levels. AMI also provides a means of informing consumers of energy use and patterns, as well as taking action to reduce electrical load in response to utility signals. Informing consumers of their energy use provides an opportunity to change behavior or assist the utility in reducing demand during peak periods. Some forms of AMI include a home area network that may include home components that may be controlled remotely. The home electric loads of interest may include the electric water heater, air conditioning systems, programmable controlled thermostat, and EVSE. When the EVSE is connected and communicating with the home area network and the utility through AMI, DR actions by the utility are possible by curtailing the power draw of these connected loads. The AMI network is a utility-controlled, secure path for bi-directional communications.

PEV owners also may own home PV systems. These solar panels are typically roof mounted, convert energy from DC to AC though a grid-tied inverter, and provide power demand for the building needs with any surplus power flowing through a reversible net meter, back onto the distribution system.

V2H applications are currently being studied for use during residential blackouts or when market prices are sufficiently elevated during peak times. The PEV battery would be used as a storage device and be made available to the home for backup power. V2H may be considered a preliminary step to V2G, because only the house receives the power and the EVSE remains isolated from the electrical grid in conformance to IEEE 1547 requirements for distributed generation (DG) interconnection.

Electric utilities that provide special low-cost electric vehicle charge rates also may require a separate meter to monitor that specific electrical usage. Some EVSE suppliers, such as ECOtality and Coulomb Technologies, provide an internal energy meter that is designed to provide the same function. That meter could allow the utility to separate electric vehicle usage from the rest of the residence for billing purposes.

While the personal residence may be the most common location for V2G operations, the electrical systems of personal residences are not standardized. Each home would require an electrical inspection and assessment to implement V2G. Requirements and codes vary by jurisdiction and characterizing this variation is a primary goal for this study.

2.2.2 Employer Facility Charging

There are differing opinions about the importance of workplace charging at an employer's facility in the overall mix of outside-the-residence recharging. There are those who suggest that employer facility charging will be nearly as important as residential charging. Others suggest it will be significantly less impactful than publicly available charging (discussed in Section 2.2.4). The differences relate to whether or not there will exist a viable business case for hosting publicly available charging at typical commercial destinations and whether the employer can overcome many of the obstacles related to employer facility charging.

The motivations for employers or commercial hosts to provide charging include credits toward Leadership in Energy and Environmental Design certification, providing amenities for employees/ customers that encourage loyalty, credit towards greenhouse gas emission reduction targets, and the potential for advertising revenue. Difficulties for employers include avoiding preferential treatment of some employees, tax implications of benefits provided, cost of EVSE and infrastructure, and managing available charge stations. The costs associated with V2G and especially V2B systems also could be quite substantial. Difficulties for commercial hosts include incurring significant additive load (and corresponding demand charges from their energy provider) to their facility and loss of general parking spaces for Electric Vehicle-Only and Americans with Disabilities Act-compliant parking restrictions.

Many of these stations could be combined with solar canopies or adjacent PV arrays, as well as large format grid-tied battery storage systems, to allow for optimal load management between the facility and multiple networked vehicles. Vehicles arriving for work will typically be connected early and fully charged before area peak demand hours arrive. Peak hours for solar output and for PEV availability then generally coincide with business operation (i.e., facility load). Therefore, these vehicles could offer a significantly cheaper solution to satisfying peak demand needs. This form of storage aggregation also may be used to generate power for an office building to lower costs for the energy requirements of the building or to deliver critical backup power for high-availability business operations, such as data centers. On the other hand, the close of business each day also falls within the peak demand hours. Thus, batteries that may have been depleted during the peak may be unable to recharge or environmentally pre-condition the vehicle cabin for the homeward trip.

Either system would require a PEV owner to determine a minimum battery SOC required for travel after work to allow the vehicle to retain enough of its charge. Both the building owner and the PEV owner must observe an economic benefit for either model to work. In a V2B scenario, the building owner would benefit from reduced energy costs, while the PEV owner receives payments from the facility for the use of the battery. In the V2G system, the facility owner would be compensated by the utility for providing the conduit, and the vehicle owner would again receive payment for the usage of the battery.

It is difficult to predict what role workplace charging will have in the long term, but it will most certainly enable more commuters to venture longer distances on electric power if this recharge option is available. As workplace charging is likely to happen, applicable codes and standards must be adjusted further to lower barriers to this desirable application of electric vehicle recharging. The requirement to evaluate the benefits provided to employees versus the desire to avoid providing free charging will likely require fee-based charging at work that will naturally limit the access to those who actually need the charge. Supply and demand will limit the number of EVSE stations the employer will install. Should V2G systems be proven and the number of employees driving PEVs increase to make a significant connected load, employers may elect to provide workplace charging for the potential benefit it provides the employer in managing electrical costs and obtaining wholesale market payment streams for grid services.

2.2.3 Fleet Charging

Fleet charging is similar to employer facility parking in that it occurs at the work environment. However, the charging stations in use here are for the PEVs owned by the company and are considered supporting systems that enable their business processes. It is not likely that a fleet owner would leave a substantial quantity of fleet vehicles (Figure 16) connected during the work day, which typically coincides with the daily peak demand times. On the other hand, it is very likely that these parked vehicles would be available for V2G services on the non-business hours. It also is likely that a fleet manager would be able to recharge more than one vehicle on a charger. Therefore, the anticipated availability of the connected load is less for fleet vehicles during peak times, yet available fully during off-peak times. Of course, this varies widely, based on the underlying nature and flexibility of the core business operations. Perhaps a business case can be made whereby the foregone V2G benefits are high enough to consider moving the business operation to off peak demand times if possible.

Figure 16. 2010 Ford Transit Connect battery electric vehicle (fleet delivery vehicle) (source: http://green.autoblog.com).

Overall, fleet vehicles account for about 18.2% of passenger and light duty vehicles in the United Stated (Automotive Fleet 2010). The penetration of PEVs into the overall automotive market will need to be substantial before the fleet charging opportunity is significant from a V2G perspective.

Certain types of fleets may have greater advantages in the area of V2G than others. As noted above, electric school bus fleets may provide a significant availability of stored energy that can be resourced quickly during off-duty times. Because these buses would have large battery packs, are typically operated on well-known routes during the weekday, and then parked for known durations overnight and on weekends, the V2G potential is large.

2.2.4 Commercial Charging

Currently, there is a push in the commercial sector to install charging stations, although the effort is just in the initial stages. The type of businesses that will install charging stations will be quite varied and the variety of EVSE installed will vary. Ideally, AC Level 2 stations will be installed in locations where PEV users will stay long enough to allow their vehicles to complete a significant portion of the charge. These venues may include restaurants, theaters, shopping malls, doctor/lawyer/dental offices, and so forth. However, there are locations such as airport parking facilities that may be more suited for the installation of AC Level 1 EVSE for several reasons. One is the relatively long length of time vehicles are parked while travelers are on trips and another is the large number of individual parking slots that may require significant numbers of EVSE. The relatively lower cost of installing AC Level 1 may make such long term parking facilities good candidates for AC Level 1 EVSE. However, the short term parking areas at airports may still require AC Level 2 EVSE, and there may even be a need for DC fast charging for those PEV drivers that are dropping off passengers and then immediately continuing on to other destinations. An airport is an excellent example that there is usually not one charging level solution for all, or even one location.

DC Level 2 charging will likely be used in locations such as fast food restaurants, coffee shops, convenience stores, and gasoline stations where customers will receive a significant charge in a matter of minutes. This placement coincides with the business owners' interest in high customer turnover. DC fast chargers also will be used along freeway corridors between metropolitan areas and in typical areas as noted above. These locations allow a PEV to travel between metropolitan areas that may be farther apart than the vehicle's typical single-charge electric range.

Table 2 provides information on several different on-road, highway-speed electric vehicles, their battery pack sizes, and charge times at different power levels to replenish a depleted battery. Several assumptions and approximations are made in this table in order to provide the illustration. It should be noted that the current mass-produced PEVs on the market (the Chevrolet Volt and Nissan LEAF) have 3.3-kW, onboard chargers, meaning that the actual power delivered to the battery is much less than the value for AC Level 2 listed in the table. It also should be noted that the BMS will often prevent the ESS from reaching a full SOC due to battery or ambient temperatures (i.e., to prevent battery damage from elevated temperatures); therefore, the times in the DC Level 2 column would never be reached in practice with today's battery technologies.

Table 2. Plug-in electric vehicle charge times.

Electric Vehicle Configuration	Useable Battery Size (kWh)	AC Level 1 120 VAC, 16 A, 1.6 kW	AC Level 2 240 VAC, 32 A, 6.5 kW	DC Level 2 480 VAC, 85 A, 60 kW
PHEV-10	4	2 h 30 m	35 m	4 m
PHEV-20	7	4 h 22 m	1 h 5 m	7 m
PHEV-40	13	8 h 8 m	2 h	13 m
BEV	20	12 h 30 m	3 h 5 m	20 m
BEV	35	21 h 53 m	5 h 23 m	35 m
PHEV Bus	50	31 h 15 m	7 h 41 m	50 m

NOTE: *Power delivered to battery was calculated as follows:*

AC Level 1 – 120 VAC x 16 A x .85 efficiency = 1.6 kW

AC Level 2 – 240 VAC x 32 A x .85 efficiency = 6.5 kW

DC Level 2 –480 VAC x √3 x 85 A x .85 efficiency = 60 kW

2.2.5 Connection Times and Durations

2.2.5.1 Residential charging. It is expected that the majority of PEV owners will decide to charge their vehicle when they arrive home from work either immediately during peak load hours or overnight during off-peak hours (Smart et al. 2010). Depending on the penetration of commercial and place-of-employment chargers, residential charging likely will be the dominant method of PEV charging. In this case, the vast majority of the charging will take place from approximately 6 p.m. to 6 a.m. It is conceivable that many PEV owners will begin charging their vehicles immediately upon arriving home after their final trip at the end of the day. For those who have time-of-use (TOU) electrical rates or the capability of programming their charge times, the start of the charge can be delayed. If enough PEV owners were to end their driving day and plug in their vehicles at the same time, there is a risk that the local distribution network may become overloaded. If this proves to be the case, it will be imperative that either individual transformers are upgraded to handle the higher load (an expensive proposition) or that the charging times are staggered so that the local network can be maintained. (Turitsyn 2010). Preliminary testing conducted by the Idaho National Laboratory and the University of California Davis determined that through differences in individual habits, PEVs will be plugged in at varying times throughout evening hours. In the absence of charge delay timers, the demand curve for the aggregate electric vehicle charging load gradually ramps upward (Smart et al. 2010).

From the perspective of the utility, the ideal time for vehicle charging would generally be between the hours of 11 p.m. and 7 a.m. (Leahy 2010). Late-night charging would increase the night-time load, thereby allowing the operation of base load generation to be more profitable. Utility companies (such as San Diego Gas and Electric [SDG&E] and Detroit Edison [DTE] are allowing their customers to choose a special TOU electric vehicle rate to encourage charging during off-peak hours (SDG&E Company 2010).

It also should be noted that not all privately owned PEVs will be used for the work commute. Many PEVs will remain in the residence and be used for other trip purposes.

2.2.5.2 Employer Workplace Charging. Travel behavior is regularly studied at the federal and state levels. These data can be analyzed to estimate when vehicles may be connected at the workplace. This information can affect V2G operations in a variety of ways. The National Household Travel Survey serves as the nation's inventory of daily travel. Data are collected from daily trips taken by survey respondents in a 24-hour period, which provides an understanding of travel behavior of a wide sample of drivers in the North American market. Data recorded in this survey (Figure 17) includes trip starting and ending date and time and destination type***.***

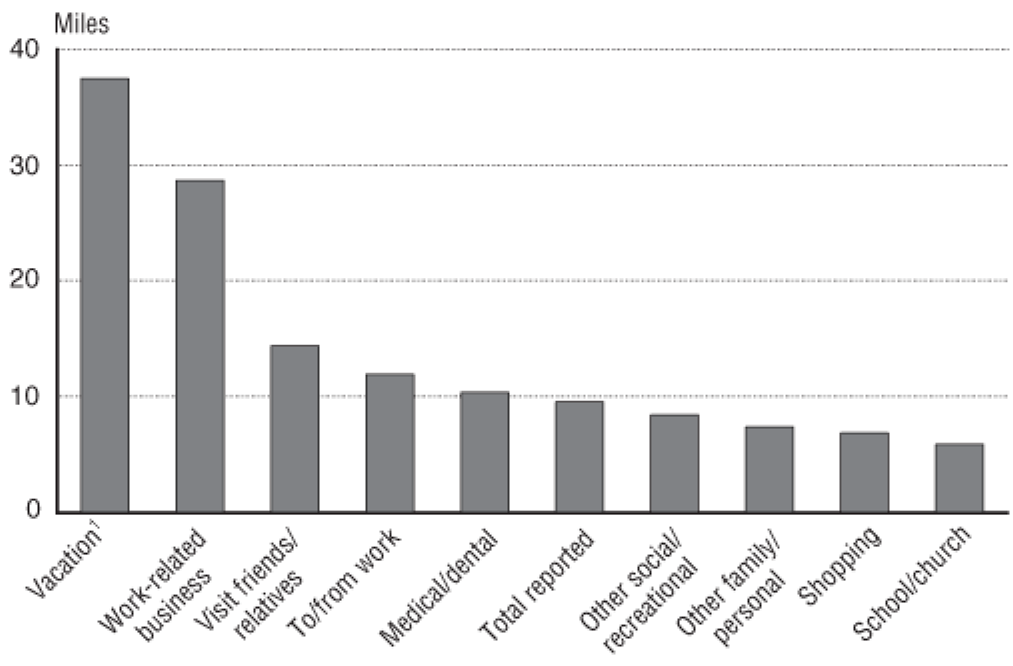

Figure 17. Average vehicle trip length by purpose (source: http://nhts.ornl.gov/).

Distances traveled to and from work are sometimes not the longest trips taken on a daily basis. Because the average distance traveled to work is 13 miles, the vehicle battery for a 100-mile range BEV is likely to still be at a high SOC when arriving at work and could be restored to full charge quickly.

Thus, workplace charging is likely to hit a peak immediately upon the start of business or if staggered start is used, within the first few hours after arrival. This would allow many hours of V2G operation before the return trip home. Control systems would need to identify the needs of the vehicle owner because the employer may not wish to have significant recharge loads late in the work day at times of peak power concerns. Informed employers may employ special workplace incentives (such as flexible hours or staggered start times) to avoid peaks and allow longer V2G operations.

2.2.5.3 Publicly Available Charging. Per the National Household Travel Survey, the 2009 average weekday daily vehicle miles traveled by cars was 31.14 miles. For the daily trips by car, Figure 18 identifies the percent of trips for each of ten purpose categories. Other than trips home, the single most common purpose for vehicle use is to go shopping or run errands, followed by work and social activities. When this information is combined with that of the average number of trips per day, it shows that most drivers make several stops per day. In fact, in the 2009 study, the average number of trips per day per vehicle was just over 3.4. Driving to and from work also generally involves a side trip and stops along the way. Errands also may include a stop for school. These data indicate the importance of providing the convenience of publicly available charging at destination locations.

Connection times at publicly available charging locations will vary throughout the day. Figure 19 can be used to infer the potential for vehicles to connect to the grid at public charging locations, based on the time people may be expected to remain at different types of destinations and the frequency of visits to certain destination types. For example, medical and dental trips will likely occur during daytime hours. Social and recreational trips will be of similar duration, although these may extend to evening hours. Placing AC Level 2 EVSEs at these destinations will provide a significant connected population of PEVs throughout the day for a relatively long period.

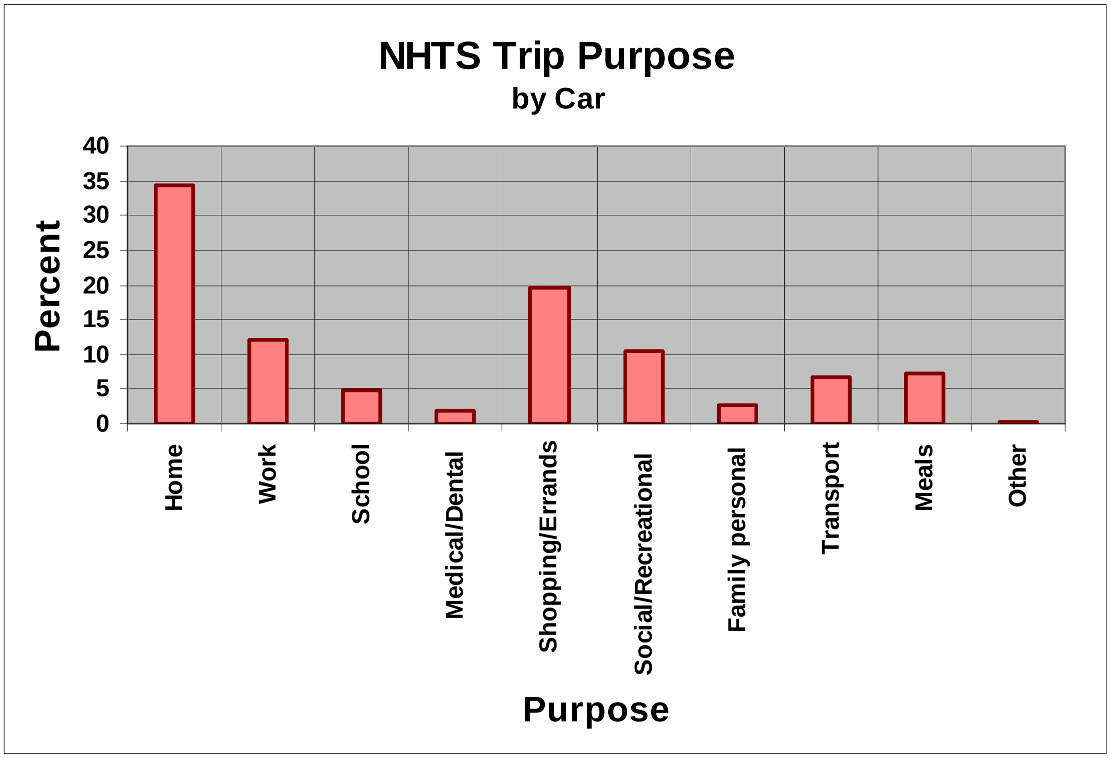

Figure 18. Percentage of daily car trips by purpose (source: http://nhts.ornl.gov/).

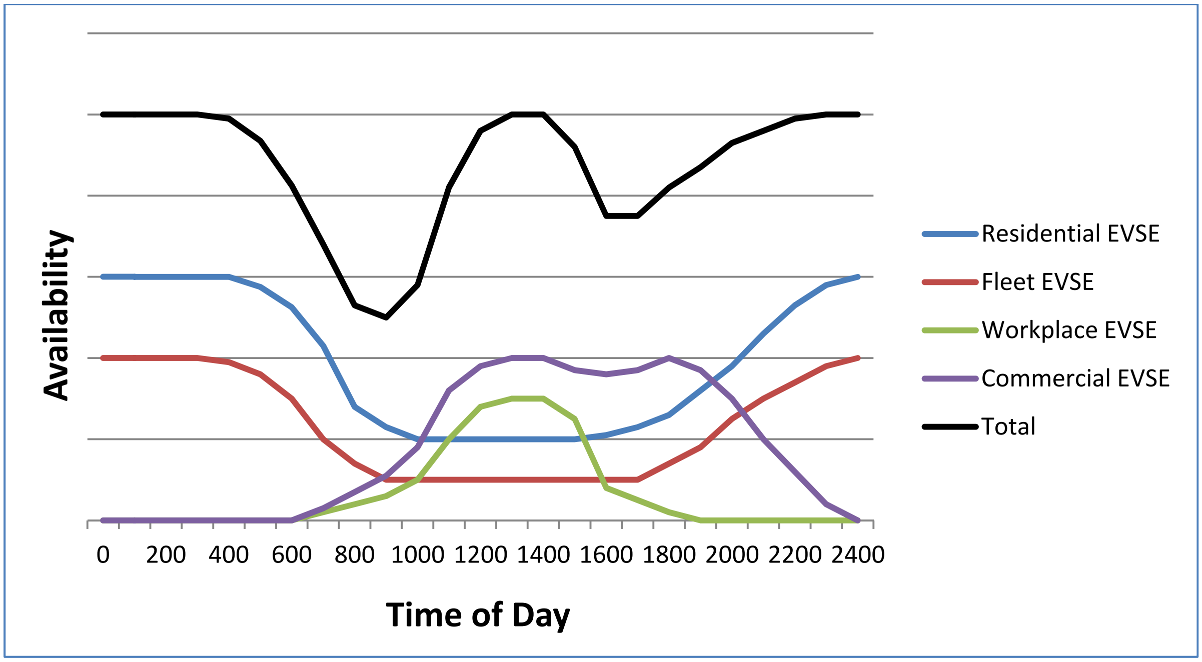

Figure 19. Relative availability of vehicle-to-grid electric vehicle supply equipment.

The availability of V2G services will vary throughout the day, based on the location and utilization of the EVSE. While data on actual usage are not yet available, combining the above evaluations provides the following illustration of expected relative availability of V2G services.

2.3 Physical Connection to the Grid

While the concept of using the stored energy in the vehicle's ESS seems straight forward, the actual equipment and services for doing so can be complex. The following subsections discuss the required equipment, onboard equipment, and V2G communications in detail.

2.3.1 Equipment

The required equipment will include the EVSE, which was described in detail earlier, and other necessary equipment to provide the reverse current flow. The EVSE forms the bridge between the PEV and the rest of the premise wiring and control.

2.3.1.1 Islanding. Before discussing the equipment further, a topic that is important to safety of equipment and personnel is required. Systems that provide power to supplement the utility power (i.e., DG) have the possibility of continuing to provide power even if the main source of power (i.e., the utility grid) is lost. That is, if a power blackout occurs and a PV system is providing power to a home, the home may still be powered, while the surrounding area is not. This situation is called islanding. It also could occur if a vehicle is providing power to the grid and local utility power is lost.

Islanding can be a dangerous situation because utility workers will believe that the local grid is de-energized but may not know that the home or business (that is now an island) remains energized. In most cases, the local utility requirements on DG require anti-islanding devices that will disconnect or shutdown any local generation in the event that power to the grid is lost.

Intentional islanding may be designed for PV systems or back-up generators that are required to continue to operate critical equipment if the local grid power is lost. Intentional islanding may be designed for large PV systems to continue to power a home or business, as well as future designs of V2H or V2B.

In the event that islanding is allowed and appropriate safety systems are included, an additional hazard may develop when it is desired to reconnect the island to the grid. The utility grid operates three-phase AC power. The island AC power must be synchronized to the grid so that all three phases are in synch prior to closing the connecting breakers. Failure to properly synchronize the two systems can lead to significant equipment damage, fire, and personal injury.

2.3.1.2 Photovoltaic systems. V2G systems may make use of the lessons learned from solar collector systems providing power to the home, business, and grid. Figure 20 shows a typical electrical connection of the PV system.

The solar panel arrays generate power and deliver DC to the grid-tie inverter. The grid-tie inverter is required to sense grid AC and synchronize with it, usually within one degree of the AC phase angle. Most times, this is achieved with an onboard computer or an oscillator. Almost all U.S. systems use a transformer for converting DC to AC and the systems are typically negatively grounded due to NEC requirements.

Typically, most grid-tied inverters also have a surge arrestor or surge protective device installed (this function is served in Figure 20 by the metal oxide varistor (i.e., MOV) between the DC disconnect and DC ground fault circuit interrupter).

Typically, the facility main service disconnect will be closed when providing power to the facility (in the case of Figure 20, it is the home). When the grid-tie inverter has the proper synchronization of AC phases, the auto switch is closed and the solar array now provides power to the local system. In a typical operation, if the power delivered by the solar array exceeds the demand of the home, the excess energy is delivered to the utility grid and the meter records the reverse power. If the power delivered by the solar array is less than the house loads, the solar array augments the utility power to supply the home. In both cases, the solar array reduces the home’s energy requirements from the local utility. Each electrical utility in the United States issues their interconnection requirements to protect personnel and equipment in their service territory. Figure 21 shows a typical interconnection layout.

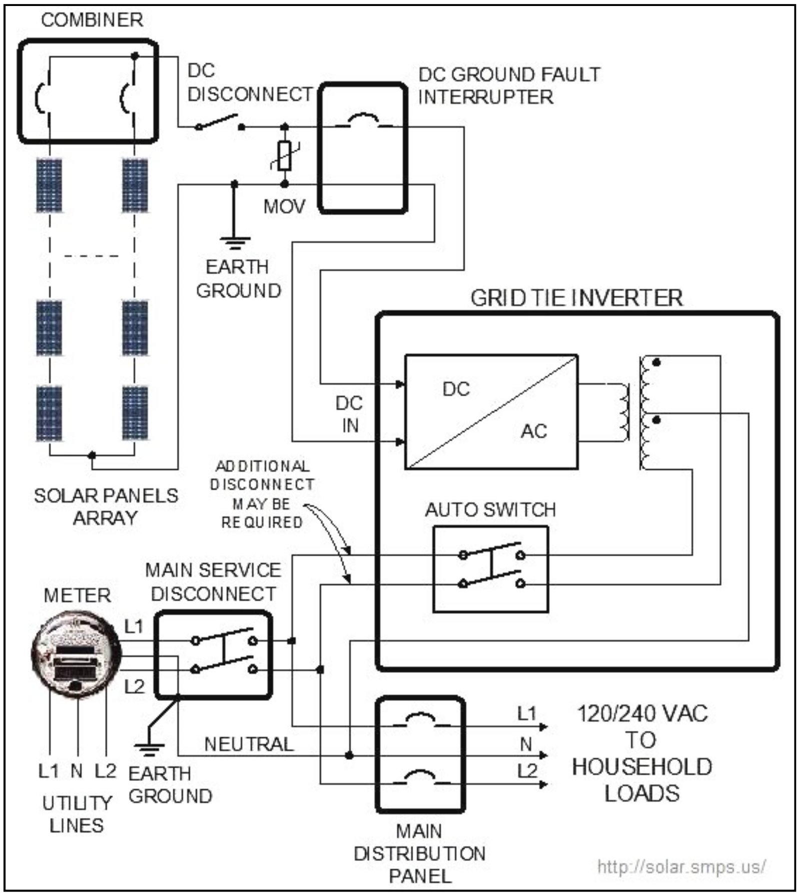

Figure 20. Typical solar interconnection diagram.

Figure 21. Typical solar interconnection (source: Arizona Public Service Handbook for Photovoltaic Interconnection).

The PV system contains equipment to control the solar array output voltage and frequency. This equipment also ensures safety by preventing over-and-under voltage conditions, over-and-under frequency conditions, short circuits, phase imbalance and reversal, and reverse power conditions. These control systems ensure that the output of the solar array meets the utility requirements for power.

In certain situations (e.g., in remote-area power supply systems), the PV system also contains a local storage battery. System operation during the day provides a charge to the battery that can be discharged later at night or during cloudy times when the output of the solar array is reduced.

Solar-assisted electric vehicle charging currently is being deployed that utilizes this equipment, albeit mostly in demonstration projects. Some units contain storage batteries and other may not. In the event that the solar array does not have sufficient output capacity to provide AC to the EVSE for charging the PEV, the connected utility grid provides the extra energy. When no PEVs remain connected, the solar array provides power to the grid. In most cases, the system operates on a "net zero" condition, where the amount of energy taken from the grid during vehicle charging is offset by the energy returned to the grid by the solar array.

With battery storage tied to solar systems, there is greater flexibility for the host, utility, and car owner.

The battery/solar combination can be operated to offset utility-imposed demand charges, it can enable direct renewable-to-PEV source power, and it can provide peak power to the utility. In the future, these batteries also may be called on to provide ancillary services (such as frequency and voltage regulation) under control from an ISO signal.

2.3.1.3 Vehicle-to-grid premise equipment. While V2G and grid-tie local generation are similar, they are not identical. V2G systems are still in the design phases, but many of the same issues will apply. The PEV's battery, through connection with the EVSE, acts as the variable load that can swing to the DG role, which delivers power to the grid when additional supply is needed. With solar systems, which are always in generation mode, the surplus power goes to the grid, whether it is needed or not.

Whether the EVSE is AC or DC Level 2, the EVSE takes on a role similar to the PV system. AC synchronization of the distributed energy resource (DER) to the utility power grid per IEEE 1547 is still a requirement. A significant difference is the ability of the EVSE to provide bi-directional power flow to allow the vehicle to charge and discharge.

EVSE is the interface between the local utility grid and the DER provided by the vehicle. Voltage and frequency controls on the EVSE (or from the vehicle through the EVSE) determine whether the current flow is into or out of the PEV. Communications and control systems signal which direction the current should flow.

PEV-based (and/or fixed local) battery storage enables a homeowner to provide power to home loads when the utility feed falls out or when the wholesale power prices at the desired TOU are excessive.

Outside the vehicle and recharging infrastructure, the smart distribution system also will prove to be extremely useful for V2G control. In situations where an onboard meter will be unavailable to measure electricity consumed and output by the vehicle's ESS, either due to vehicle design or a less advanced EVSE system, a smart residential electricity meter may be used to perform the required measurement and sensing.

2.3.1.4 Vehicle-to-home premise equipment. V2H or V2B power flow may be easier to implement than full V2G because the reverse power interface with the local grid is not required. It will be necessary to provide designs that allow the intentional islanding effects; however, the vehicle (through the EVSE) can provide the power from the ESS to power the local loads. System design must consider the equipment or procedures required to restore the electric utility grid when it is recovered.

2.3.2 Onboard Vehicle Equipment

There are three main aspects of onboard vehicle equipment that pertain to V2G systems: (1) the PEV inlet, (2) the onboard charger, and (3) the ESS. Refer to Section 1.1.3, which discusses the components of this system.

The vehicle inlet and EVSE connector provides the interface between the EVSE and PEV. If the EVSE is AC Level 2 and AC current is delivered to the vehicle, the reverse flow from the vehicle is AC. Therefore, the vehicle converts the battery DC to output AC through an onboard inverter. If the EVSE is DC Level 2 and DC current is delivered to the vehicle, the reverse current flow from the vehicle is DC and the inverter is included in the off-board EVSE.

2.3.2.1 Alternating current Level 2. The BMS will play the primary role in controlling the battery discharge in V2G operations, just as it does in the typical charge and vehicle operations modes. As before, the BMS is responsible for keeping track of the SOC of the battery and overall health of the battery and cells and will control the maximum power level of the inverter.

Communications requesting the V2G operation will originate at the electric utility station and deliver the request to the EVSE. The EVSE will communicate with the BMS to request the power flow. The BMS then controls the output of the inverter to respond.

There may be designs where the PEV provides all the equipment and controls for synchronization and anti-islanding, instead of the EVSE. In this scenario, the EVSE simply acts as the AC conduit. Such systems would require extensive communications capabilities originating from the vehicles to interface with the EVSE and the utility grid. Considering the significant number of OEMs providing vehicles, the large number of suppliers of EVSE, the varying interconnection requirements of the nearly 3,000 electric utilities in the United States, and the varying premise building codes and standards, a significant amount of standardization of codes and standards will be required.

2.3.2.2 Direct current Level 2. For DC connections, the reverse power flow from the vehicle's ESS is DC. The DC EVSE will contain the inverter components to convert the DC to AC for delivery to the grid. The BMS will control the output of the battery in response to communications signals from the EVSE. This mode of connection provides the capability for significant power flow levels, which are extremely beneficial to grid reliability. The effect on the life of the vehicle battery would require study in order to design the BMS to properly control that discharge. Because the inverter is off-board the vehicle, the vehicle could not contain all communications and controls for the interconnection requirements.

2.3.3 Vehicle-to-Grid Communications

The communication path enabling ubiquitous V2G function requires bi-directionality, common protocol, low latency (short time delay), and high reliability. It can be conveniently divided into multiple serially connected segments: utility/ISO (U/ISO) to aggregator/EVSP (A/EVSP), A/EVSP to EVSE, and, lastly, EVSE to electric vehicle BMS (EV/BMS) (see Figure 22).

2.3.3.1 Modes of operation. V2G technology should allow the vehicle operator to program when to recharge and the duration of the charge, while also utilizing information on utility rates for TOU tariffs. While supporting individual users' preferences and price elasticity, the control software will need to simultaneously manage hundreds to thousands of other vehicles, giving the utilities the tools for smart, system-wide PEV recharging, leading to a more stable grid. While the load placed on the grid will be smoothed, synchronization will allow a more efficient use of existing power generation and allow for intermittent, renewable energy generation. It is conceivable that the user could be supplied with information on when renewable energy will be available so that electric vehicle owners could opt to reduce the emissions associated with their charging, and the utility would be able to make use of a resource that might otherwise be squandered.

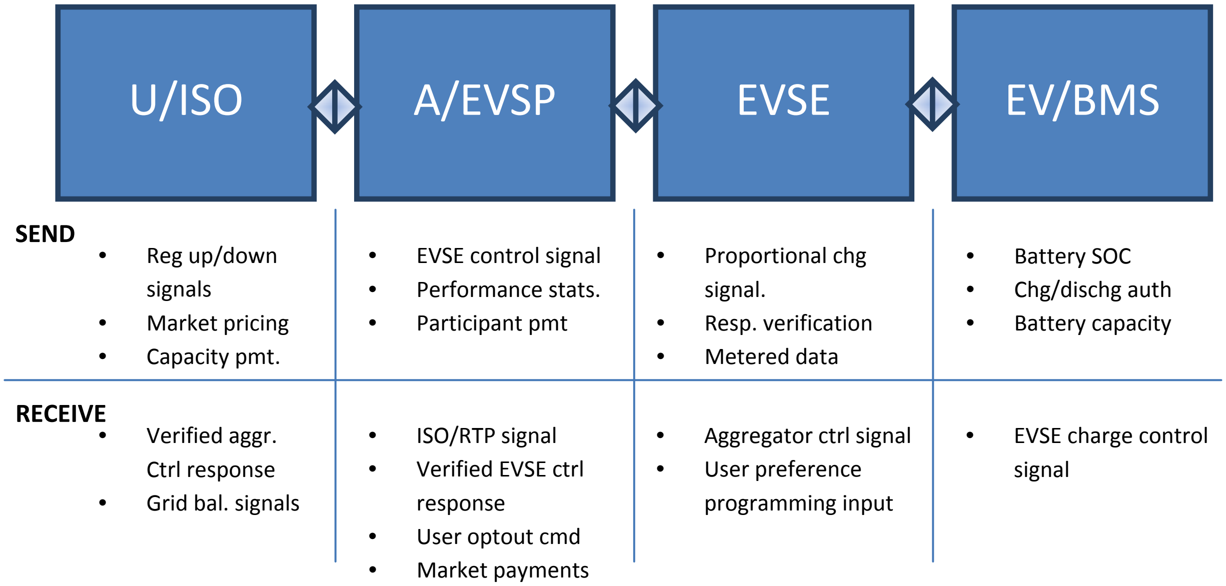

Figure 22. Typical communications paths.

In parallel to these technological advancements, standards and protocols governing the application of these technologies also are being developed. SAE Standard J2836, Parts 1 through 5 were recently updated. The scope of this standard establishes use cases for power transfer between the grid and PEVs, including reverse power flow. SAE J2847, Parts 1 through 5 apply the use cases defined in the J2836 protocol. The network used for the vehicle and the EVSE is defined in SAE J1850. SAE J2293 underwent revision in July of 2008 to define V2G bi-directional flow and update the communication medium from a previous standard to either power line communication or wireless. Establishment of communication requirements for the EVSE as it communicates with the home, an energy management system, and the utility grid systems are defined in SAE J2931. These standards provide a consistent set of requirements, ensuring that the various EVSE manufacturers create products that are compliant in their interface with the grid (Department of Energy 2010). The National Institute of Standards and Technology (NIST) standards and the IEEE Standard 1547 provide use cases for information exchange, monitoring, and control of distributed resources that are interconnected with the power grid (Mullen 2009).

As further testing of V2G technology and communication protocols are implemented, standards will require further revisions and inclusions to create a reliable and user-friendly interface between the grid, the vehicle, and the vehicle operator. These communications are a crucial aspect to the successful introduction of V2G and, particularly so, because of the distinct lack of standardization at the present time.

2.4 Implementation Issues

There are a myriad of implementation issues that must be addressed before V2G systems can be widely adopted. Many belong in the business process, public policy, or standards domains. Some of the most prominent are discussed in the following subsections, although this list should not be considered exhaustive. This section is intended to frame the discussion for potential mitigation strategies that could be used for lowering these adoption barriers.

In general, the primary issues that are holding back a broad-based V2G implementation are identified in the following subsections. The subsequent phases of this report will more fully define these issues and cite examples where mitigation measures are observed.

2.4.1 Stakeholder Motivation

The general motivation of stakeholders was explored in Section 1. This section focuses on the interests and concerns of these stakeholders that provide barriers to V2G adoption.

2.4.1.1 Electric utilities. All electric utilities face complex regulatory and financial barriers to implementing new technologies and business models. These barriers certainly apply to V2G applications, which bring new technology barriers, such as non-traditional interoperability requirements, rapidly evolving standards, unknown impacts on long-term electric vehicle battery life, and low network latency requirements. Non-technology barriers include lack of available investment capital, additional compliance filing burdens, unclear grid reliability responsibility and accountability, and lack of certainty in prices for forward capacity markets, as well as political disruption from the status quo. Electric utilities can be viewed in three distinctive classifications that are created by their ownership structure: (1) investor-owned utility (IOU), (2) municipal-owned utility (a.k.a publicly owned utility), and (3) unregulated utility. Each utility has a strong interest in implementing technology that advances the interests of their stakeholder community. They may implement DR tools to control load so that they can minimize their purchase of expensive wholesale power to serve the load during peak system operating times. For the competitive service provider, there may be strong opportunities to innovate and capture service revenue from V2G services. Also, there may be strong community centric support for environmental or energy security issues, which is a motivating factor.

For the IOU, the primary goal is to secure and preserve the allowed ratable investment, such that cost recovery can be achieved (plus a guaranteed return rate) from electric service rates, which secures the continued economic viability of the utility. This is a low-risk, guaranteed reward approach. IOUs are highly regulated by rules and restrictions aimed to protect consumers and investors and are particularly exposed to reporting requirements and intense public scrutiny of all new investments. Generally speaking, there is sufficient available investible capital from these large, publically traded entities. However, this tends to be crowded out by routine investment in more predictable and traditional opportunities for return on investment such as distribution infrastructure upgrade. These organizations usually have very technically competent staff members that could manage the service development and delivery from its initial development through pilot program deployment and into large-scale commercial program deployment. Because much of the focus is on rate basing, there is a distinct culture within this category of utilities to prefer asset ownership, management, and control through secure utility-owned communication networks.

There is another (sometimes large) form of utility known as municipal-owned utilities that are not governed by a state regulatory agency, but rather by a local board that is likely appointed from the region (often by a city's mayor and council) where the facilities are located. Municipal-owned utilities are often capital constrained and cannot afford to make large, up-front infrastructure deployment investments. They tend to follow, with some lag time, the direction that larger (regulated) utilities are taking, but look for more flexibility in investment options. This lagging nature often brings a less emphatic requirement for standards-based solutions and, in fact, will often seek only the fundamental core set of technical capabilities within a broad function such as V2G. This avoids (or at least delays) the need for more substantial process and systems integration work. Overcoming barriers with these entities can involve offering performance-based, hosted-service contracts, which could spread out repayment of deferred capital financing and also organizing complex stakeholder partnership arrangements.

Unregulated, competitive service providers represent a third class of utilities. These might be independent "peripheral" entities to large IOUs or smaller enterprises that compete for providing electric services. These entities research opportunities for clean energy (and other peripheral fields) and can place significant direct investment into realizing the opportunity potential. In general, these entities are not encumbered by lengthy regulatory or legislative review processes and can nimbly respond to emerging market opportunities such as V2G. The willingness to take on market risk (with promise for the corresponding market reward) distinguishes these entities from the others. As these utilities are the most agile in identifying and satisfying market participant needs, they will have the longest lead through experience as these services come to the mainstream. Notably, because these entities typically have relatively unbounded market geographies, they will quickly replicate best practices from their early pilot market solutions into other targeted service territories and ISO regions and will reach economies of scale more quickly.

Select utilities from each of these categories that are focused on considering providing V2G services will likely lead the way for other utilities. Overcoming general electrical utilities objections can best be accomplished by identifying standards used by those utilities that are themselves interested in V2G.

2.4.1.2 Automotive original equipment manufacturers. Vehicle manufacturers face extremely difficult economic challenges in a highly competitive world market for automobiles. The emergence of the PEV as a production platform has yet to be validated by consumer demand. Large capital investments have been made in research and development and production tooling to ensure a strong market adoption of this new product platform. Several OEMs have made strong commitments in this area and initial market reaction is positive, though limited. However, V2G adds uncertainty related to battery life and capacity. Demonstration tests will likely be required to prove the concept, along with economic analysis to determine whether this makes sense for the OEM and the battery supplier. Independent vehicle battery testing in the deep cycle of load support or shallow cycling of ancillary services will assist the vehicle manufacturers' motivation to provide V2G capabilities. This testing will lead to monetizing the effects on the battery and thus equip the vehicle manufacturer to participate in V2G.

Some OEMs have expressed a desire to participate in V2G testing. As such, they will be committed to providing the onboard equipment and developing the communications necessary for the testing. However, proof-of-concept testing is only a beginning step to what could be developed into new options offered by OEMs. Vehicle options typically have wide market appeal for consumers and this may not be the case for V2G until the codes and standards required become uniform enough across all markets, where the financial rewards are fully vetted and consumer awareness is greatly enhanced. Once these milestones are achieved, the introduction of such an option by the OEM may stimulate other OEMs to consider adding V2G capability as an option. Initial proof-of-concept success may be expanded to a unique class of vehicles in specific applications, such as fleet operations, where the fleet owner can order the vehicles and EVSE with this V2G option, knowing that the local codes and standards can be satisfied.

PEV OEMs are generally unwilling to permit discharge of energy from the battery by any control other than the vehicle's powertrain control system. This assures that battery function is always tied to incremental miles added to the odometer, which contributes toward their warranty liability reduction. It also assures control over onboard components that need to meet high-reliability performance standards. By opening up the ESS to external control interfaces (i.e., price or regulation signals from utilities or aggregators), there is incurrence of additional risk. At this point in the design life cycle of the PEV, as well as the market maturity of the industry, there is little perceived reward that offsets this risk. OEMs will have additional difficulty with this because they cannot know prior to vehicle delivery whether the owner will want to participate in V2G operations or not. Consequently, they will need to either provide all vehicles with the capabilities of long vehicle service with V2G operations or base warranty on other metrics such as the number of battery cycles.

2.4.1.3 Plug-in electric vehicle owner/operators. PEV owners will be motivated by a combination of benefits balanced with risks or impacts. For the general consumer, the drivers include monetary, environmental, and grid benefits. These must be weighed against effects on battery longevity and warranty, impact to vehicle availability, and ease of use. For fleet owners with multiple vehicles, the motivation may vary depending on local environmental regulations and grid reliability. Fleets will be primarily concerned with the vehicles still being able to perform their assigned duties as a part of their business operations. No fleet will sign up to participate in V2G if it means their vehicles will be unavailable to function as expected. Automation and impact to operations are key components in a fleet scenario. It should be noted that these motivating factors and concerns apply not only to connections to workplace and residential AC or DC Level 2, but also to publicly available units.

For the perceived benefits, there is still much to overcome in terms of barriers to V2G. Though there will be an expectation that there is a monetary benefit, any V2G program that offers payment to a customer will have to be clearly defined. Customers will need to understand if the program is through their utility or if they need to enroll through a third-party EVSP's program. The customer also will want to know how often and how much they will get paid.

Environmental and grid benefits are likely to be secondary to monetary incentives for most customers. Many customers want to take environmentally responsible action, but only if it is inexpensive and convenient. However, it is well known that many of the early adopters of PEV technology are customers that are environmentally driven. Therefore, it could be inferred that those same early adopters would be early users of V2G technology because of potential environmental impacts such as deferred capital investment in new generation plants and support of renewables. In the same way, most customers are not very aware of potential grid benefits, but early adopters are often more technologically knowledgeable and would participate in V2G because it would support the grid and help reliability. This would be especially true with any V2H capabilities (or V2B for fleet users). In addition, a small set of customers would participate early on just for the novelty of the technology factor and to show the feasibility of V2G.

On the other hand, the industry must address customers concerns of impacts and operation. The first hurdle to overcome is the demonstration that V2G participation does not significantly contribute to battery degradation and to determine the boundaries within which a V2G program must operate to maintain acceptable battery capacity. Following the determination of V2G effects on the battery, OEMs will need to determine warranty terms. If participation in a V2G program voids the warranty with an OEM, customers will not participate unless the monetary value for participation covers potential battery replacement.

Another important concern to address is the impact to vehicle availability. Simply said, V2G programming must ensure that the vehicle has enough range to meet customer needs when they need it. For example, if the customer's daily commute is 40 miles roundtrip, the overnight charge up and down cycles must result in a net state of charge that will provide the 40+ mile range by the time the customer leaves in the morning. Programming features must be available to give customers the confidence that the software will manage the charging in a reliable way.

Ease of use also is a major factor and can include the physical hardware, software programming, integration of communications systems, V2G program administration, standardization of programs across utilities, and other issues. Ideally, there would be little or no additional hardware so the customer could plug in as they would for a normal charge. The customer will need software tools to program when and what they need in terms of driving range. They also need these tools to be user-friendly and provide multiple means of access (i.e., at the vehicle, charger, online, home area network system, and through mobile applications). It is important for as much of the process to be automated as possible. Simplification is of the upmost importance on the program administration side as well. It is key that the process of enrolling in V2G programs with the utility or third-party EVSPs to be quick and easy. With the current variations in utility and EVSP provider offerings, it also is likely that these V2G programs will vary between utilities and EVSP providers. It will be important that some consistency be retained in order for there to be some common understandings among customers and confidence as they move through different program territories.

Overall, PEV owners have much to gain from a strong outreach and education effort. The vehicle owner may be motivated by special utility rate considerations to allow his/her vehicle to participate in

V2G operations, as long as it does not impact their next PEV operational trip. To increase the speed of acceptance of V2G, consumers must be properly educated and consent to the technology. Information that pertains to off-peak charging and its positive effect on load stabilization must be readily available for individuals. Additional education in regard to the way energy will be supplied from the battery to the grid will be required.

An informed consumer, backed by positive demonstration testing, can create the market demand for this option in the OEM vehicles.

2.4.2 Test and Evaluation

Sufficient scope or duration of testing has not yet been performed by industry or academia to provide supporting data that would minimize risks and remove or mitigate the barriers to adoption of V2G. This leaves the subject of V2G net benefits largely in the theoretical domain. This is one of the primary obstacles to decision making by regulators.

Current V2G evaluations mostly are limited to the simpler "smart charging" control schemes that extend basic DR applications to the PEV. Recommended test programs to fully evaluate V2G encompass three broad areas of investigation: (1) battery impact, (2) network operation, and (3) system response. Each area has specific test elements based on unique stakeholder concerns or perspectives. These areas of investigation and their relative importance to key stakeholders are depicted in Figure 23.

	BATTERY PERFORMANCE AND IMPACTS	NETWORK COMMUNICATION EFFICIENCY	SYSTEM RESPONSE VALIDATION
ELECTRIC UTILITY	Secondary	Primary	Primary
AUTO OEM	Primary	Secondary	Secondary
REGULATORS AND MARKET	Secondary	Secondary	Primary
EV OWNER	Primary	N/A	N/A

Figure 23. Grid Intelligent Vehicle Project test program investigations.

A recommended regime for this full evaluation is listed as follows:

1. Battery performance and impact testing
   a. Life-cycle impact from frequent charge/discharge cycles
   b. Thermal impact from rapid charge/discharge rates
2. Network communication efficacy testing
   a. Message transfer latency
   b. Bi-directional synch
   c. Alternative transport comparison

3. System response characterization testing
    a. Power quality characterization from inverter
    b. Application response times
    c. Data collection, storage, and presentation
4. Business modeling/cost modeling.

The following is detailed information regarding the recommended regime for the full evaluation:

1. Battery performance and impact testing (V2G cycling)

    This stage of the evaluation should determine the actual battery life under V2G conditions. This will allow the actual costs and benefits of V2G to be determined for later testing.

2. Network communications efficacy testing

    These tests will determine the capability of various communication networks and protocols to effectively carry the required messaging needed for remote operation of V2G for the full variety of use cases. The optimized (cost and performance) network topology will be identified and the evaluation will highlight cost versus performance issues, along with any specific reliability and availability issues that might be present.

3. System response characterization

    These tests will operate the end-to-end system that includes all aggregated vehicles, local and remote control mechanisms, data capture and storage, and user interfaces. The goal is to better understand the technologies and use profiles that will work effectively when they become part of an aggregated service offer. These data also will serve as verified performance data available for utility commission review that will drive regulatory policy and market creation/evolution.

4. Business model/cost modeling

    Business modeling must be accomplished for the informed consumer to make personal decisions with testing of V2G or the purchase of vehicle options that enable this option. Given that battery replacement will be expensive for the foreseeable future, the following should be performed to support V2G economic analysis:

    - Quantify costs and benefits for the vehicle battery supplier, the OEM, the vehicle owner, the EVSE owner, the services aggregator, and the network
    - Determine the actual costs of making a location V2G compliant
    - Investigate the efficacy of a TOU tariff or financial incentives in making V2G economically viable for both the network and a customer.

    Modeling will be required that utilizes predictive charge/discharge algorithms and includes the likely agreement that will be required between utility, services aggregator, building owner, OEM, and customer in order to determine under what conditions V2G is economically beneficial for all parties.

For a potential EVSP, the decision to invest in the development and deployment of the service infrastructure depends heavily on the acceptance of V2G as a viable service component. As shown in the following subsections, the relative immaturity of these markets and business models creates a major incentive for this type of foundational research. Early movers in this market will have decisions that carry far-reaching consequences, with both risk and reward; therefore, the decision makers must be as informed as possible. Utilities will need to recognize V2G and offer stable fees for grid support or the investment in V2G hardware will not be made. There is no more important benefit to drive V2G than financial return for V2G services.

2.4.3 Immaturity of Vehicle-to-Grid Aggregator Service Models

It is critical to the successful adoption of the V2G business models that aggregator services be developed for delivery of the following elements of service to the electric owner participating in the programs.

While markets for DR programs have been fairly well developed and standardized for heating, ventilation and air conditioning and building equipment load control, the ability to control the EVSE load offers new challenges to utilities. The traditional methods for shifting load (driven by either emergency or economic supply-side conditions) rely on moving load away from peak times directly (through direct load shed control) or through passing pricing signals to influence customers to reduce load themselves (price-responsive load management).

Three important differences exist with the PEV batteries as a load operating in V2G service modes:

1. There are complex power management electronics in series with the batteries that must be carefully integrated into the control scheme.
2. The PEV battery can act as a grid or building-connected power source (i.e., “negative” load, as opposed to merely an adjustment or shedding of “positive” load).
3. The PEV battery can act as a capacity-balancing resource by receiving and giving power in a nearly real-time response mode.

These differences give rise to the need for aggregator services that can logically group and manage the individual connected PEVs and pass the utility signals in a structured communication protocol. The PEV/EVSE response must be measured and confirmed in order for the system to be viable as a practical market clearing tool. The aggregator has the responsibility for ensuring that all participating PEVs are safely connected to the electrical grid, suitable metering and data management is in place, messaging applications and protocols are well defined and operational, and the required market signals and customer education are properly integrated into the business process.

At this point, because most of these elements are not fully defined, do not have governing standards, nor are they connected into a cohesive service model, the deployment of programs is limited to small pilot evaluations and development programs. Furthermore, the more advanced capabilities of V2G are not being pursued and the early evaluations are limited to simple load-control signaling for peak-load response.

The aggregator will be interested in a significant quantity of connected vehicles in order to have the desired impact on the grid. The impact V2G will have on utilities requires the consideration of many potential issues and the analysis of driver habits and preferences. Vehicle availability for grid connection is one issue and a vehicle’s need for recharging is another. Vehicles will likely be connected far longer than is necessary for the recharging of the battery. Figure 21 shows relative availability of V2G EVSE and connected vehicles. The type of services the aggregator provides may vary during the time of day. Part of the day may be supporting renewable energy storage and load shifting, while other parts of the day may be demand reduction.

Aggregation on a smaller scale also may be desirable to the utility in residential applications. A single PEV on a residential transformer should not pose a problem to utility companies. However, PEVs that appear in clusters on the same transformer could cause the transformer to fail, especially if electric vehicle drivers are charging at the same time. A possible solution may lie in development of micro grids, which allow for control of supply and demand of power and prioritize the power supply. Controlling which EVSE is on and which is not reduces the load on the transformer, yet allows all vehicles to be fully charged overnight.

In general, electric utilities are the only authorized resellers of electricity. Working on demonstration projects generally does not warrant the scrutiny that a full-services aggregator would receive. It is likely that if V2G were implemented on a large scale and aggregator services are in demand, new cases would be brought before the public utilities commissions to review whether the aggregator is a reseller of electricity and ought to be regulated. The current direction for utility commissions is generally that providers of EVSE public infrastructure are not resellers of electricity and not subject to regulation. There is a considerable difference between a single EVSE and the collective operation of hundreds or thousands of EVSEs. The rulings of these commissions may be a barrier to the introduction of large-scale aggregator services.

Significant adoption of V2G services can alter the capacity of each utility affected by the technology. As the number of vehicles involved in bi-directional power flow increases and the need for peaking plants begins to decrease, stabilization of the base load will continue to fluctuate until the aggregated number of vehicles used for storage surpasses the additional plants. In effect, the aggregator or aggregators serve the function of the peaking plants. Utilities will be required to closely monitor the transition to ensure that their capacity can support the needs of the customers. Reducing the number of peaking plants before there is a significant amount of V2G support will cause a lack of energy to meet the demand of the region.

2.4.4 Low Risk Tolerance by Plug-in Electric Vehicle Original Equipment Manufacturers

PEV OEMs generally are unwilling to permit discharge of energy from the battery by any control other than the vehicle's powertrain control system. This assures that battery function is always tied to incremental miles added to the odometer, which contributes toward their warranty liability reduction. It also assures control over onboard components that need to meet high-reliability performance standards. By opening up the ESS to external control interfaces (i.e., price or regulation signals from utilities or aggregators), there is incurrence of additional risk. At this point in the design life cycle of the PEV, as well as the market maturity of the industry, there is little perceived reward that offsets this risk. OEMs will have additional difficulty with this because they cannot know prior to vehicle delivery whether the owner will want to participate in V2G operations or not. Consequently, they will need to either provide all vehicles with the capabilities of long vehicle service with V2G operations or base warranty on other metrics such as the number of battery cycles.

2.4.5 Expense of Adjacent Smart Grid Control Technology

Fully implementing V2G requires the existence of several critical adjacent technology elements that will enable correct operation of the vehicle battery services. Some of these elements are as follows:

- Utility/ISO control signal
- Utility/ISO communications network
- Utility/ISO back end billing system and CIS integration
- Automaker/EVSP program data systems
- EVSE control application interface
- Premise-based net metering
- Grid-tie inverter
- Local electromagnetic system

These expenses can vary depending on the standards in place at the time of deployment, the scope of smart grid system adoption and the depth of system integration in each utility service region, the amount of competition in the vendor markets for the products and services, and the regulatory requirements that are placed on operation and reporting. Based on the fees/costs associated with each component, the total expected cost per residence for a fully equipped smart grid, AMI-connected network with internal home area network technology and smart-charging EVSE could typically range from $2,500 to $7,000.

The cost of the appropriate charging unit in a residential area ranges from approximately $500 to $1,500. Electrical service panel upgrades also may be required, which may increase charges by $1,000 or more. Obtaining permits for installation in garages or carports may cost between $45 and $110. General labor fees and ventilation systems, if required, also may increase costs. Some PEV manufacturers may include installation fees in their lease agreements. Prospective PEV owners would be recommended to discuss installation details with the dealer prior to vehicle purchase (PG&E n.d.).

The cost of installation in the public sector will include charges that differ from residential fees. While it is likely that the individual will pay for the electricity used in private homes or businesses, the cost of electricity consumed at public chargers may be free or included in an access fee for use of the charger. There are many business models emerging; however, it is common that hosts will charge a fee per time parked at the charger or a one-time access fee. Many potential hosts or EVSPs are avoiding a fee per kWh used because of ambiguous regulations that may consider an entity to be a “utility” if they provide electric service and bill by kWh. To avoid potential regulation, a time-based or access-based fee is common. Some private retailers, such as grocery stores, will offer charging as a free service to customers (Hatton 2010) as an amenity. Cities such as Los Angeles and San Francisco have stated that charging at city-owned chargers will be free for a limited amount of time to stimulate the industry (Wierderer 2010). As with the private area, grid upgrades may be necessary for the adoption and load control related to PEV charging.

2.4.6 Lack of Clear Government Policy Directives, Standards, and Market Support

2.4.6.1 Regulatory uncertainty. With the relatively new market transformation to electric transportation, many utilities (and their regulatory overseers) now see both threat and opportunity as this paradigm shift accelerates. The past structure of the electricity markets, based on relatively stable and long-term, planned traditional generation matched against a fairly predictable growing consumer demand, has been impacted greatly by the following relatively recent shifts:

- Worldwide recession
- Advancement of renewable portfolio standards
- Launch of widely available electric vehicles
- Instability in oil rich regions, impacting petroleum prices
- Promotion/funding of energy efficiency and DR programs.

The general approach of regulators in this period of uncertainty is to stay abreast of developments in the market adoption of PEVs (as indicated by the sales volumes of these vehicles) and to collect as much information from the utility, OEM, and EVSP industry as possible. This is called the *gathering* phase. Also happening in this phase are pilot programs that are providing useful data that may influence proposed policy changes.

Because California is typically more proactive regarding environmental issues, the California Public Utilities Commission has been aggressively participating in the gathering phase and has advanced some early regulation and guidance that will accelerate the market viability of EVSP. Notably, the California Public Utilities Commission has ruled that the electricity “resale” can occur by third parties without requiring regulatory oversight on these activities. This is a watershed decision that, if adopted in other states, breaks the hegemony that regulatory agencies have over entities that want to host EVSE and provide electricity as a transportation fuel only.

2.4.6.2 Regulatory restrictions. Regulatory restrictions on utilities will contribute to the difficulty of executing V2G technology. Regulatory restrictions are in place to ensure utilities charge their customers a fair rate, while they also see a profit and return on their investments. As environmental and fuel constraints increase, new alternatives (such as integrated resource planning, revenue decoupling, and cost-recovery mechanisms) are emerging as viable alternative regulation schemes. These new alternatives consider environmental factors and the desirable integration of renewable resources into the supply mix. As each PEV operator will be able to store energy and sell it back into the grid, it will be more difficult for utilities to determine initial load stabilization. While peaking plants will still be in use, the incorporation of PEVs supplying power to the grid may result in additional fees and a climate where it may be increasingly more difficult for utilities to make a profit (Rocky Mountain Institute 2008).

As mentioned above, the incidental resale of electricity by retailers generally is prohibited by regulation in most states. Although the charging of a battery simply could be considered a service made possible by the electric power, much as selling a block of ice at a convenience store is made possible by electricity, the downstream ability to resell that stored power into the markets through V2G makes it different. These issues currently are under discussion throughout the utility regulatory community and will be subject to much public vetting.

One of the regulatory mechanisms utilized for preserving grid reliability and ensuring utility profitability is the allowance of a *demand charge* as part of most commercial rate structures. This charge is levied when the facility draws power at levels above a predetermined threshold. These levels typically start at 20 to 30 kW for light commercial facilities. The existence of this charge is a strong deterrent to hosting public charging infrastructure. Demand charges are particularly onerous when the high power of DC Level 2 charging stations is considered, where the demand charge can be the dominant portion of the utility bill.

Another restriction comes from the inconsistent statutory application of net-metering requirements that provide fair market wholesale power reimbursement for local generation (or battery discharge) into the grid at distribution endpoints. These regulatory restrictions hamper deviation from the previous model of central station generation to distributed resources. The lack of a net-metering capability or compensation is a direct deterrent to V2G services (although V2B can still be effectively carried out).

2.4.7 Multiple Charging Networks and Billing Systems

The incorporation of multiple charging networks by EVSPs introduces concerns related to billing subscriptions and profit loss during initial installations. Studies indicate that a subscription fee may cost between $11 and $192 per month (Wierderer 2010). The Wierderer study uses projections for the year 2020. By that time, the study suggests PEVs and related technology will be accepted and widely used on a global level. Charging stations will need to be provided during the early years of PEV adoption. However, companies may have to take a loss on each station if vehicle deployment is less than projected. Initial losses may discourage private investors, which also may prevent investors from making additional investments due to the relatively unknown customer behavior in this field. Another approach could relate to an increase in initial subscription fees that, over time, would decrease. However, this solution will appear unsatisfactory to early adopters and may potentially slow PEV population growth.

3. VEHICLE-TO-GRID PILOT PROJECTS

The following subsections describe pilot V2G projects of note around the world, with particular attention paid to U.S.-based projects.

3.1 ECOtality North America Bi-Directional Charging Project

In support of the Idaho National Laboratory, ECOtality demonstrated V2G capabilities using battery power in PHEVs with a bi-directional fast charger to support/offset peak building loads and studied the impact to the battery. A Hymotion-converted Prius was used for bi-directional flow of electricity through one of ECOtality's grid-tied DC charger products at 25 kW. The system was used to gather information to further understand the complexities of bi-directional charging and show that a bi-directional vehicle charging system is possible using current commercially available technology. A hypothetical charging/discharging scheme was developed to demonstrate how the system could be used as part of a DR initiative.

3.2 Nuvve Vehicle-to-Grid Project

In June 2011, an American company, Nuvve, completed development on a new V2G-related innovation. Nuvve has designed a server that connects PEVs to the grid operator. The customer will make the vehicle's battery available to Nuvve through use of a server, which, depending on supply and demand on the grid, will use the car as a short-term solution to frequency regulation. Denmark was selected as a test site because of the large amount of renewable wind energy in the grid, which results in significant power fluctuations. Denmark's grid also is very closely related to the rest of Europe's grid. Although most PEVs are designed with bi-directional drive trains, vehicles lacking this technology may still participate by storing electricity, relieving the grid of surplus energy. After being in development for 10 years, Nuvve is ready to begin V2G testing in Denmark beginning September 2011 (EV World 2011).

3.3 E-Moving

In June 2010, Italy began its first electric vehicle experimentation in the cities of Milan and Brescia. This pilot project, E-Moving, will use both the Kangoo and Renault Fluence electric vehicle models. The scope of the project is to test the technology and distribution of charging resources, commercial processes and offerings, the interaction between the charging network and the vehicles, electricity supply for the vehicles and associated invoicing systems, and battery and electric vehicle management. During the pilot phase, both electric vehicle models will be available to consumers and businesses for testing and will even be available for an exclusive rental that is comparable in price to similar diesel vehicles (Telematics News 2010).

3.4 MeRegio Mobil

A project funded by the Federal Ministry of Economics and Technology of Germany is investigating how electric vehicles can connect to a house electromagnetic system by way of an intelligent charging station while testing bi-directional energy management. Partners within the project include six companies and two research institutes. Electric vehicles will be used as mobile energy stores once they are integrated into existing networks through the use of intelligent charging stations. Through this process, the MeRegio Mobil Project will collect and analyze the data, guided by six goals found within the scope. These goals include studying the intelligent control of load and charging phases and energy feedback; establishing up to 600 private, commercial, and public charging points in the state of Baden-Wurttemberg; providing charging and billing management between grid operators and suppliers; studying cross-border roaming; designing innovative local vehicle telematics services; and designing a prototypical Smart Home for the integration of the electric vehicles. The long-term planning of this study began in late 2009, with the aim of one million electric vehicles on the road by 2020.

The current phase began in July 2009 and will continue through the end of October 2011. This portion of the project included the planning, prototyping, and testing stages. Intelligent charging stations will be developed and tested. Billing management and cost of the stations will be planned. Electric vehicles will be adapted for field-testing, while development of a prototypical smart home will continue.

The next phase will include roll out and start of field testing. This will begin with the operation of charging infrastructure in Stuttgart, Karlsruhe, and Kehl. The smart home will be operational and implemented based on testing simulations. Cost and billing management and intelligent charging management for use of V2G will begin. The final phase will continue testing and compiling information as provided by the prior stage.

The MeRegio Mobil Project takes into consideration that a customer should not be limited to one energy provider through traveling and public intelligent charging. Instead, the system allows the amount to be calculated, offset, and paid through the customer's next electric service bill. Intelligent energy feedback allows the electric vehicle owner to charge the electric vehicle in public, at home and at work, while providing grid access to stored energy during periods of high demand. The electric vehicle owner is then compensated with a credit on his/her electricity bill. A program also will be available to inform the customer of excess renewable sources available in the network that can be purchased for a lesser monetary value. Intelligent management within a smart home will allow the consumer to monitor and manage energy feedback via the internet. The Smart Meter also will assist with informing customers of their energy consumption and provide assistance with determining the optimal time to feed energy back into the grid (MeRegio Mobil 2010).

3.5 RechargeIt

In 2007, Google.org began the RechargeIt program with aims to reduce greenhouse gas emissions and oil use and provide stabilization to the grid by accelerating the adoption of PEVs. Google.org has been demonstrating the capability of PHEVs at their Mountain View headquarters by converting eight Toyota Priuses with the Hymotion/A123 conversion module. These vehicles are shared between employees during work hours to encourage the use of alternative-fueled vehicles. Each Prius is outfitted with data recording devices that are designed to track use patterns, charging history, and technical and environmental performance. Existing conventional hybrid vehicles were outfitted with similar recording devices in an effort to offer a realistic comparison between the technologies. Data were collected and placed on their website and updated periodically as more information was provided. To demonstrate the effectiveness of renewable electricity in replacing gasoline and other fossil fuels, vehicles involved in the RechargeIt program are connected to solar charging stations located at Google's campus.

In addition to the company fleet, PEVs were used in a 7-week, controlled experiment. The RechargeIt driving experiment collected data on three different types of trips: (1) city trips driven on surface streets, (2) trips that exclusively used highways and, (3) a combination of the two were used to measure fuel efficiency. The results between the tests were varied due to the following reasons:

- Drivers in the controlled experiment lacked the experience related to operating the vehicles in a more conservative, fuel efficient manner.
- Duration of the trips also was a factor, with trips in the employee fleet usually being more frequent with shorter intervals.
- The SOC and the plug-in conversion equipment also was a factor. Google believes that upcoming vehicles that are intended for plug-in use will offer increased efficiency.

Regardless of the variance between the tests, the RechargeIt Project was able to record an average of 93 miles per gallon across all city trips when using a PEV (Google.org 2009).

3.6 SmartGridCity Project

In 2008, Xcel Energy partnered with GridPoint, Accenture, Current Group, SmartSynch, Ventyx, and OSISoft to launch a project that allowed the exploration of smart grid tools through a large-scale pilot project. Boulder, Colorado was the home of the SmartGridCity Project. The project served to upgrade Boulder with smart grid technology, as well as energy management and conservation tools. The effectiveness of technologies in their delivery of power, the incorporation of smart grid technology in the business world, and replicating the results on a wider scale were factors being examined. Additionally, Xcel Energy is currently performing one of the nation's largest V2G pilot projects. Four PHEVs will be converted for use in the V2G study. The first vehicle was converted by the University of Colorado. This will be followed up with three more Toyota Prius PHEVs to be used as storage devices for testing at Xcel's SmartGridCity Project. The second phase will involve converting 60 PHEVs for use with the

University of Colorado's fleet. A combination of both onboard V2G technology and V2G-enabled charging stations will be used in this phase of the project. Xcel and its partners anticipate a grant of about $6 million to complete Phase 2 of their project. In later phases, Xcel will increase the number of PHEVs involved in V2G testing to 500 to begin larger-scale studies (Xcel Energy 2008). Although the SmartGridCity Project was initially projected to cost well under the estimated $44.8 million it has currently reached (Berst 2010), the focus of the project has now shifted more toward the applications of the smart grid such as TOU-pricing studies, the concept of the integration of DG, and distributed storage (Munro 2010). The results of the testing of these applications will become extremely important to the implementation and various related aspects of V2G.

3.7 Austin Energy and V2Green

Austin Energy, a public utility, began a V2G pilot study using two PHEVs equipped with a V2Green connectivity module, a charging management technology made by GridPoint. The study examines the potential of PHEVs through maximizing the use of renewable energy, thereby reducing greenhouse gas emissions and impacting the smart grid in a positive way. Each PHEV is fitted with a V2Green connectivity module to establish two-way communications with the power grid and to control the timing and extent to which the vehicles are charged. The data are monitored by V2Green's server software. This software will collect the field data for analysis. Austin Energy will be able to increase or decrease charging to match grid requirements and capitalize on the availability of renewable resources. Wind-generated power tends to flow predominantly overnight from West Texas, where the tests are conducted (Automotive Fleet 2008). Based on Austin Energy's historical load profiles for peak days and results from this study, it was determined that it would be possible to charge 10,000 PHEVs at a rate of 1 kW during off peak hours without causing load spikes. Austin Energy reports that, based on the results and incorporating rates for one-way directional power flow (grid-to-vehicle) from 2006, each vehicle capable of participating in the program has a value of $122. Introducing V2G capability will nearly double the value of the PHEV (i.e., $225), while decreasing the value of additional ancillary services (Austin Energy 2009).

3.8 Mid-Atlantic Grid Interactive Cars Consortium

The Mid-Atlantic Grid Interactive Cars Consortium conducted a test of V2G in 2006. A Scion xB, dubbed the "eBox," was equipped with an AC Induction Motor, AC-150 Power Electronics Unit, and a 355-V, 35-kWh battery. This study predicted 21.5 hours tied into the grid and 2.5 hours of drive time. The information studied included the battery SOC, plug capacity, battery voltage, line current, and the regulation signal. Data were transmitted to the University of Delaware over the internet every 10 seconds.

During simple charging, battery SOC fluctuated slightly, rather than a smooth increase due to the measurement being to the nearest 1%. Power was manually discharged into the local grid. Testing began with 11% SOC and put 10 kW continuously back into the grid. The eBox was set up so that even when the battery SOC indicated 0%, there was still power stored in the battery. At low states of charge, power was withdrawn from the battery at a slower rate than during periods of high SOC.

The project is relevant in regards to batteries because grid regulation (frequency response) requires relatively short energy discharges (or charges). With short-duration cycles, the battery will experience far less wear than in continuous or deep cycles. If the charge control is properly balanced, the battery will not be allowed to fully charge or fully discharge. The quick response time from a PEV battery used as a storage system was projected to more than meet the needs of system operators. Though battery use may be less effective over long durations, this study concluded that, on average, it is extremely rare for the duration of an activity to continue for extended periods of time. Although this study relied on information gathered from one vehicle, it is projected that the use of a significantly larger test pool will support the conclusions gathered (Kempton 2009).

3.9 AC Propulsion Vehicle-to-Grid Demonstration Project

In December 2002, AC Propulsion, Inc. upgraded a Volkswagen Beetle with a bi-directional grid power interface; wireless internet connectivity; thirty 12-V, Panasonic, lead-acid (model EV-1260) batteries; and AC Propulsion's second-generation AC-150 Drive System. This vehicle was converted for use in a study on the potential of V2G usage. The AC-150 Drive System acted as a charger, converted AC power to DC power, and allowed it to operate in reverse. An aggregator function was developed to act as a commercial middleman between a grid operator and the vehicle. The power dispatch commands were sent wirelessly to the electric vehicle at 4-second intervals and the vehicle response was recorded. This study assumed that the vehicle would be plugged into the grid at home for 14 hours and at work for 9 hours. In addition, a 48-hour continuous grid connection study was performed. A total of 227 hours of connected grid time was studied.

AC Propulsion Inc. recorded that the wireless data transmission times were within California International Organization for Standardization System requirements. Energy throughput through the battery equaled regular driving habits per day and also accounted for all regular driving conditions (such as heat). Although the long-term effects of the battery were beyond the scope of this study, energy capacity within the battery increased by about 10% during the course of testing. The feasibility of V2G was successfully demonstrated.

An issue described within the project was the need for real-time control over the balance between generation and load, provided either by the electric vehicle or an ancillary service provider. It is projected for V2G systems that each PEV will have a capacity of 5 to 24 kWh. Because it will require hundreds of connected PEVs to match the capacity of typical small power plants, grid operators will require the understanding that adoption of V2G will be a slow building process (Brooks 2002).

3.10 Vehicle-to-Grid Estimations and Future Plans by Country

It is difficult to quantify the V2G plans for the various regions around the world because the technology is still in its nascent stage and there are no reliable predictions for how quickly V2G systems will be adopted or even where. The list presented here should not be considered exhaustive.

3.10.1 United States

Current environmental issues in the United States are playing a vital role in the demand for V2G technology. The decrease in costs for implementation of V2G will be directly related to the speed of adoption by consumers. As the smart grid rollout continues and the population realizes the lower cost of electric vehicle ownership, demand will increase. Continued V2G testing and the further development of two-way communications standards will offer interoperability across systems. Fleets such as the U.S. Postal Service will be crucial to V2G development. Private grid testing will continue as utilities, automakers, and colleges form partnerships. The University of Delaware recently has signed its first license for V2G testing with Autoport, Inc. They expect that by spring or summer 2011, 100 electric vehicles on the road will be capable of V2G testing (Bryant 2010).

PJM Interconnection has envisioned using U.S. Postal Service trucks, school buses, and garbage trucks that remain unused overnight for grid connection. This could generate millions of dollars because these companies aid in storing and stabilizing some of the national grid's energy. The United States is projected to have one million electric vehicles on the road between 2015 and 2019. Studies indicate that 160 new power plants will need to be built by 2020 to compensate for electric vehicles if integration with the grid does not move forward (ZigBee 2010).

3.10.2 Japan

Japan currently is a leader in the electric vehicle industry. This may allow the country to pioneer new V2G technology for the mainstream. In order to meet the 2030 target of 10% of Japan's energy being generated by renewable resources, a cost of $71.1 billion dollars will be required for the upgrades of existing grid infrastructure. The Japanese charging infrastructure market is projected to grow from $118.6 million to $1.2 billion between 2015 and 2020 (ZigBee 2010). Starting in 2012, Nissan plans to bring to market a kit compatible with the LEAF that will be able to provide power back into a Japanese home. Currently, there is a prototype being tested in Japan. Average Japanese homes draw 10 to 12 kWh, and with the LEAF's 24 kWh battery capacity, this kit could potentially provide 2 days of power (Howard 2011). Production in additional markets will follow upon Nissan's ability to properly complete adaptations.

3.10.3 Denmark

Denmark currently is a world leader in wind power generation, with 20% of the country's energy coming from wind (there are enough installed turbines to meet up to 40% of the country's energy needs). Initially, Denmark's goal is to replace 10% of all vehicles with PEVs, with an ultimate goal of a complete replacement to follow. The EDISON Project implements a new set of goals that will allow enough turbines to be built to accommodate 50% of total power while using V2G to prevent negative impacts to the grid. Because of the unpredictability of wind, the EDISON Project plans to use PEVs while they are plugged into the grid to store additional wind energy that the grid cannot handle. Then, during peak energy use hours, or when the wind is calm, the power stored in these PEVs will be fed back into the grid. To aid in the acceptance of electric vehicles, policies have been enforced that create a tax differential between zero emission cars and traditional automobiles. The Danish PEV market value is expected to grow from $50 to $380 million between 2015 and 2020. PEV developmental progress and advancements pertaining to the use of renewable energy resources will make Denmark a market leader with respect to V2G innovation (ZigBee 2010).

3.10.4 United Kingdom

The V2G market in the United Kingdom (U.K.) will be stimulated by aggressive smart grid and PEV rollouts. Starting in January 2011, programs and strategies to assist in PEV have been implemented. The U.K. has begun devising strategies to increase the speed of adoption of electric vehicles. This includes providing universal high-speed internet for use with smart grid meters, because most V2G-capable PEVs will not coordinate with the larger grid without it. The "Electric Delivery Plan for London" states that by 2015, there will be 500 onroad charging stations; 2,000 stations off-road in car parks; and 22,000 privately owned stations installed. Local grid substations will need to be upgraded for drivers who cannot park on their own property. By 2020 in the U.K., there will a smart meter in every residential home, and about 1.7 million PEVs on the road. The U.K.'s electric vehicle market value is projected to grow from $0.1 to $1.3 billion between 2015 and 2020 (ZigBee 2010).

3.10.5 South Korea

South Korea has set a goal that by 2030, 100% of electric customers will be using smart grid technology. Beginning in March 2010, the government will invest $23.3 billion in development and rollout of smart grid technology. Grid revenues are projected to increase from $4.8 to $53.2 million between 2015 and 2020 (ZigBee 2010).

4. CODES AND STANDARDS

Although there have been significant technology studies and policy discussions for the V2G concept validation, many practical level grid, V2G equipment, and vehicle-related standards must be revised or created to form a practical framework that enables V2G business models. Many of the current standards in place were developed specifically for one-way power flow.

Standards development will be necessary in areas of equipment installation, communication, security, interconnection, billing, permitting, and so forth. This section discusses relevant standards organizations, the specific applicable standards currently in place or revised versions in review, and provides an overview of the variations of codes and practices in selected regions in the United States.

The adoption of a common set of codes and standards is necessary for a variety of reasons. Each participating publicly available charging station will require electronic identification in order for participating electric vehicle owners to connect and be included in V2G operations. Electronic offers and acceptance of a power contract by the customer would be required. For billing purposes, each vehicle would require an identifier that could report the location of the vehicle, the specific meter being used, and the terms of use agreed upon by the vehicle operator back to the utility. Standards need to be designed that allow vehicle and grid operators to manage the rate of energy transfer and to establish a limit to the amount of power that can be drawn from the vehicle. This will allow grid operators the ability to better predict and shape the transportation load as they receive data in real time. Systems that record information (such as customer preferences and overrides) and enable interactions between the customer and the utility, require highly repeatable and predictable control functions. To incentivize participating electric vehicle owners to sell their power back into the grid, a set of standards for time-varying pricing must be in place (Schwartz 2009). Standards in relation to cyber security need to be in place, especially when dealing with the protection of multiple charging stations located in public places, such as parking lots. As many vehicles will be plugged into the grid and left unattended, personal information must be protected and prevented from criminal access. Additionally overrides must be developed so the vehicle preserves the ability to discontinue charging in the event of unsafe battery conditions, even in the presence of grid-side charge commands. As the shift from internal combustion engine vehicles to electric vehicles begins to take place, the auto industry and utility companies must begin to work together to provide an interoperable and secure system for their common customers.

The terms codes and standards are often found linked although they carry different meanings and implications. A code indicates that a requirement must be met and it has regulation and enforcement backing. Authorities having jurisdiction are tasked with reviewing permits and other documents with an eye toward ensuring the appropriate codes are enforced and followed. Codes are typically prepared to protect health and safety concerns and are endorsed by local governmental or regulatory bodies. Examples of codes include NEC, International Building Code (IBC), and International Residential Code (IRC). Codes are primarily addressed in Sections 4.1 and 4.2.

Standards are typically prepared to identify equipment and system design requirements in order to meet code requirements. Authorities having jurisdiction can often be assured that code requirements are met when equipment is certified by testing to meet specified standards. Standards are addressed in Sections 4.3 to 4.7. The status of code adoption is presented in Sections 4.8 and 4.9.

4.1 National Electric Code

NEC is a single code that identifies the regulations for the safe installation of electrical equipment and wiring. It is part of the National Fire Protection Association (NFPA) standards development and is identified as NFPA 70®. Use of NEC frequently is required by state or local municipal law. The authority having jurisdiction for implementation of codes and standards for each state or local governing body will refer to NEC as a set of minimum requirements and make additional amendments as needed.

The 2011 version of NEC Article 625 was published in November 2011. This article details wiring methods, equipment construction, control and protection, and equipment locations related to EVSE. The intent is to prevent users of the electrical equipment from being exposed to energized live parts, creating a safe vehicle charging environment. Article 625, in general, covers all electrical wiring between the service point to the connection with the PEV. This code is used (in various adopted dated versions) by municipalities and government inspection officials to validate suitability for use through well-defined local permitting and inspection processes.

There are many sections included in NEC Article 625. Section 625.2 defines the industry standards related to EVSEs. Other sections of 625 cover all labels, voltages, and wiring methods to ensure safety and a clear communication of any related requirement due to a need for ventilation. Section 13 outlines that EVSEs rated at 125 V, single phase, 15 or 20 amps (AC Level 1) are permitted to be cord-and-plug connected. All other EVSEs shall have no live exposed parts and equipment must be permanently secured and fastened in place (Advanced Energy 2011). An exception is allowed if the other EVSEs meet additional requirements of NEC. They too may be cord-and-plug connected. Several EVSE suppliers have met this requirement with AC Level 2 equipment. Cable length and a specific guideline for an interlock device that de-energizes the electric vehicle connector when it is uncoupled from the electric vehicle are explained in Articles 625.17 and 18. Level 1 EVSEs do not require an interlock device (Advanced Energy 2011). Overcurrent protection (i.e., a required listed personnel protection system for the prevention of electric shocks) and the necessity of the disconnecting means being installed in an accessible location are described at length in Sections 21 to 23 of Article 625. NEC 625.25 states that upon loss of voltage from the utility, energy cannot be fed back through the PEV and the EVSE unless permitted by Section 625.26. This section lists and identifies the EVSE and the vehicle's onboard power production system as components intended to be interconnected. They also may serve as an optional standby system, an electrical power system (EPS) or for bi-directional power feed. The final sections, Article 625.28 to 30, outline locations where an EVSE may be installed and all safety provisions noted for each location such as outdoors, classified locations, and various indoor sites (National Electric Code Handbook n.d.).

The contents of Article 625 have been revised four times since its inclusion in NEC in 1995. These revisions typically involve adding clarity to definitions pertaining to electric vehicles and EVSEs as the related technology continues to develop. Revisions made in 2002 introduced the guidelines for cable management systems, lengthened the cables, and included indoor ventilation options. In 2005, it was expanded to include low speed electric vehicles and interactive systems, as well as addressing the prevention of the back-feed of energy in circumstances where there is a loss of primary power. The 2008 revisions clarified requirements for disconnecting means. The 2011 revisions now formally recognize PHEVs as a classification of electric vehicle, as well as officially identifying that PHEVs include a second source of motive power, while still retaining many similarities to electric vehicles (Thomas and Betts 2011). It is up to the discretion of each governing jurisdiction to select the year code they want to adapt.

4.2 International Codes Council

The International Codes Council develops codes and standards directed to the building safety community and construction industry. Through the developed international codes, or I-Codes, a complete set of minimum requirements for building and fire safety are published. I-Codes are adopted and enforced at both the state and municipal levels, with each governing body being responsible for which codes are enforced or combined with other I-Codes into a state-specific code. The codes that are applicable to V2G technology include the IBC, IRC, and the International Energy Conservation Code (IECC). Each I-Code is revised every 3 years, with 2012 being the latest edition.

4.2.1 International Building Code

IBC establishes the minimum standards for building construction. A significant portion of IBC deals with fire prevention in relation to building construction and design. This I-Code was developed to consolidate existing building codes into a singular code for national adoption. Every 3 years, a new edition of IBC will be published. Currently in the United States, the 2003, 2006, and 2009 IBC are in use. The 2012 edition of IBC has been published and enforcement of this version is expected to begin in 2012, a more immediate timeframe than the expected 1-year lag. Significant documentation on differences between IBC 2012 and prior publications is expected to be available starting in mid-2012, as seminars and conferences begin to meet. IBC places an emphasis on the design and construction of electrical components and the equipment and systems used in buildings to adhere to the regulations imposed by NFPA 70.

4.2.2 International Residential Code

IRC creates the minimum regulations for one and two family dwellings. IRC includes all building, plumbing, mechanical, fuel gas, energy, and electrical codes for the residential sector. The purpose of IRC is to preserve health and safety in residential communities. Section E3405 of IRC specifies the proper location of energized equipment installations, as well as establishes the accepted working space and clearances for panel boards (International Code Council 2011, Q-1). Definitions included in each revision are added and updated based on technological advancements. IRC 2009 includes a revised list of electrical repairs and installations that require inspection.

4.2.3 International Energy Conservation Code

IECC is very similar to the energy-related codes of IRC, except that it encourages energy conservation and efficiency. Multi-family buildings, like apartments, are covered by IECC, in addition to the guidelines followed by IRC. The 2012 version of IECC is referenced in IRC as requirements, thereby providing a more simplified interaction between the two I-Codes. Each state will develop its own energy code requirements, which are usually based on IECC.

4.2.4 International Green Construction Code

In 2009, the International Code Council announced development of the International Green Construction Code (IGCC) initiative. The IGCC Public Version 1.0 was released in March, 2010, with Version 2.0 quickly following, which was released in November 2010. The 2012 IGCC was officially published in March 2012, with the intent to be revised every 3 years in accordance with all I-Codes.

IGCC is designed to synchronize its terminology with existing I-Codes, while specifically aiding in construction of both commercial and residential green sustainable buildings. This applies to both new and existing buildings that are subject to additions and alterations. IGCC is the first I-Code of its kind to include compliance measures that cover the initial design and construction of the building through its occupancy (International Code Council 2012). Section 604 of IGCC defines the baseline capabilities for buildings to measure, report, and monitor energy consumption. Section 605 sets the requirements for building energy consuming components to respond accurately to DR programs. Additionally, IGCC contains policies for water and energy conservation, land use, indoor environment quality, building operation, and building owner education.

IGCC differs from most I-Codes in that it provides each authority having jurisdiction the flexibility to customize the code to address local environmental concerns, while also sanctioning the ability to respond to local environmental political agendas. Because of the variance of environmental issues, IGCC does not demand full compliance of its requirements, but rather sets a minimum number of best practices to be followed on a project-to-project basis (International Code Council 2010).

4.3 National Institute of Standards and Technology

The National Institute of Standards and Technology (NIST) operates with the goal of enhancing the U.S. economy and improving the quality of life through development of standards and technology. NIST is responsible for development of many innovative products and services that are in use. In addition to the development of standards, NIST relies on its own testing laboratories to further development of products and resources.

The Energy Independence and Security act of 2007 assigned NIST the responsibility to "…coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems..." NIST developed a three-phase plan to "accelerate the identification of standards while establishing a robust framework for the longer-term evolution of the standards and establishment of testing and certification procedures." NIST identified 77 existing standards that can be used to support Smart Grid development and 14 high-priority gaps, along with cyber security, for which new or revised standards are required (Figure 24).

"The NIST Smart Grid Conceptual Reference Model identifies seven domains (bulk generation, transmission, distribution, markets, operations, service provider, and customer) and major actors and applications within each…." This reference model "…will be further developed and maintained by a Smart Grid Architecture Board, a subcommittee of the Smart Grid Interoperability Panel."

"The Smart Grid will ultimately impact and shape hundreds of standards..." (Figure 25). To prioritize its work, NIST chose to focus on standards needed to address the priorities identified in the Federal Energy Regulatory Commission Policy Statement plus four additional items. The priority areas are as follows:

- DR and consumer energy efficiency
- Wide area situational awareness
- Electric storage
- Electric transportation
- AMI
- Distribution grid management
- Cyber security
- Network communications,

"Through the NIST workshops… a total of 70 gaps and issues were identified. Of these, the NIST selected 14 for which resolution is most urgently needed to support one or more of the Smart Grid priority areas."

- Smart meter upgradeability standard
- Common specification for price and product definition
- Common scheduling mechanism for energy transactions
- Common information model for distribution grid management
- Standard DR signals
- Standard for energy use information
- IEC 61850 objects/DMP3 mapping
- Time synchronization
- Transmission and distribution power systems model mapping
- Guidelines for use of IP protocol suite in the Smart Grid
- Guidelines for use of wireless communications in the Smart Grid
- Electric storage interconnection guidelines
- Interoperability standards to support PEVs
- Standard meter data profiles.

"A robust framework for testing and certification of Smart Grid devices and systems must also be established to ensure interoperability and cyber security."

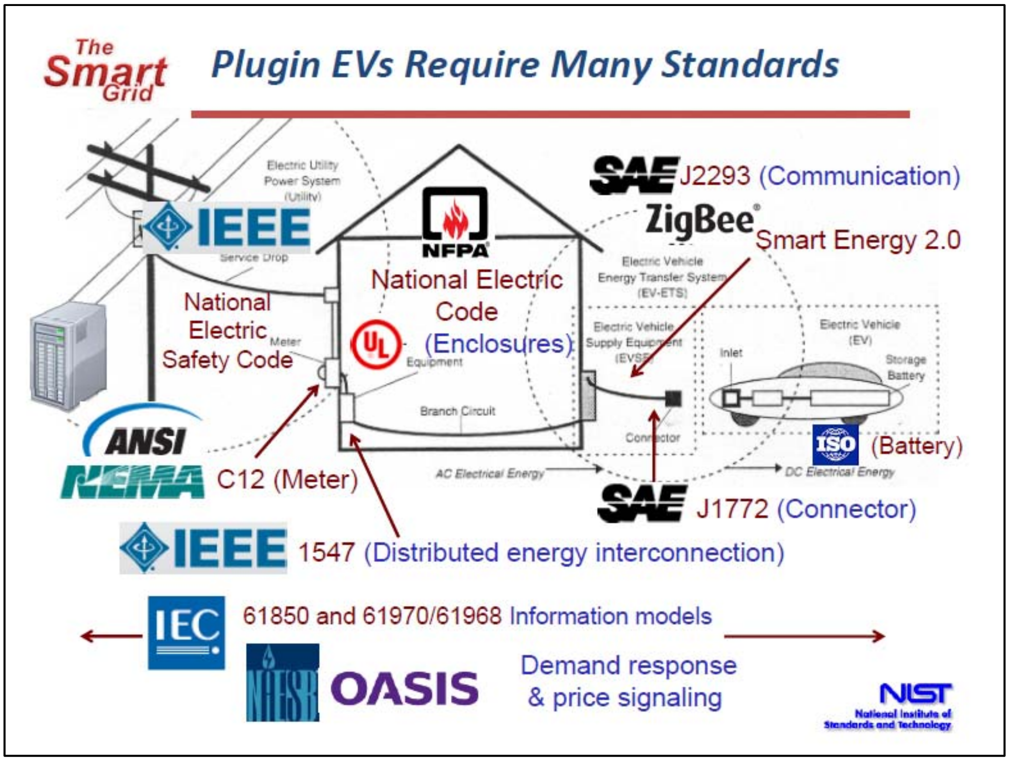

Figure 24. Plug-in electric vehicles require many standards (source: Allen Hefner, NIST Smart Grid Team, “Coordination and Acceleration of Standards for Smart Grid,” presented at Military Smart Grids and Microgrids Conference, October 19, 2011).

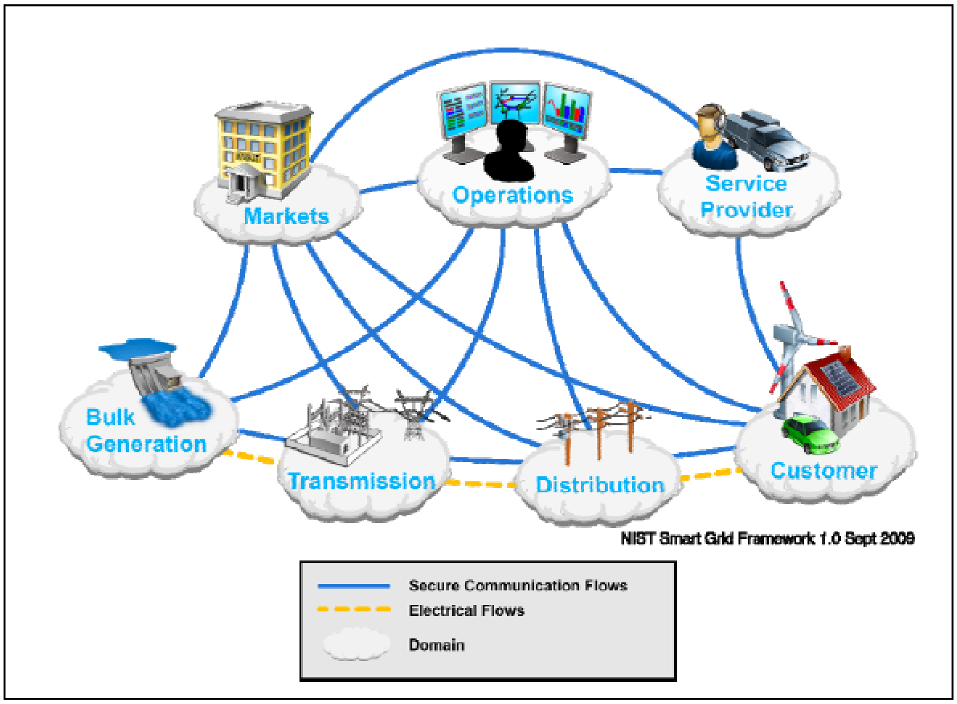

Figure 25. National Institute of Standards and Technology Smart Grid framework (source: NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 [Draft], September 2009).

The NIST architectural initiative lays the framework for standards development organizations to prioritize and develop appropriate standards. The most relevant of these standards development organizations for implementation of a safe, secure, and robust smart charging integration with the Smart Grid are as follows:

- IEEE
- SAE
- NEC.

Other important policy, technology, and advocacy organizations that are influencing development of V2G standards include the following (not an exhaustive list):

- Electric Power Research Institute
- Electric Drive Transportation Association
- Edison Electric Institute
- National Resources Defense Council
- California Energy Commission
- California Public Utilities Commission
- Rocky Mountain Institute
- National Association of Regulated Utility Commissions
- U.S. Department of Energy (multiple program offices)
- Argonne National Laboratory
- Idaho National Laboratory
- National Renewable Energy Laboratory
- Pacific Northwest National Laboratory
- Oak Ridge National Laboratory.

4.4 American National Standards Institute

The American National Standards Institute (ANSI) is a not-for-profit organization that oversees the creation, promulgation, and use of standards and guidelines to ensure the safety and health of consumers and protection of the environment. A recommendation was presented to ANSI in March 2011 that there needed to be a more coordinated approach to keep pace with electric vehicle development around the world. ANSI responded by forming the Electric Vehicles Standards Panel "…to assess the standards and conformance programs needed to facilitate the safe, mass deployment of electric vehicles and charging infrastructure in the United States." In April 2012, this panel presented the *Standardization Roadmap for Electric Vehicles*, Version 1.0.

The specific goals of this roadmap are as follows:

1. Facilitate development of a comprehensive, robust, and streamlined standards and conformance landscape
2. Maximize coordination and harmonization of the standards and conformance environment domestically and with international partners.

The Roadmap acknowledges that the electric vehicle and infrastructure industry is "… very complex and dynamic, undergoing continual evolution and adaption, with many parties involved." The specific focus of the Roadmap is to identify gaps in standards, codes, regulations, conformance programs, and harmonization efforts. It then provides recommendations and priorities related to filling these gaps (ANSI 2012).

4.5 Institute of Electrical and Electronics Engineers

IEEE develops technical standards that are in use throughout the world. These standards are developed for power and energy-related industries, among many others.

4.5.1 IEEE P2030 Smart Grid Infrastructure

The IEEE P2030 draft for smart grid interoperability of energy technology and information technology operation with the EPS and end-use applications and loads standard is in place to provide guidelines for smart grid interoperability. A knowledge base containing terminology, characteristics, and additional criteria for the application and the relation to smart grid interoperability is defined. It also discusses alternate approaches to best practices and minimization of the impact of lagging participants on compliant ones. Currently, AMI smart meters contain software that easily may be manipulated when remotely accessed. The P2030 standard minimizes ‘hacking’ of these smart meters through vigorous cyber security requirements. The primary purpose of the P2030 directive is to promote a more reliable and flexible power system, while permitting two-way power flow with communication and control. Open standards will be developed that will drive the rapid integration of renewable energy sources, smart buildings, community energy storage, electric vehicles, and other intelligent systems. Technologies used in the EPS will merge with communication networks and device monitoring and control capabilities.

The IEEE P2030 contains two work groups that include more specifics related to electric transportation infrastructure and extend the work aimed at utility deployed storage systems for transmission and distribution networks. P2030.1 incorporates the emerging guidelines of the proposed standard P1809 in April of 2010 (IHS Energy 2010). This addresses applications for PEVs and related support infrastructure used in both personal road-based travel and with public transportation. Utilities, manufacturers, transportation providers, infrastructure developers, and end-users are being addressed. P2030 and P2030.1 share many of the same objectives with an overarching goal of sparking new smart grid developments and technological innovations that are interoperable and create entirely new value chains. P2030.2, which is still under development, defines the characteristics of the ESS and its compatibility and integration with electric power infrastructure. Applicable terminology, performance functions, operations, testing, and the functional performance between the electric power infrastructure and integration of the ESS also are provided. The IEEE P2030.3 workgroup develops standardized test procedures for the storage equipment and systems that connect to an EPS. These defined procedures must be repeatable and accommodating to the variety of possible storage technologies.

4.5.2 IEEE P1547 Physical and Electrical Interconnections between Utility and Distributed Generation

IEEE P1547, established in June 2003, is the standard for interconnecting distributed resources with electric power systems. It provides requirements relevant to performance, operation, safety considerations, testing, and maintenance of the interconnections regarding distributed resources and EPSs.

There are four work groups established under P1547. IEEE P1547.1 specifies the type, production, and conformance of test procedures that will be performed to demonstrate that the interconnection and equipment functions of a distributed resource conform to the guidelines specified in P1547. Standardized tests and procedures are required to ensure compliancy. These tests must provide repeatable results and the flexibility to include a multitude of DER technologies.

IEEE P1547.2, approved in 2008, provides technical background and application details to support the understanding of the details outlined in P1547. This includes the characterization and identification of the various forms of DR technologies and their related interconnection issues. P1547.2 enhances the use of P1547 by inclusion of technical descriptions and schematics, applications guidance, and examples of interconnection.

IEEE P1547.3 provides the guidelines for monitoring, information exchange, and control for DER interconnection with EPS. This standard provides a description of functionality, parameters, and methodology for monitoring information exchange and control for interconnected DER with energy service providers. This includes systems in the areas of fuel cells, PV, wind turbines, micro turbines, other distributed generators, or other distributed ESSs. P1547.3 is helpful to manufacturers and implementers of communications systems for loads, energy management systems, supervisory control and data acquisition, EPS, and equipment protection and revenue metering by providing use-case methodology and examples such as ancillary services, maintenance, and scheduling.

IEEE P1547.4 was approved in early 2011. The scope of this standard is to provide alternative approaches and good practices for design, operation, and integration of DR island systems with EPS. This contains inclusion of the ability to separate from, and reconnect to, part of the area EPS, while providing power to the islanded local EPS. This includes the DER, interconnection systems, and participating EPS. P1547.4 is intended for use by EPS designers, operators, system integrators, and equipment manufacturers to provide an introduction and overview and to address engineering concerns of DER island systems. The expansion of the benefits of using DG by targeting improved EPS reliability and building upon interconnection requirements stated in IEEE P1547 will result from implementation of this guide.

Currently, there are an additional four workgroups expanding on IEEE P1547. IEEE P1547.5 provides technical information relating to interconnection of the EPS with a capacity greater than 10 MVA to the grid and establishes the parameters that define a correct interconnection. IEEE P1547.6 focuses on the practices for interconnecting distributed resources with EPS distribution secondary networks. The recommendations on performance, operation, safety, maintenance, and testing of the interconnection are provided. P1547.7 describes the methods for performing engineering studies of a distributed resource interconnected to an electric power distribution system. The IEEE 1547.8 expands on the use of IEEE Standard 1547 by defining procedures that support implementation of this standard (Institute of Electrical and Electronics Engineers 2010).

4.6 Society of Automotive Engineers

The SAE is a standards development organization established for the purpose of defining technical standards for the automotive, boat, truck, and aircraft industries. The purpose of these technical standards is to improve safety and the market position, positively affect productivity, and assist in the advancement of technology. This international organization has grown to include 120,000 members, many of whom reside outside of the United States.

4.6.1 SAE J2293 Communications between Plug-in Electric Vehicles and Electric Vehicle Supply Equipment for Direct Current Energy

SAE J2293 details the transfer of electrical energy from the utility power system to the PEV traction battery and other vehicle loads. This standard operates in conjunction with guidelines set forth in IEEE P1547.3. There are two parts detailed in standard SAE J2293. J2293.1 establishes the requirements for the PEV and EVSE when transferring energy from the utility to the PEV. This standard defines all characteristics of the electric vehicle energy transfer system necessary to ensure the functional interoperability of a PEV and EVSE. The energy transfer system is responsible for the conversion of AC to DC power to be used to charge the PEV battery. The second part of this standard, SAE J2293.2, establishes the communication requirements and network architecture related to the electric vehicle energy transfer system. Although this document does not detail the characteristics of the interface between the EVSE and the utility, it does acknowledge the utility as the source of energy to be transferred to the electric vehicle. The requirements model is not intended to specify a certain design or physical implementation, but to describe a functional description of the expected operational results of the system. Comparison of these results may be used against the operation of any design, because this document takes into account the potential for various architectures (SAE International 2010).

4.6.2 SAE J1772 Electrical Connector between Plug-in Electric Vehicles and Electric Vehicle Supply Equipment

The SAE Standard J1772 charging connector for PEVs is the common standard used by all automakers with highway-capable PEVs in the United States (with Tesla being a partial exception). This recommended practice covers the general physical, electrical, functional, and performance requirements intended for facilitating conductive charging of a PEV. The J1772 coupler and electric vehicle inlet are intended for use with AC Level 1 and 2 charging. DC Level 1 charging also is being considered for future incorporation into this standard. This coupler supports both charging and a simple one-way communication, where the vehicle signals that it is present, capable, and ready for charging, while also being designed to withstand at least 10,000 connection and disconnection cycles. It is designed to be corrosion resistant, withstand a vehicle being driven over it, and exposure to dust, salt, and water. The J1772 standard and NEC requirements create multiple safety levels (Electric Transportation Engineering Corporation 2010).

4.6.3 SAE J2847 Communications for Plug-in Electric Vehicle Interactions

SAE J2847 relates to the recommended practice for communication between PEVs and the utility grid. This standard is designed to work closely with SAE J2836. There are five work groups intended to better define J2847. SAE J2847.1 is a communications standard that establishes requirements and specifications for communication between PEVs and the electric power grid for applications such as energy transfer. This document relates to interactions between the vehicle and vehicle operator, where applicable. SAE J2847.1 is directed toward organizations representing automotive OEMs, suppliers, the government, academia, and the automotive industry.

SAE J2847.2 establishes the communication between PEVs and the EVSE. Use cases, specifically in relation to reverse power flow, will be defined in this standard. This supports additional messages and detail for DC energy transfer while replacing SAE J2293 for communication between the PEV and the EVSE. It also compliments SAE J2836.2 for general information regarding DC energy transfer.

The communication structure between PEVs and the electric power grid for reverse power flow will be established in standard J2847.3. This document will identify the equipment or system elements and the interactions to support grid-optimized AC or DC energy transfer for PEVs using reverse power flow.

SAE J2847.4 will establish the communication requirements between the PEV and the EVSE for charge or discharge sessions. It takes the use case and general information established in SAE J2836.4 and provides the detailed messages and diagrams to implement the communication. The diagnostic requirements and interactions to charge or discharge PEVs will be identified.

SAE J2847.5 outlines the communication requirements to the customers in relation to charge or discharge sessions. Customer interface requirements will be outlined, as well as interactions to charge or discharge the vehicle. The general information and use cases provided in SAE J2836.5 are the foundation for the detailed messages and diagrams to implement the communication as outlined in J2847.5 (SAE International 2010).

4.6.4 SAE J2836 Use Cases for Plug-in Electric Interactions

SAE J2836 is a recommended practices document. It provides the automotive standards for V2G communications message structures and formats. There are four workgroups related to SAE J2836. SAE J2836.1, published in April 2010, establishes the use cases related to communication between PEVs and the electric power grid for energy transfer and other applications. The use cases for communication between PEVs and the EVSE are described in SAE J2836.2. SAE J2836.3 establishes the use cases for communication between PEVs and the electric power grid in relation to reverse power flow. Using SAE J2283 as a basis, this standard incorporates off-board rechargeable ESSs and PEVs, because these technologies have changed dramatically. Use cases for diagnostic communication for PEVs are outlined in SAE J2836.4. This standard introduces detailed messages and information intended for the customer and service personnel to aid in identification of the source of potential issues and their resolutions. Existing diagnostics related to the PEV and EVSE may be included to assist in resolution of the issue (SAE International 2010).

4.7 Underwriters Laboratories, Inc.

The Underwriters Laboratories, Inc. (UL) is a global independent safety science company. UL provides safety design and testing standards across several industries. Several standards apply directly to the design of electric vehicles, including the cords, cables, connectors, and traction motors. The following standards are specifically noted.

4.7.1 UL 2202 Electric Vehicle Charging System Equipment

These requirements cover conductive and inductive charging systems equipment for electric vehicles. The standard provides detailed requirements for equipment that can be onboard or off-board the electric vehicle. This equipment is intended to be installed per the requirements of NEC.

4.7.2 UL 2231-1 and 2231-2Personnel Protection Systems for Electric Vehicle Supply Circuits

These requirements cover devices and systems intended for use in accordance with NEC Article 625 external or onboard the electric vehicle.

4.7.3 UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles

These requirements cover plugs, receptacles, vehicle inlets, vehicle connectors, and breakaway couplings intended for conductive connection systems for use with electric vehicles.

4.7.4 UL 2580 Batteries for Use in Electric Vehicles

These requirements cover electrical energy storage assemblies for use in electric vehicles.

4.7.5 UL 458A Power Converters/Inverters for Electric Land Vehicles

These requirements cover power converters and power inverters intended for use in electric vehicles.

4.7.6 UL2594 Electric Vehicle Supply Equipment

These requirements cover investigation for EVSE for power outlets, cord sets, and AC Level 1 and 2 EVSE.

4.8 Codes and Standards in Select Municipal Areas of the United States

Because the V2G concept is still in the stages of development and demonstration, there are not many clear codes and standards that specifically address V2G. In order to evaluate the applicable regional codes and standards that apply, this section looks at regulatory, utility, implementation, and market barriers to similar electrical configurations of power back flow (i.e. solar or other DERs) and the surrounding rate and interconnection issues.

Regulatory barriers focus on the local authority having jurisdiction and their imposed regulation. Utility barriers are mainly addressed through electric service rules, which govern types of DER allowed, interconnection restrictions, and other relevant topics. Implementation barriers include installation and operating restrictions, including permits and equipment approvals. Lastly, market barriers, such as rates and incentives, are explored to look at potential financial hurdles.

The regions explored in this report were selected for their diversity in government, geography, and utility structure. In order to capture information and relevant topics, a survey was developed and provided to a municipal or utility representative from the region. The tutorial that explained the survey is included as Appendix B. The survey is attached in Appendix C.

4.8.1 Phoenix, Arizona

Several cities in the Phoenix, AZ area are members of the Maricopa Association of Governments. Each municipality has a representative that participates in code committee meetings. As the Maricopa Association of Governments agency itself does not have jurisdiction over building and electrical codes, they are adopted and enforced by each member agency in the Maricopa Association of Governments region. The City of Phoenix is the authority over developing and implementing all city codes. Phoenix has adopted NEC 2008, where enforcement began in May 2009 (NEMA 2011). All international codes, such as IRC and IBC, are selected at the Phoenix local level. The 2006 editions of all I-Codes have been implemented by the City of Phoenix (International Code Council 2012). As of 2009, 31 Arizona municipalities have adopted energy codes. While no energy inspection procedures exist at the state level, local agencies are responsible for code enforcement. Energy codes in Phoenix currently do not have a set policy to determine the schedule of review (Database of State Incentives for Renewables and Efficiency 2012).

Salt River Project (SRP) and Arizona Public Service (APS) are the major electricity providers for Phoenix and the surrounding municipalities. Both SRP and APS have TOU rates in place for residential and commercial customers. Arizona has filed tariffs to allow all renewable energy technologies the ability to implement net metering capabilities. This will only be applicable to residential customers. Currently, there are no service rules in place for V2G or PEV and EVSE-related technologies. There are service rules that address solar/PV, DG, and net metering technologies. APS has proposed an electric vehicle TOU rate that would be available only to qualified electric vehicle owners. It currently is offered until December 31, 2014, after which extensions will be granted at the company’s discretion (APS 2012).

SRP and APS, depending on the customer’s service provider, are the agencies that maintain operating permits. Both residential and commercial customers will require permits for back up generation installations. APS requires a completed interconnect agreement and an electric supply purchase agreement, as well as an inspection completed by APS for all generators running parallel to the utility. Energy compliance certificates and PV applications are available through the City of Phoenix website (City of Phoenix 2012).

4.8.2 Orlando, Florida

Florida’s building code is statewide; however, under certain strictly defined conditions, local governments may be able to amend requirements to make them significantly more stringent than the original code. This statewide policy came into effect in 2009. Florida Building Code 2007, which includes all of 2006’s IBC and IRC codes, cover the building, structural, mechanical, plumbing, and fire-life safety regulations within Orlando, FL. The 2009 international codes are to be re-evaluated and take effect in March 2012 (International Code Council 2012). Orlando has adopted the 2008 version of NEC and is taking the appropriate steps toward assimilation of the 2011 NEC by offering proper training in August 2012 (NFPA 2012). Based on the 2006 edition of IECC, the energy efficiency standards of the 2007 Florida Building Code are a mandatory statewide policy (Database of State Incentives for Renewables and Efficiency 2012).

Progress Energy is the dominant utility serving the Orlando area. Although their service rules are updated infrequently, there are current service rules in place addressing solar/PV technology and net metering for both residential and commercial customers. Progress also has policies in place for DG and

TOU rates. Progress Energy requires installation of a bi-directional meter and completion of an application and interconnection contract to operate in parallel to the utility. No application fee is required for generation that is less than 10 kW. For generation up to 100 kW, an application fee of $240 is required, as well as an inspection completed by a Progress Energy employee. An application fee of $750, as well as all aforementioned procedures is required for use of a system that will generate up to 2,000 kW. The Progress Energy Distribution-Interconnected Generation Office issues all required documents and procedures related to DG and net metering. Feed-in-tariffs (FITs) were approved recently and are currently offered to qualifying customers. Currently, Progress Energy has not considered V2G policies or electric vehicle-only rates for their customers (Progress Energy 2011).

All commercial and residential electrical permitting services are available at Orlando's City Hall Office and through an application that may be submitted online. These forms include options that include any solar generation devices (City of Orlando 2012).

4.8.3 Boston, Massachusetts

All international codes and the version of NEC adopted are decided on by the State of Massachusetts. The 2009 edition of IBC and IRC form the basis of the Massachusetts State Building Code, with state specific amendments (Database of State Incentives for Renewables and Efficiency 2012). Boston implemented the 2011 version of NEC on January 1, 2011. The 2011 NEC became the basis of the 2011 Massachusetts Electrical Code (NEMA 2011). As of the 7th Edition of the Massachusetts State Building Code, newly constructed houses must be in compliance with 2009 IECC. As new editions of IECC are released, Massachusetts must update the State Building Code (Database of State Incentives for Renewables and Efficiency 2012). Public hearings are held to determine amendments to the code.

NSTAR provides retail electricity to its customers in the Boston area. While DG and net metering are supported, there are no solar/PV special rate schedules. For all projects that are greater than 10 kW single phase or 25 kW three phase, NSTAR provides a process form that is available on their website. For all simplified projects, NSTAR offers a separate simplified process form. An application package, an installed disconnect switch, and an inspection certificate, documenting that the interconnection meets all national, state, and local codes, are required before equipment may be connected to the electrical grid. Equipment that is intended to be operated with net metering capabilities must have the Net Metering Application Schedule Z completed and returned to the Interconnection Program Manager at NSTAR. TOU rates are available to customers, which may allow for an easier adoption of electric vehicle-only rates in the future. Both FITs and V2G-related policies have not been considered for implementation by NSTAR (NSTAR 2011).

Permits for the City of Boston may be obtained through the forms from the Inspectional Services Department. Forms may be completed and submitted online with payment or in person at the Inspectional Services Department main office. Upon inspection and submission of the permit, fees will be determined (City of Boston 2012).

4.8.4 Detroit, Michigan

The Michigan state government is responsible for setting codes and standards, while local agencies are responsible for enforcement. The 2009 Michigan Building/Residential/ Rehabilitation and Energy Code Rules were filed with the Secretary of State on November 8, 2010, and became effective March 9, 2011. These state-mandated codes reflect the 2009 editions of the international codes (International Code Council 2012). In March 2011, the 2008 NEC was enforced. The State of Michigan will not start reviewing the 2011 NEC until the end of 2011 (NEMA 2011). As of July 2012, there has been no indication that Michigan will adopt and enforce the 2011 NEC. The 2009 Michigan Uniform Energy Code is based on the 2009 edition of IECC. This code is reviewed and updated every 3 years (Database of State Incentives for Renewables and Efficiency 2012).

There are orders by the Michigan Public Service Commission on net metering and guidelines are filed by Michigan utilities that specify the technical requirements for PV and DG. In addition, regional EVSE standards are in place.

DTE Energy, an IOU, provides electrical service to the Detroit region. Their service rules are updated infrequently. There are service rules in place for net metering and related concurrent reverse power flow procedures, both by phase and power level. These features currently are used strictly in conjunction with a renewable generator's interconnection to the grid, and supplying the customer the option of these services is required by utilities in both the commercial and residential sectors. Electric vehicle and EVSE equipment, solar/PV, and DG technologies also are services in use with DTE Energy. DTE closely follows IEEE 1547 in regard to voltage minimums and maximums, with the point of common coupling being the main determining factor. Both power outage restoration targets and compliance metrics are tracked (Asgeirsson 2011). In order to operate equipment in parallel with the electrical grid, DTE requires a completed and submitted interconnection application, a signed parallel operating agreement, and a site inspection of the completed installation. Depending on the capacity of the equipment, application fees may be required. DTE Energy purchases renewable energy credits from customers using revenue metering. Both residential and commercial TOU rates are in place through DTE Energy, along with electric vehicle-only rates (DTE Energy 2011).

Currently, permitting for EVSE installation is administered by local jurisdiction. Permitting is required for backup generators in both commercial and residential circumstances. Permits may be obtained through the City of Detroit Buildings and Safety Engineering Department, or online through the city website. All electrical equipment must be installed according to guidelines set in the electrical code and must be inspected and approved by the electrical inspector (City of Detroit 2012).

4.8.5 Raleigh, North Carolina

The authority having jurisdiction in Raleigh, NC is under the City of Raleigh's Inspections Department (City of Raleigh 2012). The 2012 North Carolina State Building Code is in place throughout Raleigh's municipal region. The 2012 North Carolina Codes are based on the 2009 editions of the international codes (North Carolina Office of State Fire Marshall 2012).The 2012 North Carolina Electrical Code is the most current observed code, effective July 3, 2012, based on the 2011 version of NEC (Holt 2011). The North Carolina Building Code Council has voted to defer any action on the 2012 North Carolina Electrical Code, which is based on the 2011 NEC, until further legislative review. The 2012 Codes were set for implementation on September 1, 2011, but letters of protest pushed for a reevaluation of the proposed codes (NEMA 2011). The 2009 IECC forms the basis for the more stringent state-developed 2012 North Carolina Energy Conservation Code (Department of Energy 2012). This mandatory code is under review everything 3 years (Database of State Incentives for Renewables and Efficiency 2012).

Progress Energy, an IOU, is the utility company provider for Raleigh, NC. Their most recent updates to their service rules were effective April 1, 2011, and are updated annually. Currently, no specific service rates are in place for V2G, electric vehicles or EVSE, solar/PV, DG, or net metering technology in Progress Energy's service area. Net metering with renewable energy resources is supported through this utility. Customers preparing to interconnect generation equipment to Progress Energy in the North Carolina service territory must complete an interconnection request form, along with a $100 application fee. A representative from the Interconnected Generation Office will contact the customer to assist with additional procedures. While there are TOU rates currently in place for commercial and residential customers, there are no electric vehicle-only rates being executed for applicable customers (Progress Energy 2011).

Permits are required for backup generator installations in both the commercial and residential customer areas. Permits may be obtained (in person) for a cost of $152.00. The City of Raleigh requires approval from UL, Electrical Testing Laboratories, and any additional Nationally Recognized Testing Laboratory testing agencies for V2G-related equipment (Olafson 2011).

4.8.6 Maui, Hawaii

The State of Hawaii allows each jurisdiction to implement their specific codes and standards. The City of Maui has implemented the 2006 IBC, but does not recognize IRC (International Code Council 2012). Maui is not required to follow a statewide adoption of a specific edition of NEC, because this is more commonly determined by the local jurisdiction. In this case, however, Maui has conformed to the state adoption of the 2008 NEC. Implementation of the NEC code took place in the summer of 2010 (NEMA 2011). Last updated in 2009, the Hawaii Building Energy Code adopted the 2006 edition of IECC. This statewide code may be modified at the county level, as long as the codes they adapt are at least as stringent. Currently, there is no set schedule for code review (Database of State Incentives for Renewables and Efficiency 2012).

Maui Electric Company (MECO) meets the commercial and residential needs of the customers in the Maui area. Currently, no V2G policies are in place. Net metering is available to all residential and commercial customers, according to Hawaii state law, and each system must be registered with their utility. Interconnection procedures with approved AC-DC solar equipment are streamlined up to 100 kW in capacity. MECO requires submission of the net metering agreement and inspections from both MECO and from a Maui county electrical inspector before interconnection will be approved. A manual lockable disconnect switch also is required. The net metering policies include solar and PV technologies. MECO also has a FIT program in effect, which is designed to encourage growth in the number of renewable energy projects in Hawaii (Maui Electric Company 2011).

Permits may be obtained through the Maui county website or in person at the Building Plan Review Section for any construction, alteration, and repair of any building. Permit fees vary depending on the scope of work and are outlined within the Maui County Code. Review of the application will be completed by the Building Plan Review Section (County of Maui 2012).

4.8.7 San Diego, California

As of January 1, 2011, the California Building Standards Commission adopted the 2010 editions of the California building, fire, mechanical, and plumbing codes. The latest edition of the California Building Codes is based on the 2009 IBC, 2009 IFC, and 2008 NEC (International Code Council 2012). The guidelines in the California Building Code exceed the information contained in the 2009 IECC (Database of State Incentives for Renewables and Efficiency 2012). The California Residential Code is based on the 2009 IRC. Section R328 of the California Residential Code defines electric vehicles and states that all EVSE installations must be in accordance with the California Electric Code (California Building Standards Commission 2011). Development of the 2010 California Energy Commission was based on the guidelines outlined in the 2008 publication of NEC. The City of San Diego adopts the latest codes defined by the California Building Standards Commission. Only with approval from the California Building Standards Commission can these codes be adjusted for each jurisdiction. The 2010 California Green Building Standards Code briefly mentions electric vehicles in Section 406.7, but provides no additional insight into V2G technology (California Department of General Services 2010). The 2008 NEC was implemented on January 1, 2011. Codes are under review every 3 years (NEMA 2011).

SDG&E covers the entire San Diego service area. Electric vehicle TOU rates are available for PEV owners to encourage “off peak” charging. SDG&E also offers net metering options for customers that utilize PV technology with their home and supports renewable energy systems up to 1 megawatt (MW) in capacity. FITs are in place to provide a standard contract and tariff price for renewable generators up to 10 MW in capacity. In general, FITs are used to incentivize renewable energy generation. A key goal of SGD&E during their Smart Grid roll-out is to enable DR programs. These programs will provide more options for customers to manage their energy consumption, while choosing to enable automated device control, or setting smart devices to react based on pricing events and the support of grid operations. Solar policies are offered in conjunction with net metering for smaller systems that generate under 10 kW. This technology must comply with NEC, and SDG&E must supply bi-directional metering (San Diego Gas and Electric 2011).

The City of San Diego offers several types of permits depending on the type of construction. Typically, combination permits will be issued to homeowners. An electrical permit is required when changes are made to the building's existing system. Permits may be issued in person at the city's Development Review Center. Approved contractors also may obtain the necessary permits (City of San Diego 2012). To obtain approval for installation of self-generation equipment, various forms must be obtained through SDG&E's website. If the equipment qualifies for net metering, the customer will be exempt from many application fees. An interconnection agreement, an application, and written authorization from SDG&E are required. Forms may be obtained through SDG&E's website (San Diego Gas and Electric 2011).

4.8.8 Dallas, Texas

The State of Texas allows jurisdictions to adopt later editions of I-Codes when authorized. The City of Dallas has maintained the 2006 editions of IBC, IRC, and IFC (City of Dallas 2012). The City of Dallas is granted the ability to select the I-Code edition because it is a larger jurisdiction with a full service inspection department to enforce the particular codes. On September 1, 2011, the 2011 NEC was implemented without amendment throughout the State of Texas (NEMA 2011).

Oncor and TXU Energy service the Dallas area. For the purpose of this document, TXU Energy will not be included because it is not a transmission and distribution utility. TXU is unable to ensure interconnection agreements for services such as net metering and DG and will refer their customers to Oncor. After a series of company buyouts, TXU is only a retail provider of electricity. Energy Future Holdings Corporation is the parent company to both Oncor and TXU Energy. Currently, Oncor does not offer any service policies on electric vehicle-related technology such as V2G, an electric vehicle-only rate, or FITs to their customers. While DG and net metering are supported, Oncor has not included solar or PV-specific rate policies. Oncor requires an approved application for interconnection; all related fees and procedures will be outlined by the company once the application has been completed and submitted (Oncor 2011).

The City of Dallas offers building permits online or through the Oak Cliff Municipal Center Building Inspection Permit Center. All building inspections will be scheduled through the Building Inspection Division. As of October 1, 2010, there is a $65 verification fee required for each Certificate of Occupancy application (City of Dallas Permit Office 2012).

4.8.9 Seattle, Washington

The State Building Code Council is the authority having jurisdiction presiding over the City of Seattle and the construction codes and standards observed. The State Department of Labor and Industries adopts and is responsible for enforcement of the electrical code, except in cases where cities enforce their own electrical program. The codes in effect in Seattle are determined at the state level. The 2009 versions of IBC and IRC are adopted and enforced (International Code Council 2012). As of July 2012, the 2008 NEC is the latest edition of NEC. In late 2011, adoption of the 2011 NEC was underway; however, all non-critical rulemaking was suspending by the governor through the rest of the year. The Washington State Government has indicated that it will not enforce the 2011 NEC, but will evaluate the 2014 NEC once it is released (Holt 2011). NFPA will be offering a 3-day training session on the 2011 NEC in August 2012 (NFPA 2012).

Seattle City Light (SCL), a municipal-owned utility, services the Seattle Metropolitan Area. Their electric service rules are updated infrequently (i.e., the last known revision took place in 2007). Currently, they do not have a stated policy on V2G, FIT, or DG-related services. SCL supports and offers solar/PV systems and recommends using in conjunction with net metering plans they offer. SCL also offers related Washington State production incentives for use of solar technology. To qualify for SCL's Renewable Energy Production Incentives, an SCL production meter is required. A $62 meter fee applies to all requests. An Interconnection Application and Agreement for New Generating Systems application is required for all customers interested in connecting generation equipment to the electrical grid. This form is available through SCL. Annual payments will be based on kWh of electricity produced. Code requirements for solar electric systems are based on NEC Article 690, which details the requirements for designing and installing code-compliant solar electric systems. Washington State Law requires the 16 largest utilities in Washington, including SCL, to offer net metering for customers for energy generation up to 100 kW. SCL's meters allow bi-directional power flow (Seattle City Light 2011).

The Department of Planning and Development issues electrical permits for Seattle residents. They are committed to responding to inspection requests within 3 days (City of Seattle 2012).

4.8.10 Portland, Oregon

The State of Oregon is the authority having jurisdiction for the Portland area. The 2011 NEC is in effect for the Portland area as of April 1, 2011. Each city has its permit and inspection requirements, which are based on the codes set by the State of Oregon. The State of Oregon 2011 Edition Electrical Specialty Code is derived directly from the 2011 Edition of NEC (NEMA 2011). Additionally, NFPA is offering a training session for the 2011 NEC in October and November of 2012 (NFPA 2012). The 2011 Oregon Residential Specialty Code is an up-to-date residential code that addresses construction and design of single and dual family dwellings. This code is fully compatible with all I-Codes including, but not limited to, the 2009 Editions of IBC, IRC, IECC, and IFC. In order to keep this code current, committee hearings are scheduled regularly, and changes are reviewed by code enforcing officials, design professionals, and industry representatives (International Code Council 2012).

Portland General Electric (PGE) is the utility covering the Portland service area. PGE serves 53 cities, mainly located around the greater Portland/Salem metropolitan areas, providing service to over 800,000 customers. The utility's service rules are updated on a regular basis, with April 2011 being the effective date for the latest updates. Currently, there are no V2G-related service rules; however, the utility has expressed interest in developing pilot programs to determine the viability of this technology. There are service rules in place for solar/PV technologies, DG, and net metering. PGE has placed a great amount of support for DG technologies. Currently, PGE has over 50 MW of DG and over 3 MW on solar payment options. PGE would require special applications and rules to allow V2G technologies, because the state rules currently apply only to renewable power sources and are limited to a generating installed capacity of 25 kW or less for the residential sector and 2 MW for commercial customers (Portland General Electric 2011). This may require any V2G-related testing and implementation to be tied in with a solar project (Durst 2011). Net metering facilities are intended to first offset the customer's load before excess energy generation will be exported to the grid. Electricity supplied by PGE and the excess customer-generated energy pass through a bi-directional meter that is provided free of charge to the customer. A second bi-directional meter, known as a solar production meter, is provided free of charge to customers to measure all solar generation in cases where solar power generation technology is used (Portland General Electric 2011). All interconnections at the utility level are required to meet the standards set in IEEE 1547 (Database of State Incentives for Renewables and Efficiency 2012). PGE provides the application forms for small generator facilities and net metering facility interconnections. While PGE does not have electric vehicle-only rates in place, TOU rates for both commercial and residential sectors exist. PGE also tracks the system average interruption duration and system average interruption frequency indices. The system average interruption duration and system average interruption frequency indices targets are imposed by the Oregon Public Utilities Commission. The system average interruption duration and system average interruption frequency indices figures (i.e., indicators of system reliability) are available through PGE's Main Office (Durst 2011).

The State of Oregon has permitting requirements in place for use of commercial and residential backup generators. The cost for installation and renewal of permitting varies, even though the interested party may apply both online and in person. All new V2G equipment will require approval from UL, Electrical Testing Laboratory, or any additional Nationally Recognized Testing Laboratory testing agency. The state electrical inspector also has a program for special deputy certification for new and emerging technologies (City of Portland 2012).

4.8.11 New York, New York

The New York State Fire Prevention and Building Code Council determine the mandatory minimum requirements throughout the state, with the exception of New York City. With approval first from the New York State Fire Prevention and Building Code Council, local jurisdictions may adjust the codes to include more firm guidelines. New York City has continued to implement the 2006 edition of all I-Codes (International Code Council 2012). The 2011 NEC was officially adopted and enforced in July 2011 (Holt 2011). These codes were voted into effect by the Building Code Council in April 2010. The New York Building Energy Code is based on the 2009 IECC. There is no set schedule for code review and revisions (Database of State Incentives for Renewables and Efficiency 2012).

Con Edison (ConEd), an IOU, provides electrical services to its customers in the New York City area. ConEd does not offer an electric vehicle-only rate; however, they encourage the use of their TOU rates for customers with EVSE. These rates are designed to encourage charging during off-peak periods at a lower cost to the customer. ConEd installs digital electric meters for net metering customers. These meters are programmed to calculate the net energy that is delivered to the customer. Because ConEd supports solar and PV systems, net metering programs are recommended to maximize the use of the customers’ renewable energy systems. ConEd also permits any customer to operate DG-related equipment within their service territory as long as it adheres to company standards when connected to the utility’s electric system. In order to receive approval from ConEd to interconnect power generation facilities to their power distribution system, an application must be submitted, along with developing a cost estimate, for the coordinated electric system interconnection review. Final testing and inspection will be completed by ConEd before the system will be approved for parallel running with the electrical grid. Application fees vary depending on the capacity of the equipment (Con Edison 2011).

Two permits are required for solar/PV customers that are obtained from the Bureau of Electrical Control and a building permit that is obtained through a third party structural engineer. The Department of Buildings has established the permitting requirements (New York City 2012).

4.8.12 Washington D.C.

In the Washington D.C. area, the Construction Codes Coordinating Board is the newly assembled authority having jurisdiction, replacing the Building Code Advisory Committee. The Construction Codes Coordinating Board maintained that the 2006 Editions of the I-Codes will be the referenced codes for their jurisdiction. The State of Maryland, including Washington D.C., is the first state to officially adopt IGCC (International Code Council 2012). The 2005 NEC is currently enforced (Holt 2011), with intentions to complete review of the 2011 NEC and a target adoption date for the spring of 2013 (The District of Columbia 2012). The 2008 DC Construction Codes are more stringent than the codes they are based on as depicted in the 2009 edition of IECC. The Construction Codes Coordinating Board has voted to implement the 2012 IECC, with adoption to take place in the latter half of 2013 (Department of Energy 2012). Codes are under review every 3 years.

Potomac Electric Power Company (Pepco) is a public utility that supplies electrical power to Washington D.C. TOU rates are offered to customers, which increases the ease of eventual adoption for electric vehicle-only rate schedules. Recently, Pepco offered an experimental electric vehicle-only rate schedule for electric vehicle owners in the service area. These specific rate structures have since been removed from the service plan options and are no longer offered. V2G policies and services also are not offered by Pepco at this time. Both DG and net metering are supported for qualifying customers. Pepco offers these customers the Green Power Connection, which enables installation of renewable-powered generators and the sale of unused power back to the grid. Installation and inspection of related generation systems is handled by an outside contractor, because Pepco does not sell or install these systems. Solar and PV-specific rate schedules, however, are not supported. Currently, there have been no advancements in development of FITs for the Washington D.C. area.

Customers interested in the interconnection of a generator facility must submit an interconnection request to the utility. The commission overseeing the utility will determine the appropriate application fees. A representative of the utility will contact the customer and delegate the next steps of the application process (Potomac Electric Power Company 2011). The District Department of the Environment offers financial incentives to support and promote installation of these energy systems. To be eligible for these incentives, all installations must be completed by a licensed contractor to ensure all D.C. building and electrical codes are satisfied. Self-installations are not eligible for the District Department of the Environment incentive. All applicable installations are subject to mandatory inspections (District Department of the Environment 2011).

All permits are issued by the D.C. Department of Consumer and Regulatory Affairs. For more common home improvement and small construction projects, however, permits may be obtained and paid for online. This is available to any homeowner that lists the location as their primary residence. If the customer requires permits in addition to a building permit, a licensed contractor must contact the D.C. Department of Consumer and Regulatory Affairs Permit Center to continue the application process. All fees will be issued depending on the scope of work (The District of Columbia 2012).

4.9 Regional Codes and Standards Commonalities and Conflict

One of biggest challenges in any industry is complying with varying codes and standards that apply to the different aspects and across the different geographic areas of the business. With the structure of local government control and the number of electric utilities reaching over 3,000 in the United States, there are variations to the way that resources are connected to the grid. Although codes and standards specific to V2G have yet to be developed, it is assumed that the same variation will be encountered on a local level and present implementation challenges to companies in the industry. In this section, we summarize and provide examples of commonalties and conflicts amongst the regions presented.

4.9.1 Regulatory

On the regulatory side, all regions have building codes and specific electrical building codes based on IBC and NEC. Both standards are updated on a 3-year review cycle. The current versions for IBC and NEC were updated in 2011 and 2012, respectively. Upon review of the regions, it is found that different versions of IBC and NEC are in effect and that the most recent version is not always immediately adopted.

Across the regions, versions from 2006 and 2009 were found in place. For instance, for San Diego, the State of California has adopted the 2009 version of IBC for implementation statewide, whereas Orlando (under the State of Florida building codes) is using the 2006 IBC as a baseline. Of the regions surveyed, six have adopted the 2009 version of IBC. Six regions were still using the 2006 version. Because of the recently released 2012 publications of the I-Codes, all regions are currently reviewing for potential enforcement between late 2012 and early 2013.

Because the latest 2011 NEC was recently finalized, the majority of the regions surveyed reference the 2008 version or earlier versions. Boston, Dallas, New York City, Raleigh, and Portland are already using the 2011 version and Washington D.C. is still using the 2005 standards. All regions using the 2008 NEC, with the exception of Seattle, are currently reviewing and amending the 2011 NEC with possible adoption dates of late 2012 or early 2013.

Aside from the codes and standards in place for a region, an important component to understanding potential regulatory barriers to V2G is identifying the appropriate authority having jurisdiction. Region to region, the authority having jurisdiction could be at the local city, region, or state level. Often times, the local city or region opts to amend what is adopted at a broader level. These local variations and inconsistency of the level of government that the authority having jurisdiction is at can make it challenging for a business to understand local nuances and set broadly applicable processes for project deployment.

In terms of specific codes and standards that address V2G, none of the regions surveyed have any reference to the technology. However, many had language specific to electric vehicles, solar, and DERs.

In addition to the building permit required for installing equipment, often (as is the case in New York) an electrical safety permit will be required from a local agency.

4.9.2 Utility

The regions have clearly defined interconnection and net metering standards, which are provided by the State's utility commissions and the local utility. The regions vary in terms of the types of electric utilities providing service to the region. Regions are served by single or multiple utilities and the utilities are represented both IOUs and municipal-owned utilities. IOUs are regulated by electric utility commissions and generally need to make a case for new rate structures or technologies to be implemented. Municipal-owned utilities also need to go through an approval process for such changes, but often it is through their own local government and can happen in a more timely process.

The relevant standards that need to be adhered to in order to interconnect with the grid through the utility are often referred to as electric service rules or requirements for electric service. Some utilities review and revise on an as-needed basis. For instance, MECO had different effective dates for different sections of the rule book, with some sections being updated last in 1988 or as recent as 2011. Some review and adopt a new version on a regular basis, with many having updates dated in past few years. For instance, both SCL and Progress Energy have service rules dated 2007.

None of the utilities have any specific electric service rules or programs that covered V2G; however, they all have interconnection rules and most have net metering rules for solar and other DER. It is important to note that some of the utilities do have pilot projects in progress or planned for the future that contain some V2G component. Many of the utilities also have designated informational pages on electric vehicle technology. Some even have their own designated staff resources to help educate and walk customers through the process of getting an appropriate charger installed to support their electric vehicle and have their own financial incentives to encourage customer electric vehicle adoption. For instance, DTE offers customers up to $2,500 for a Level 2 EVSE installation at a residential property.

Any time that billing features are involved in a utility service, the metering of the energy must be through approved devices. The approval of such devices involves both the utility and the regulating authority. Legacy systems involve a utility revenue grade meter that is accessible outside a residence or commercial facility to the utility's metering service. Periodic inspections and calibrations can be performed, as well as verification of any tampering by the customer. These rules are very utility or regulatory centric and vary widely across all regions. Net metering can be accomplished by a single utility meter, but V2G ancillary services operations will likely involve the EVSE located where the legacy rules of accessibility and calibration cannot apply.

These utilities will need to review and revise their current approaches to energy metering. Support from the regulatory authority is desired to attempt to standardize this approach across as wide a region as possible.

4.9.3 Implementation

One of the challenges to the V2G market will be an understanding of the permitting process. As mentioned previously, each region has its own authority having jurisdiction at varying levels of government. After determination of the proper authority, one must determine what equipment and installation methods are required and what documentation and submittal options are available for obtaining a permit. Boston offers an online permitting process, but many regions still only allow permits through a walk-up counter and in-person review of plans. Permit fees are another area of wide variation between regions.

Additionally, authorities having jurisdiction or utilities in many regions require operating permits for emergency generators or other DERs. This could be seen as an indicator that other grid-connected resources, such as V2G resources, would require regularly renewable operating permits and fees. The variable fees add an unknown financial component to the process, which could be a huge barrier to entry in the industry.

4.9.4 Market

Because there are no current off-the-shelf solutions for V2G, it is important to look at precursors that may help foster the V2G market potential. Therefore, it is important that the adoption of electric vehicles and installation of smart EVSE are encouraged through market incentives. As an indicator of market readiness, the regions were surveyed about net-metering, FIT programs, and TOU rates.

Most of the regions had net metering (especially to accommodate solar installations) and options for TOU rates. The regions were split on FIT programs with five (i.e., Orlando, Maui, San Diego, Portland, and New York) of the 12 having such programs. In general, more options for financial recovery available to customers create a better environment for the technology to thrive.

4.9.5 Summary Table

Tables 3 and 4 summarize the findings from the regional survey.

Table 3. Regional conditions related to codes and standards.

Region	Authority Having Jurisdiction	NEC	IBC	IRC	Online Permit
Phoenix	City of Phoenix	2008	2006	2006	Yes
Orlando	Florida Building Commission	2008	2006	2006	Yes
Boston	Board of Building Regulations and Standards	2011	2009	2009	Yes
Detroit	State of Michigan	2008	2009	2009	Yes
Raleigh	City of Raleigh Inspections Department	2011	2009	2009	No
Maui	Hawaii County Council	2008	2006		Yes
San Diego	California Building Standards Commission	2008	2009	2009	No
Dallas	City of Dallas	2011	2006	2006	Yes
Seattle	State Building Code Council	2008	2009	2009	No
D.C.	Construction Codes Coordinating Board	2005	2006	2006	Yes
Portland	Residential Structures Board	2011	2009	2009	Yes
New York	Division of Code Enforcement and Admin.	2011	2006	2006	No

Table 4. Regional conditions related to codes and standards (utility).

Region	Utility	V2G Policy	EV-Only Rate	Solar/ PV Policy	[1]DG Policy	Net Metering Policy	FIT	TOU Rate
	Utility							
Phoenix	SRP/ APS	No/ No	No/ No	Yes/ Yes	No/ Yes	Yes/ Yes	No/ No	Yes/ Yes
Orlando	Progress Energy	No	No	Yes	Yes	Yes	Yes	Yes
Boston	NSTAR	No	No	No	Yes	Yes	No	Yes
Detroit	DTE Energy	No	Yes	Yes	Yes	Yes	No	Yes
Raleigh	Progress Energy	No	No	Yes	Yes	Yes	No	Yes
Maui	MECO	No	Yes	Yes	No	Yes	Yes	Yes
San Diego	SDG&E	No	Yes	Yes	Yes	Yes	Yes	Yes
Dallas	Oncor/ TXU Energy	No	No	No	Yes	Yes	No	Yes
Seattle	SCL	No	No	Yes	No	Yes	No	No
DC	Pepco	No	No	No	Yes	Yes	No	Yes
Portland	PGE	No	No	Yes	Yes	Yes	Yes	Yes
New York	ConEd	No	No	Yes	Yes	Yes	Yes	Yes

[1]DG is electricity that is generated from small energy sources, typically renewable energy resources, and is generally used near its generation site, thereby reducing lost energy through transmission.

5. RECOMMENDATIONS

5.1 General Recommendations

In general, standardization eases implementation. Many refer to the SAE J1772 standard connector as highly important for widespread adoption of electric vehicles. As much as possible, it is important for local regions to adopt national standards. The vehicles and EVSEs will be mostly standardized through the SAE proceedings and regulatory areas the automotive manufacturers must follow. It is recommended that local authorities having jurisdiction and utilities follow NIST, IEEE, and SAE proceedings and participate, when feasible, to understand and follow the guidelines that will drive V2G technology development.

In surveying the regions, many local variations exist that can complicate implementation of V2G technology. Recommendations for more standardization are presented in the following subsections. The four main codes and standards areas that were surveyed are discussed, as well as a brief discussion on the systems standardization for vehicles and EVSE.

5.2 Regulatory Code Recommendations

A lack of consistency exists in which IBC or NEC versions are adopted. In order to increase uniformity in building and electrical codes across the country, it is recommended that regions set goals to review and adopt the latest versions of the IBC and NEC within a reasonable timeframe after approval.

Ideally, regions could synchronize review cycles; however, because of differences in the authority having jurisdiction and the review and approval process, implementing this change will be a challenge.

One significant shift to looking at V2G implementation is that this technology will be available to both residential and commercial customers. Because of that, it is important to keep in mind that codes are not written for the layperson. In order to assist potential customers with identifying and understanding who the authority having jurisdiction is and what codes may apply, it is recommended that customer facing resources be clear and easy to understand. Most people will not take the time to read through complicated code language. It would be helpful to have resources available that distill applicable code requirements into a user-friendly form.

One general recommendation is to support market alignment with utilities' interests to offset their ancillary services system obligations with favorable treatment for verified V2G services. Assuming that V2G can become predictable, reliable and profitable, this can be accomplished through favorable regulatory allowances that include specific rate structures for participation in these Ancillary Services markets with V2G-enabled EVSE solutions.

While the change process to an existing code is an industry procedure, the adoption of code changes on a local basis is a political action. As seen in Section 4.9, each state and local authority chooses to adopt the code requirements but also may amend the code to suit the local political environment.

IGCC is a real example of how local political decisions can dramatically affect the variations in code adoption. In its overview, it states the IGCC "…is a document which can be readily used by manufacturers, design professionals and contractors; but what sets it apart in the world of green building is that it was created with the intent to be administered by code officials and adopted by governmental units at any level on a *mandatory* basis." (Italics are included in the original.) Thus IGCC, which does address electric vehicles, may be adopted by one community and not the next.

IRC does not specifically address requirements for installing EVSE circuits in residences. A check of a local authority having jurisdiction in Arizona of their "2006 International Residential Code Building Code Plan Review Checklist" reveals no mention of electric vehicles or EVSE. Several state and local governments, which have high interest in the adoption of electric vehicles have introduced local ordinances or additions to local codes related to the adoption of electric vehicles. In California, AB2644 was introduced in February 2012 to require the California Building Standards Commission to "…adopt building standards for the construction, installation, and alternation of electric vehicle charging stations for parking spaces in single-family residential real property…" (Assembly Bill No. 2644 2012).

Understanding the political climate related to electric vehicles leads to the recognition that national codes related to electric vehicles in general and V2G in particular may be well into the future. It is possible that some states will place code requirements for electric vehicles and EVSE long before they are addressed in other states. This can lead to conflicts in requirements between local jurisdictions. It is recommended that affected stakeholders (e.g., automotive companies, EVSE suppliers, and electrical contractors) remain informed to provide input to the review process to minimize differences across jurisdictions.

5.3 Utility Recommendations

Utility Electric Service Rules need to be accessible and easy to understand. Many of the utilities already have their rule book available online; however, it may not be easy to find or interpret. As utilities roll-out new rates, incentives, or programs related to V2G, it will be important to keep the target customer in mind when designing communications and participation requirements.

Looking specifically at interconnection standards, they often apply to a well-defined set of generation resources (such as solar). For instance, MECO restricts net metering to "solar, wind, biomass or hydroelectric generation facilities, or a hybrid system of two or more of these technologies, with a capacity up to 100 kW." Language in their electric service rules would need to be revised to specifically include storage batteries using V2G systems. It is recommended that mandatory net metering should be available upon request for all participants with any type of DG, with consistent and common interconnection and operation rules, wherever possible.

Accurate sub-meter data within EVSE systems are important to understanding verified response and will be a critical data source for system operators to manage V2G aggregation. Utility acceptance of qualified sub-meter data delivered through secure internet connection for billing purposes is a recommended practice.

It is recommended that utilities that intend to allow V2G indicate to their customers that V2G rules or programs are in development. For those developing pilots, draft interconnection guidelines could be published to help potential customers understand what might become standard in the future and to allow comment by local providers. Clear guidance can be given for customers who wish to participate in a V2G pilot.

5.4 Electric Vehicle Supply Equipment Installation Recommendations

For ease of implementation, it is recognized that there needs to be a clear and streamlined process for permits obtained for installation of energy generation equipment, renewable power sources, and general building and electrical permitting. It is recommended that as many steps as possible within the permitting process be automated through an online system. The number of contractor and inspector visits and time spent waiting for an in-person permit process will deter development in localized regions. As much as possible, it is recommended that the process be standardized.

If possible, it also is recommended that the permit/inspection process be centralized at the state jurisdictional level to ensure consistent, timely, economical and safe deployment of the required infrastructure for V2G operations. In conjunction with a uniform application of NEC for acceptance criteria, this should lead to the most efficient widespread deployment of the capability throughout the nation.

5.5 Market Recommendations

Net metering, FIT programs, and TOU rates are all customer options that encourage adoption of smart technologies and energy-efficient customer behavior. Programs and concepts need to be simply defined. It is recommended that utilities offer all of these options to their customers and allow them to choose the programs and rates for their needs and applications. It also is recommended that customers have the flexibility to change programs and rates if they find that another option would be more beneficial to them. For instance, a customer may find that they are earning credits for spinning their meter backwards, but are never able to use that credit and would prefer to be paid out through a FIT program instead. Customers should have the option to switch back and forth with ease as their usage changes. Mandatory net metering should be required for any type of DG. Required tariff-approved rates should reflect fair wholesale market values.

Easy to use financial models should be available for customers who are considering V2G, which show the net benefits of participating in these service markets, and highlight the optimal use cases for highest expected return on investment.

With the shift toward active customer participation in ancillary services, it will be useful for customers who are not familiar with regional transmission organization/ISOs to have descriptions of such programs from their utility provider, because they already have an existing relationship, with potentially vetted and approved aggregator vendors.

5.6 Electric Vehicle Supply Equipment and Vehicle Standards Recommendations

Aspects of the V2G technology must be standardized for widespread adoption. The recommendations that follow are deemed necessary for V2G systems to function and also will serve to provide incentives to all of the stakeholders involved that will make such systems financially attractive.

The bi-directional charging protocol must be standardized across all EVSE and automotive OEMs. None of the worldwide standards, such as SAE J1772 for charging in North America, IEC 62196 for charging in Europe, and CHAdeMO for DC fast charging worldwide, have currently included provisions for bi-directional charge capabilities, although SAE J2836 and SAE J2847 are in development for this purpose. These protocols need to all be updated and the safety concerns specific to bi-directional charging addressed in order to begin implementation of V2G on a large scale. The protocols will include the plug, cable, and power electronics (if applicable) to enable the physical charging, but also will include the communications protocol that will allow for the vehicle, EVSE, and utility to communicate and judiciously control the flow of electricity. The protocols also could include specifications for the quality of electricity (e.g., high power factor or low total harmonic distortion) that the V2G system must supply to the grid. Currently, there are several competing standards in different countries and, unless there is consolidation and agreement, this fracturing of the EVSE industry will hinder and delay the adoption of V2G systems.

An essential component of the bi-directional charging protocol will be for the EVSE to have a national standards-driven, automated authentication system for recognizing whenever a V2G-capable vehicle is connected. The EVSE must be able to identify when an eligible vehicle has been connected and what operating mode and constraints the vehicle owner has agreed to. When the connection is made and the V2G capability and standards compliance is confirmed, the EVSE must either prompt the user to authorize participation in the V2G process or default to the user's previously defined participation preferences. The payment process that is required for the authenticated and verified V2G participant must include a secure, transparent, and reliable method for transaction processing and auditing of the payment data. These capabilities are critical for development and support of market-driven service offers that will allow electric vehicle owners to enroll and participate with properly equipped electric vehicles, such that connection to a capable EVSE can seamlessly authorize, activate, and compensate V2G operation.

Different constraints on participation in V2G services for residential, commercial, and workplace charging should be considered; however, the basic participation process will be the same.

For safety concerns, the V2G system must be capable of anti-islanding (i.e., restriction of a live V2G system connection to a de-energized distribution system), so that the V2G resource automatically isolates in coordination with the grid disabling. This function will ensure the safety of utility workers and is a standard interconnection requirement of all DG facilities, as referenced in the IEEE 1547 standard. The island status must be able to be remotely tested and verified by the utility.

A standard set of data must be accessible from the onboard electric vehicle BMS to support effective V2G operation, such as the following:

- Instantaneous SOC
- Maximum allowable recharge power
- Maximum allowable discharge power
- Battery status indicator
- Maximum time at maximum charge power
- Maximum time at maximum discharge power

- ESS real capacity in kWh.

This core set of data can be mandated by government in a similar manner to the emission-related requirement that prompted OBD-II (on-board diagnostics, where other vehicular data [in addition to emission-related data] can be extracted in common non-proprietary format, leaving adjacent proprietary data segments for individual OEM feature differentiation). These data will allow the EVSE (or home area network or utility directly) to control the power flow to make the V2G system function, as required.

It was noted previously that ANSI has embarked on the *Standardization Roadmap for Electric Vehicles*. This effort includes identification of current standards and where gaps might occur in industry development. This roadmap does address V2G along with V2H and other EVSE bi-directional power flow features. In addition, this effort seeks to harmonize standards across country borders. It is important this effort continue.

Also noted previously is the work that NIST is contributing in this area. It is important that this work continue as well.

5.7 Action Plan for Implementation

The electric vehicle industry is new and evolving. Manufacturers and other stakeholders are in a rush for competitive advantages in features and services development that frequently will outpace the development of standards, which typically precede code development. In the absence of specific standards, business decisions will drive this innovation. It is recommended that standards development consider the business innovation that is driving the industry as much as possible to avoid creating roadblocks and barriers to electric vehicle adoption. A case-in-point is development of the SAE standard combo connector as the DC fast charger connector. In the absence of this standard during the introduction of the Nissan LEAF, the CHAdeMO standard for the fast charge inlet was provided. EVSE suppliers then adopted the CHAdeMO standard for their connectors. The new SAE alternative design combo connector creates a dilemma not only for DC fast charger suppliers and electric vehicle drivers, but also delays any V2G design work related to DC fast charger until the connector is UL certified and adopted.

In an ideal world, codes and standards would be the same in every target implementation region for V2G. In actuality, there are many nuances that will cause challenges for customers and vendors. The recommendations summarized in the sections above all have to do with standardization and ease of understanding. Moving forward, authorities having jurisdiction and utilities should be encouraged to share best practices and information with other agencies in order to work toward common practices and quick adoption of nationally approved standards. Also, authorities having jurisdiction and utilities should take care in preparing any customer facing programs and language as more and more connected resources are moving from commercial entities to everyday consumers.

Appendix A
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Appendix B
Vehicle-to-Grid Codes and Standards Outreach Tutorial

This document is intended to prepare code officials for a meaningful dialog regarding V2G. The capability description section describes emerging V2G applications. The next section details the system interconnections.

Capability Description

V2G is defined as a system in which there is capability of controllable, bi-directional electrical energy flow between a vehicle and the electrical grid. The electrical energy flows from the grid to the vehicle in order to charge the battery; it flows in the reverse direction when the grid requires the energy. This technology will enable the user to transfer stored power back into the home (V2H) or back into the grid (V2G), when called upon for reliability reasons (Figure B-1). Where PV systems and wind turbines exist within the grid, electric vehicle battery storage can help optimize these renewable energy resources. On the horizon, this connection of V2G can be used for continual buffering services.

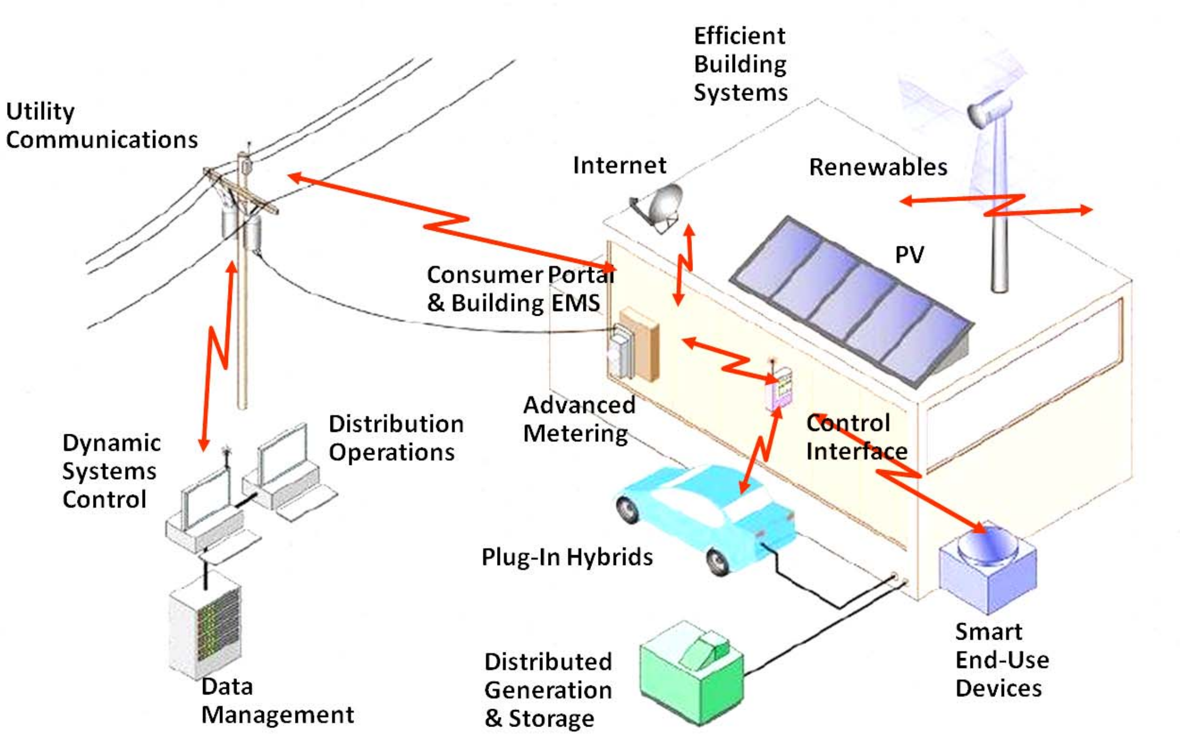

Figure B-1. Energy flow diagram.

Electric vehicles will remain idle throughout the majority of the 24-hour day. When the vehicle is plugged in to the grid during these periods of inactivity, the energy stored in the battery could possibly be used for a variety of non vehicle propulsion situations. During daylight hours, PV systems convert sunlight into energy. This energy can be stored in the electric vehicle battery for use during night-time hours when there is no potential for solar energy (load shifting). Likewise, wind turbines typically generate more electricity during night-time hours and it could be stored in the electric vehicle battery overnight. Conversely, stored renewable energy could be drawn into the power grid, by utility command, for economic or emergency reasons, allowing the user to receive compensation in the form of net metering or other payment mechanisms.

The use of electric vehicles as a fast-response storage element could prove beneficial to grid load balance and require low latency (a highly efficient network) and high-reliability communication networks. Using the electric vehicle battery to provide power as a reserve during peak electrical system use could be beneficial, because it will lessen the need to rely on peaking power plants, which can be costly to operate. Owners of V2G-capable electric vehicles would by necessity receive monetary compensation for their participation in these services.

The utility will be able to control the rate of charge or discharge through either prescheduled or real-time charge control. In addition, this may allow utilities to track the electric vehicle's usage while charging and while on the road.

Inherent in this control capability is the safe isolation of all necessary power sources. Safety considerations and islanding requirements are defined in the IEEE P1547 standard. This standard is observed during all design and manufacturing processes with the related equipment.

System Interconnections

In a V2G connection, the EVSE acts as the interface between the utility and the onboard energy storage provided by the vehicle. For AC Level 2 charging, the EVSE coordinates with the onboard charger to pass AC current, which is rectified to DC for charging the batteries, and for connecting inverted DC power back to AC and into the grid. For DC fast charging, the onboard charger is bypassed and these functions are controlled by the BMS. Located onboard the vehicle, the BMS is responsible for keeping track of the battery's SOC, and the overall health of the battery, while establishing the maximum power flow permitted through the power system. The EVSE can adjust the power rates allowed to flow within that maximum envelope. The PEV inlet couples with the EVSE connector (SAE J1772) to provide the interface for the EVSE and the PEV.

The ISO will provide communication to the aggregator in the form of a frequency response diagram (Figure B-2), which will manage the V2G connections. The EVSE will then communicate with the BMS to request the power flow. The BMS controls the output of the inverter to respond to communications. If the PEV's battery requires energy, the rectified DC power will be used. However, when the ISO provides communication to the aggregator that the power grid level is fluctuating, DC power from the electric vehicle's battery pack will flow back through the EVSE and into the grid. This results in the ISO compensating the vehicle owner, the government through tax payment, EVSE host, or the aggregator. Additional batteries may be used as storage devices in the event of an abundance of power in the utility grid. The ISO again communicates to the aggregator that additional power may be stored. This energy then passes through a separate control device and into the battery for storage. Likewise, the energy may be pulled from the storage battery and fed into the grid. An example of these interconnections and their relationships is depicted in Figure B-3.

Storage-assisted recharging for vehicles also could include PV systems, which are similar to V2G systems, but not identical. While V2G systems will deliver power to the grid when it is needed, PV systems will send power to the grid whether it is needed or not. A diagram of a typical ESS, in this case a connected PV system, is displayed in Figure B-4.

The solar panels on a PV system will generate the power and deliver the DC energy to a grid-tie inverter. The grid-tie inverter is in place to sense grid AC, and when present, synchronize power delivery to the grid. When AC is not present, the grid-tie inverter will isolate from the grid for safety purposes. A transformer will rectify AC power into DC power. The inverted power from the PV system will be sent to the EVSE, while non-inverted DC power can be stored in a storage battery. When the PEV no longer requires charging, the solar array will provide power to the grid instead. As power is delivered to the grid, the owner's meter will record the reverse power.

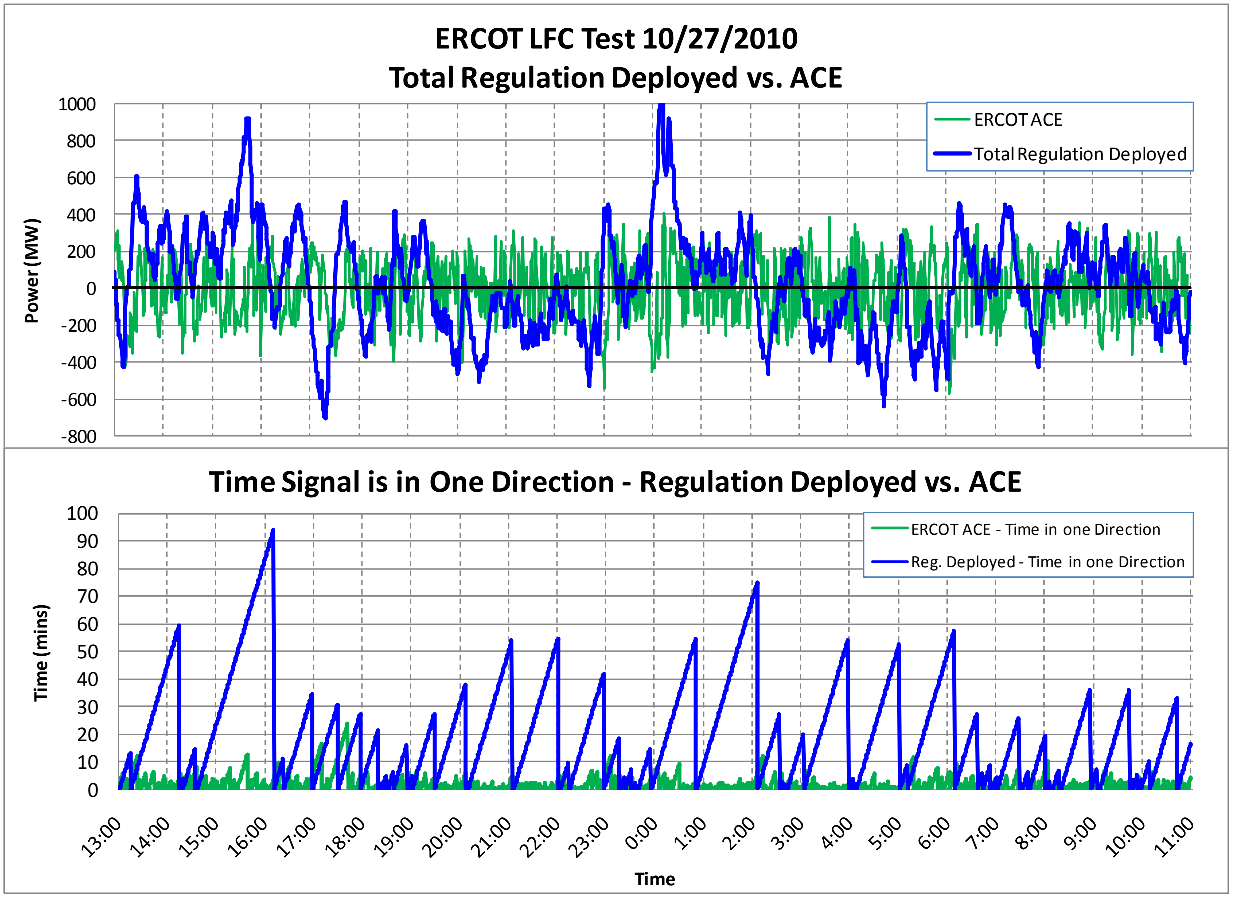

Figure B-2. Frequency response diagram.

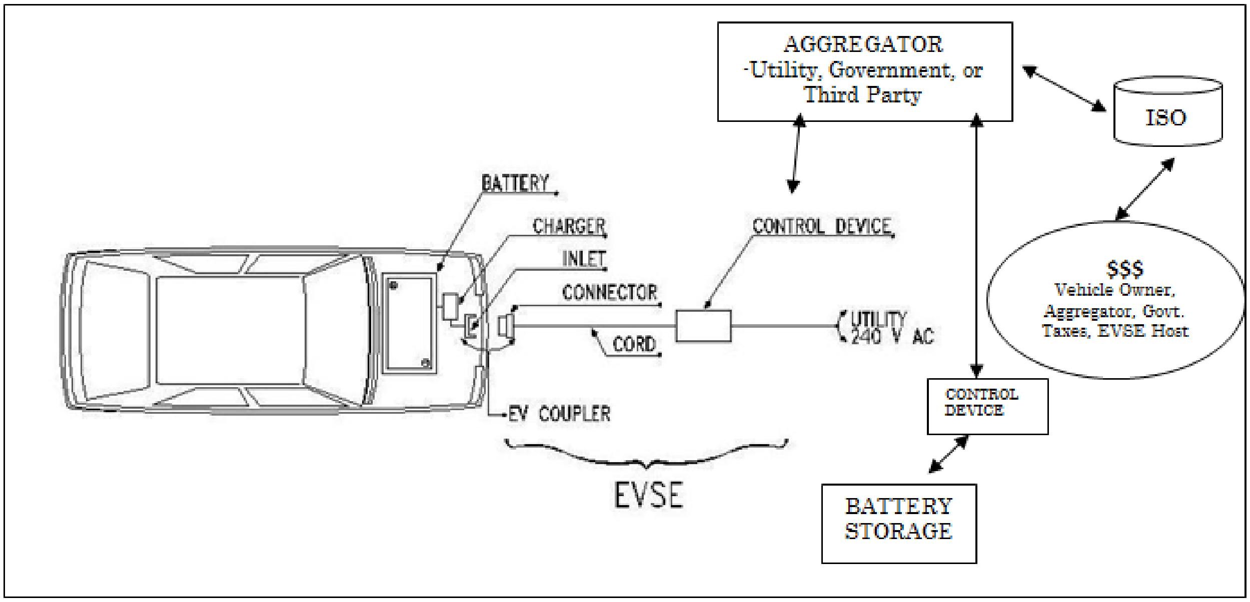

Figure B-3. System interconnections.

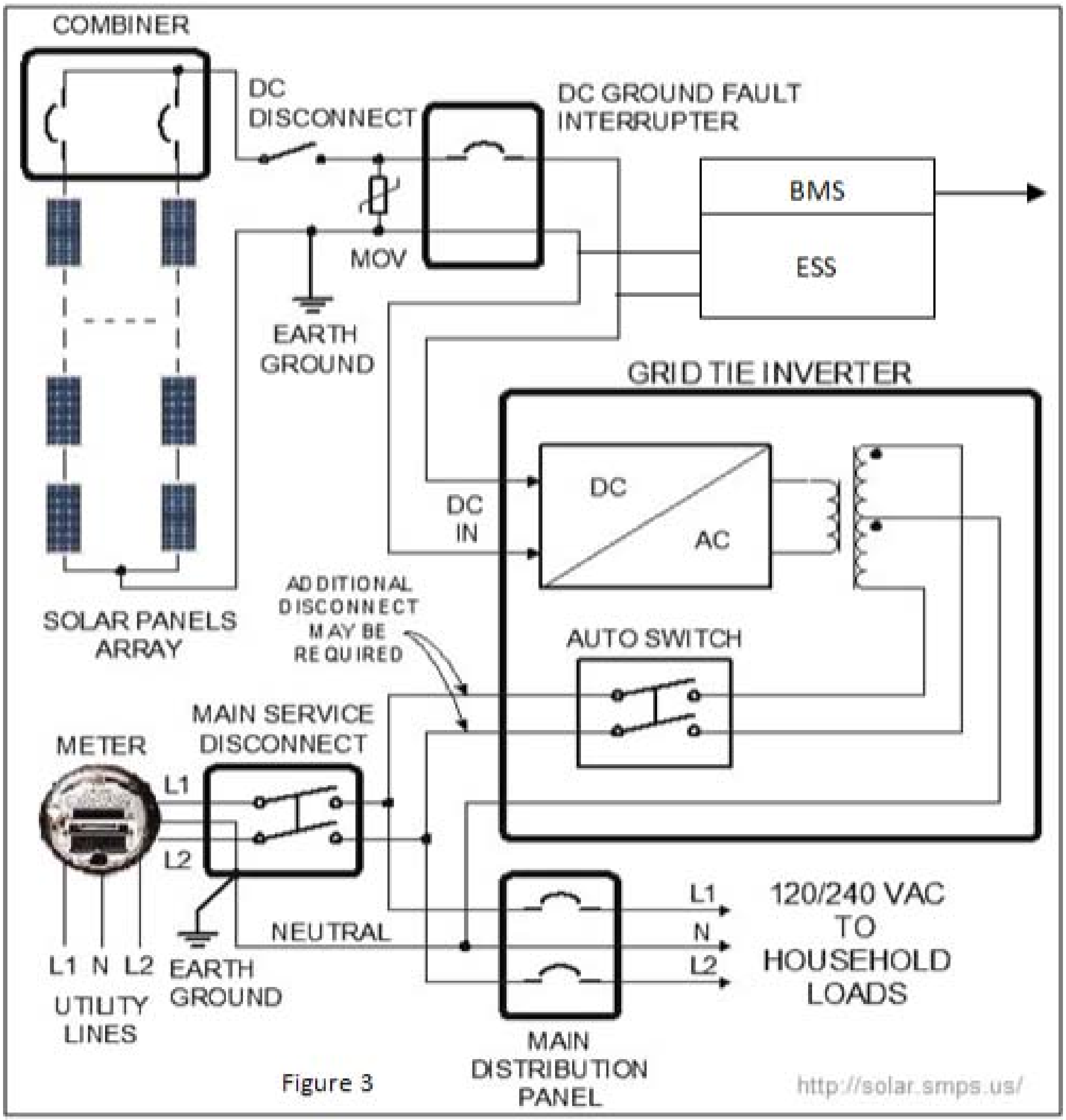

Figure B-4. Typical energy storage system diagram.

In preparation for V2G, many grid and security-related standards must be revised or created to form a secure and reliable experience for all parties involved. The IEEE P1547 standard provides requirements relevant to performance, operation, safety considerations, islanding, testing, and maintenance of the interconnections regarding DG resources and energy service providers. IEEE P2030 provides guidelines for smart-grid interoperability and develops a knowledge base pertaining to terminology, characteristics, functional performance and evaluation criteria, and the application of engineering principles relating to smart grid interoperability. SAE J2293 details the transfer of electrical energy from the utility power system to the electric vehicle storage battery and other vehicle loads. SAE J2836 establishes use cases for two-way communication between PEVs and the electric power grid for energy transfer and other applications. SAE J2847 documents the communication between the PEV and the utility grid, EVSE, the utility grid for reverse power flow, diagnostic communication for PEVs, and their customers. These national codes and standards may differ significantly from the codes and standards in place at the city level. Identifying differing regulations, standards, and building codes is the beginning of the process of designing a single national regulatory framework. With this in place, widespread adoption of V2G services will be a possibility.

Appendix C
Vehicle-to-Grid Codes and Standards Survey

PARTICIPANT INFO

Be sure to **SaveAs** then **Print** a completed copy for your files before **Submit**ting Email

Print Form

Submit by Email

Name

Title

Company/Agency/Employer

Organization Website

Jurisdiction Territory

Municipality County State Multi Region

Population (thou)

REGULATORY BARRIERS

Please identify the PRIMARY local agency in your region that is the authority having jurisdiction (AHJ) over building and electrical standards and permitting

Provide the title of and link to the codes/standards that are adopted by the AHJ

Code/Standard Title — Eff. Date — URL

Code/Standard Title — Eff. Date — URL

Code/Standard Title — Eff. Date — URL

Code/Standard Title — Eff. Date — URL Website

What Version **National** Electric Code is referenced?

If applicable, please provide URL to **Regional** Electric Code ...

Is there a secondary LOCAL agency that may impose codes/ standards or impose permits/inspection? Please Identify (w/URL)

Are there **Codes/Standards** that specifically address the following topics? If yes, please provide reference URL link for additional information.

- **Vehicle 2 Grid** — **URL**
- **EVs or EVSE** — **URL**
- **Solar/PV** — **URL**
- **Dist/Cust Gen** — **URL**
- **Net Metering** — **URL**

Please provide Text Area below to provide general comments regarding potential Regulatory Barriers.

UTILITY ENVIRONMENT

Please identify the primary Electric Utilitie(s) in your region.

Utility 1 ☐ Investor Owned ☐ Municipal ☐ Non-regulated

Utility 2 ☐ Investor Owned ☐ Municipal ☐ Non-regulated

Utility 2 ☐ Investor Owned ☐ Municipal ☐ Non-regulated

Please provide URL Link to Utilities Electric Service Rules

Eff. Date of Current Rules

How Frequently are the Electric Service Rules revised? ☐ Annually ☐ BiAnnually ☐ Every few yrs. ☐ Infrequently

Are there **Electric Service Rules** that specifically address the following topics? If yes, please provide reference URL link for additional information.

- ☐ **Vehicle 2 Grid** URL
- ☐ **EVs or EVSE** URL
- ☐ **Solar/PV** URL
- ☐ **Dist/Cust Gen** URL
- ☐ **Net Metering** URL
- ☐ **Reverse Power Flow (a)** URL
- ☐ **Reverse Power Flow (b)** URL

Type (a) By *phase* 1ph, 3ph Type (b) By power *level* high volt, low volt

IMPLEMENTATION BARRIERS

Are there **Permitting** that specifically address the following topics? If yes, please provide reference URL link for additional information.

Methods for Obtaining/Filing *Install* Permit? ☐ **Online** ☐ **Telephone** ☐ **In Person**

Permit Cost:

What Agency Maintains the *Operating* Permit?

Agency:

Frequency of renewal

Renewal Cost:

Do you require approved testing marks for certification testing, and permit/inspection of V2G related equipment?

Testing Agencies (check all applicable)

- ☐ UL
- ☐ ETL
- ☐ Other NRTL
- ☐ Local Agency

Name or URL

POWER QUALITY: Are there standards in place for the quality of the energy provided by the PV systems or wind turbines? Would this same criteria be applied to that must be observed **before** stored energy is drawn into the power grid?

Are there voltage minimums or maximums? How often are they measured? Where are they monitored?

Min 3phase 480V		**Max** 3phase 480V	
Min 3phase 208V		**Max** 3phase 208V	
Min 1phase 240V		**Max** 1phase 240V	

Do you have power outage restoration targets? Yes No

Do you track compliance metrics? if Yes, include URL. Yes No URL

Are Intelligent Appliances supported? Yes No

MARKET BARRIERS

Functional Capability: V2G can only economically compete with distributed generation if supportive policy environments exist.

What are the standards involved with grid load balance? What determines a balanced load in your municipal area?

	COMMERCIAL		RESIDENTIAL	
Do you require permits for backup generator installation?	YES	NO	YES	NO
Are utilities required to provide net metering?	YES	NO	YES	NO

What are the existing codes and standards regarding distribution endpoints, and the requirements of the electric utility? This considers the existence of net metering and feed-in-tariffs (FIT)

Ref Statute requiring Net Meter

Do Feed In Tarrifs exist for selling back power? YES NO YES NO

FIT Rate Structure Ref URL

General Comments on Support for Distributed Generation

Rates and Incentives: V2G can only economically compete with distributed generation if supportive rate structures exist.

	COMMERCIAL		RESIDENTIAL	
Do Time of Use (TOU) Rates Exist from the Utility?	YES	NO	YES	NO

If Yes, Which Utilitie(s)?

Which of these utilities offer EV Only rates?