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# Delivering Energy from PEV batteries: V2G, V2B and V2H approaches

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**Abstract.** Plug-in electric vehicles (PEVs) sales have grown in the last years. Depending on the PEV model, each PEV can store approximately between 5-40 kWh of energy. This energy can be used not only for travel purposes but also for other appliances like providing energy for homes (V2H) or buildings (V2B) and even for supply ancillary services to distribution network operators, through vehicle to grid concept (V2G).

This paper presents the different strategies that can be found in the literature about delivering energy from PEV batteries. Also, commercial solutions and pilot projects are presented.

## Key words

Plug-in electric vehicles, smart grids, vehicle to grid, vehicle to building, vehicle to home.

## 1. Introduction

Nowadays, most of car drivers use their vehicles to get to work, buy goods or return to home. Drivers usually use their cars to do short trips of about 15 km [1]. As a consequence, it is estimated that vehicles are parked on average 96% of the time [2]. So, it can be said that conventional private cars are under-utilized most of the time. However, with the emergence of plug-in electric vehicles this trend can be reversed.

Plug-in electric vehicles are attracting more and more interest from drivers, car companies and society in general. In fact, plug-in electric vehicles sales have been increased in last years (Fig. 1). It is expected that more than 20 million of PEVs will be on the road by 2020 [3].

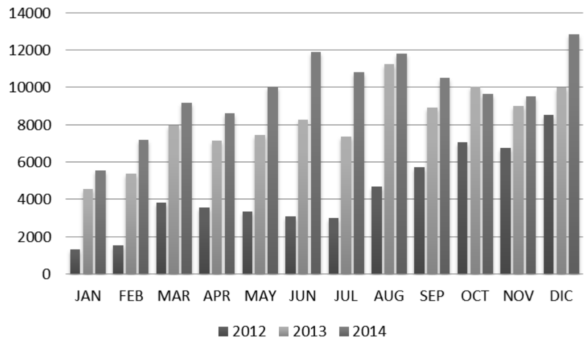


Fig. 1. Evolution of PEV sales in United States [4]

PEVs present several advantages compared to internal combustion engines cars, such as: reduce GHG emissions, improve road transport efficiency, reduce oil dependence, and reduce air pollution in cities. They are usually powered by batteries that can store and deliver energy to the grid when necessary. Also, other electric vehicles like fuel cell vehicles can deliver energy.

This way, PEVs can work as distributed generators and provide different services when they are parked and connected to an electrical outlet. Exploiting these services add an extra economic value to PEVs, making them more profitable for PEV owners and accelerating their market introduction [5], [6].

Furthermore, using PEVs as electric energy storages may give other important advantages to users, for example, they can act as emergency generators when a blackout occurs in the electric grid or when a natural disaster happens, improving security of supply.

However, a PEV capable to deliver energy to the electric grid must have some extra hardware components: a charger that permits the bi-directional power flow of energy, a control and communication system for exchange information and commands between PEV and system operators and finally, a metering device that records energy exchanges for information and billing purposes.

Apart from the mentioned extra hardware, delivering energy from PEV batteries can bring other problems related with premature battery degradation, due to limited cycle life of actual batteries [7], [8]. In addition, it is necessary to take into account that drawing energy from PEV batteries will suppose an increase of energy losses in batteries and chargers.

Depending on the type of service and the number of PEVs involved, extra services can be classified in three types: vehicle to grid, vehicle to building and vehicle to home. The purpose of this paper is to review the opportunities, challenges and strategies used in these three concepts, as well as, the existing commercial and pilot projects around the world.

This paper is structured as follows. In Section 2 a brief review of actual battery technology is presented. The role that PEVs can play inside homes, buildings and vehicle to grid concept is presented in Section 3. In Section 4 a comparison between these three concepts is presented. Finally, Section 5 concludes by extracting some relevant findings.

## 2. Battery Technology

Battery is the key component of PEVs so the feasibility of V2H, V2B and V2G concepts depends heavily on battery technology status.

Present battery technology for electric vehicles is based on lithium-ion (Li-Ion) batteries but nickel-metal hydride (NiMH) batteries still have an important market niche, especially for plug-in hybrid electric vehicles (PHEV). NiMH batteries are comparable in cost per kWh respect to Li-Ion ones but they have twice the weight. In contrast, NiMH batteries have longer cycle life and are safer because its design is more mature. However, it is expected that NiMH technology will be obsolete due to falling prices of Li-Ion batteries [9].

Battery cost is the responsible of 20-40% of PEV price. In last years, energy density of batteries have been improved from 60Wh/L to 150Wh/L while cost per kWh fall from 800€ to approximately 200€, as can be seen in Fig. 2. In short-medium term it is expected that battery cost will continue falling due to technology improvements and economic scale.

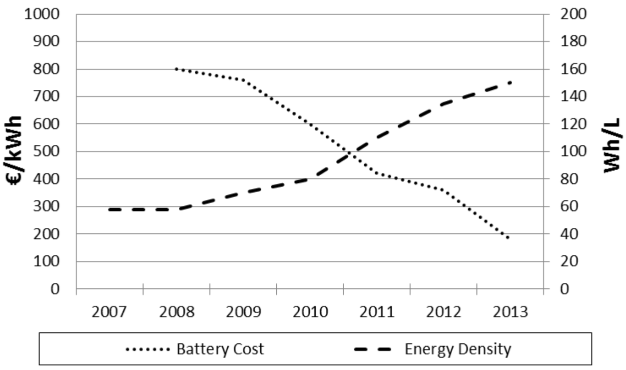


Fig. 2. Evolution of energy density and battery cost for PEVs [9]

Battery degradation has to be taken into account when it is used not only for travel purposes but also for delivering energy to provide others services. Two types of aging process can be distinguished: aging during cycling and calendar aging. On one hand, the calendar life is the loss of capacity due to the pass of time although no use of the battery is made. The calendar life is influenced by temperature and state of charge (SOC) level. On the other hand, the cycle aging refers to the loss of capacity produced by the repetitive process of charging and discharging and depends on number of cycles, deep of discharge level (DoD), temperature and charging/discharging rate (C-rate).

As can be seen in Fig. 3, DoD has a great influence in battery degradation. Thus, delivering energy from PEV batteries makes only sense if DoD is limited to small values of SOC.

Although several studies have been carried out in order to develop the next generation of batteries, Li-Ion remains the more feasible solution. Furthermore, some aspects of Li-Ion technology are still not well understood and have to be improved such as battery life and safety and therefore, Li-Ion battery has room to be improved.

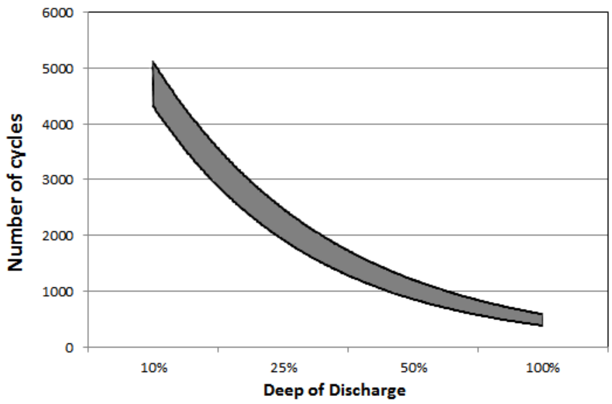


Fig. 3. Cycle aging in function of DoD

Finally, different approaches have been proposed as alternatives to actual Li-Ion batteries in medium-long term. Lithium sulphur (Li-S) with an energy density of about 300Wh/L is one of them but battery life is still limited. In this contest, graphene is proposed to solve this problem [10], [11]. Another promising and cheap technology is Lithium-air batteries which can achieve 1500 Wh/L of volumetric energy density but it is necessary further research in order to address several technical challenges [12].

## 3. Integration of PEV in the electric grid

As mentioned before, the integration of PEVs will carry a set of advantages not only for PEV users but also for electric grid operators and electric companies. This integration has to be done managing the charge or discharge of PEVs by applying different strategies or control algorithms in order to achieve certain pre-established objectives.

Three technological concepts can be distinguished in function of number of PEVs and application: V2H, V2B and V2G. All of them are analysed in following subsections starting from the most simple (V2H) to the most complex architecture (V2G).

### 3.1 Vehicle to Home

The objective of vehicle to home concept is to exploit PEV possibilities to store energy from local distributed energy resources (DER) such as photovoltaic modules or small wind generators and provide energy to home loads. V2H technology can reduce energy bills, improve overall system efficiency and provide backup power [13]. Generally, this concept is integrated into smart homes.

A V2H system is composed by at least one PEV, a bi-directional charger, home loads, small-scale distributed generation, a smart meter, home grid itself and a home energy management system (HEMS) [14], Fig. 4. Other components that can be present in a V2H system are smart loads, other static storage systems and combined heat and power generators (CHP) such as micro gas-turbines.

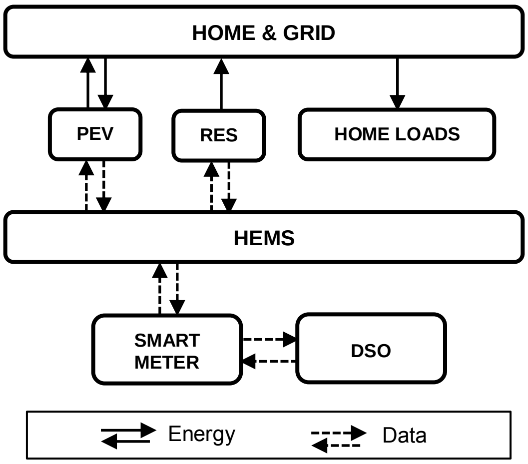


Fig. 4. Vehicle to home scheme

HEMS calculates charging set-points for the PEV, taking into account electricity prices, state of charge of the PEV, local energy production, home power consumption and user preferences.

HEMS can apply algorithms to reduce charging cost through buying energy at low prices and selling it at higher prices in a liberalised energy market. The quantity of energy traded by HEMs must be limited in order to avoid damage in the PEV battery, i.e. DoD should not exceed 10% of the battery SOC. Also, it must be taken into account the possible consequences of this practice in battery guaranty.

The user has to provide to HEMS their preferences such as typical departure time; minimum SOC required at all times, in order to have enough energy in the PEV to do non-expected trips, and the minimum SOC at departure time. Some of this data can be inferred from statistical data obtained during the use of the PEV.

Japan has pushed demand-side management technology since 2011 earthquake in order to limit demand peak power. Under this scheme, consumers are requested to moderate their use of air conditioning and lightning. However, using V2H systems, consumers can reduce their consumption without turning off their appliances. This is particularly useful in commercial establishments. In this contest, some V2H pilot projects have been carried out by automakers such as Toyota, Honda and Nissan. The last one launches "Leaf to Home"[15] system (Table I) which could power a typical Japanese house during two days.

Table I. Leaf to Home charger characteristics

| | |
|---|---|
| **Peak power output** | 6 kW |
| **Output voltage** | AC 100V (±6%) 50/60 Hz<br>AC 200V (±6%) 50/60 Hz (±2%) |
| **Output current range** | AC 0-30 A |
| **Conversion efficiency** | 90% at rated power |
| **Mass** | Approx. 60 kg |
| **Cost** | Approx. 2400 € |

Smart metering can play an important role in V2H concept. Smart meter not only will register data about system consumption but also provide an interface to send or receive information from utilities. This way, V2H concept can be integrated in larger control systems so as to reduce the burden of distribution electric grids. In fact, it is being considered the possibility that PEV user can receive stop charging request from grid utilities in their smartphones.

In this contest, a new experimental program has emerged called BMWi ChargeForward, with participation of BMW Company and Pacific Gas and Electric Company (PG&E). A hundred of BMW i3 will receive up to 1300€ for delaying the charging of PEV by up to one hour based on signals provided by PG&E, while always prioritizing the user preferences. This program will start in July of 2015 until December of 2016 in California Bay Area. The aims of the program is reduce the impact of PEVs charging on the grid, lower charging cost and also supports integration of renewable energy [16].

### 3.2 Vehicle to Building

Recently, vehicle to building concept have attracted more and more interest. This concept is an intermediate step between V2H and V2G but provides important advantages for PEVs and buildings owners [17]. Both can achieve savings in energy bill, especially in office buildings due to arrive and departure times of workers are known. This aspect facilitates the management of PEVs and permits that PEVs will be fully charged when workers return to home.

Hospitals, hotels, universities, office buildings, shopping malls, sport centres and more can be benefit from V2B technology. Furthermore, V2B can support critical loads of mentioned buildings like data servers, computers, emergency lights, lifts, water pumps, etc. in emergency situations if there are power outages and/or shortages. This way, data loss and service interruptions could be avoided

A V2B system (Fig. 5) is typically composed by a set of PEVs, local distributed energy generators, critical loads, a control system called building energy management system (BEMS) and optionally, other static storage.

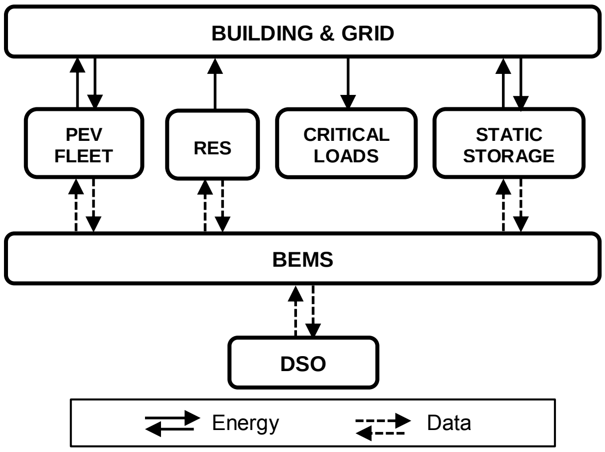


Fig. 5. Vehicle to building scheme

BEMS will execute optimization algorithms and send the calculated set-points to the different subsystems including the PEVs under its control. Thus algorithms will seek economics revenues such as energy trading and, peak power reduction. As mentioned in V2H systems, the control will be centralized due to them reduced number of vehicles that can be involved in this type of systems.

C. Marmaras et al. have carried out an analysis in order to know which is the best control approach for V2B. Researchers model an office building with 450 workers, 450kW of peak power and a total of 60 PEVs. The behaviour of the drivers was extracted from National Travel Survey in Wales (U.K.). Researchers applied two different control strategies: building peak power reduction and cost reduction with different charging power (3, 7 and 11kW) and different levels of DoD limits. Authors claim that a 3kW charging rate power, 5% of DOD level and peak reduction strategy could be the most balanced solution between cost savings and battery life impact.

Nissan Motor Company has carried out a project with six Nissan Leaf to reduce its energy bill. At peak hour, when electricity is expensive, the building draws energy from PEV batteries. However, when electricity prices are lower, batteries are charged. This way, Nissan claims that a 2.5% of peak power reduction is achieved and a saving of nearly 3,500 € per year [18] is obtained.

### 3.3 Vehicle to Grid

The vehicle to grid concept was first introduced in 1997 by Willet Kempton and Steven E. Letendre [19]. This concept explores the possibilities of using PEVs as distributed energy generators. Thus, PEVs can provide ancillary services like spinning and regulation services, peak power and even voltage regulation to distribution system operators or distribution utilities. These aspects can result in a better reliability, use of resources and efficiency of electric distribution networks.

PEVs also can provide distributed storage capacity for renewable energy sources (RES), thus allowing integration of more RES in electric generation mix [20]–[22] and, as a consequence, a reduction of greenhouse gas emissions is expected.

Providing ancillary services from PEV batteries has some advantages such as batteries have a very fast response so they are well suited for primary and secondary frequency regulation. Moreover, batteries are more efficient than other technology that actually provides these types of services. With regard to voltage regulation, PEV batteries can inject or drawn reactive/active power when is necessary through the use of droop methods [23]. Furthermore, PEV will be distributed throughout the distribution networks so they can act in specific part of them.

Managing PEVs individually is inefficient, so it is necessary to introduce a new entity called aggregator which will be responsible of managing the charge/discharge of PEVs under its area of influence. This new entity will seek economic profits acting as middleman between electricity markets and PEV users. Thus, aggregators will buy energy for its users at lower prices as possible, while it provides different services to distribution system operators (DSO) [24], Fig. 6. The functions of aggregators can be developed by electric utilities.

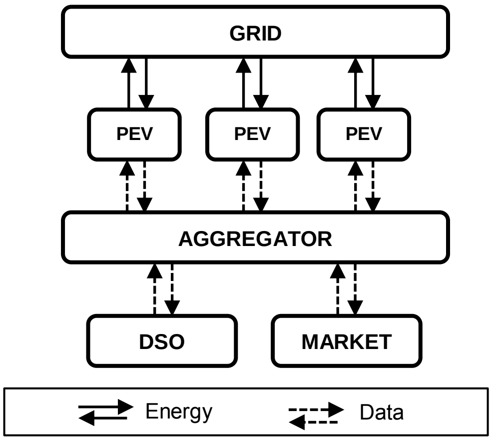


Fig. 6. Vehicle to grid architecture

In general, two types of control architectures can be found in V2G systems: centralized and decentralized control systems [25]. In centralized control architectures the decision of charging or discharging of every PEV in the system is made by the aggregator or similar entities. In contrast, in decentralized controls this decision corresponds on every PEV of the system, i.e. each PEV will run its control algorithm and calculate the charging profile to be applied in function of the different preferences defined by the PEV user. This way, final charging control remained in the PEV user and not in an external entity like the aggregator. However, there are ways to influence the overall charging behavior of PEVs using price or volume signals [26].

Economic feasibility of V2G is a key factor. Chioke B. et al [27] analyse the influence of battery size, charger power and number of vehicles on the potential PEV user compensation for providing frequency regulation ancillary services. Authors extract two main conclusions: PEV battery size has little impact on PEV user revenues (Fig. 7) but in contrast, power of the charger has huge impact on cited revenues (Fig. 8). Also, in larger number of PEVs are involved in provide this services, economic profits will be reduced due to market saturation.

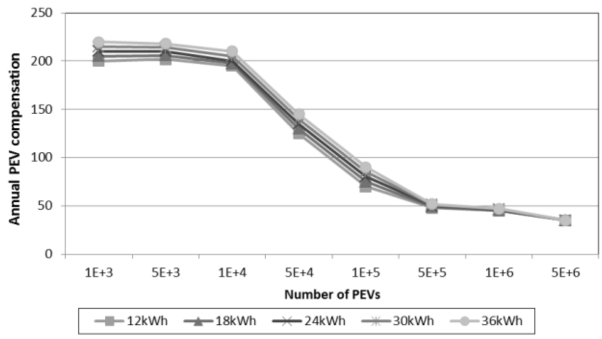


Fig. 7. Annual PEV revenue in function of battery capacity [27]

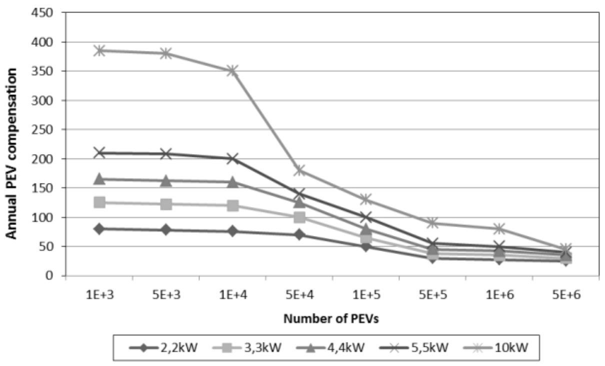


Fig. 8. Annual PEV revenue in function of charger power [27]

V2G technology has great potential but still have some barriers, obviously first of them is the lack of plug-in electric vehicles in the market. Another one is the lack of regulation framework and the fact that every country has different market regulations. This can lead that in some countries V2G technology will be economically feasible while in other countries will be totally unfeasible.

With regard to industry standards, North American SAE 1772 and Japanese Chademo plug standards allow bi-directional charging and they are ready to be implemented in V2H, V2B and V2G technology concepts.

Finally, V2G requires an important communication infrastructure to work properly. However, it is expected that in the short-term more and more vehicles will be connected to internet to provided different services to the users so V2G will be one of these services.

## 4. Comparative analysis

In this section characteristic, drawbacks and pilot projects of the analysed three architectures are presented in Table II.

Table II. Different approaches for delivering energy from PEV batteries

| | V2G | V2B | V2H |
|---|---|---|---|
| **Characteristics** | Operation at large scale<br>Supply ancillary services<br>Reactive power support<br>Improve grid reliability<br>An aggregator is needed<br>New business models<br>Electricity market participation<br>Large scale RES integration | Operation at building level<br>Ideal for little fleets<br>Improve local DER integration<br>Reduce electricity bills<br>Provide backup power<br>Easier PEV demand prediction (fleets)<br>Less investments needed | Operation at home level<br>Normally one PEV<br>Reduce electricity bills<br>Provide backup power<br>Easy implementation<br>Provide energy in isolated houses<br>Interaction with larger systems<br>Integration of local DER |
| **Drawbacks** | Complex operation<br>Complex prediction of PEV demand<br>Large number of PEVs involved<br>Communication infrastructure required<br>User willingness required<br>Lack of regulation framework<br>More industry standards needed | User willingness required<br>Quite complex operation<br>Poor market integration | Not adequate to residential blocks, only for single family homes. |
| **Pilot Projects** | SMARTV2G [28]<br>eV2G Project [29]<br>CGI Project: National V2G school bus demonstration [30]<br>Grid-on-wheels [30], [31]<br>The Nikola Project [32] | Nissan Leaf to Building [33]<br>CGI Project: National V2G school bus demonstration [30] | Leaf to Home [15]<br>Toyota Smart Homes [34]<br>Honda Smart Home [35] |

## 5. Conclusion

In the future, plug-in electric vehicles not only will be used for displacements but also for providing other services. Three main appliances can be considered: vehicle to grid, vehicle to building and vehicle to home.

From the above three concepts, V2G concept is the most ambitious one but also, the most complex to apply in large scale. V2G need an important growth of PEV market share and a favourable and stable regulation framework.

V2B and V2H are relatively new concepts focused on buildings and homes respectively. Compared with V2G, these concepts are easier to implement, do not require external entities to be fully operational and provide more visible advantages for users.

Finally, between these three systems, only the V2H system called Leaf to Home is commercially available, actually limited to Japan, but Nissan manufacturer already has developed and tested the V2B version with the intent to be marketed.

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## References


[1] J. Krumm, "How People Use Their Vehicles: Statistics from the 2009 National Household Travel Survey," Apr. 2012.

[2] W. Kempton and J. Tomić, "Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy," *J. Power Sources*, vol. 144, no. 1, pp. 280–294, Jun. 2005.

[3] E. V. Landscape, "Global EV outlook for 2020," 2013. [Online]. Available: http://www.iea.org/publications/globalevoutlook_2013.pdf. [Accessed: 12-Jan-2015].

[4] "Monthly Plug-In Sales in US." [Online]. Available: http://insideevs.com/monthly-plug-in-sales-scorecard/. [Accessed: 09-Jan-2015].

[5] B. K. Sovacool and R. F. Hirsh, "Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition," *Energy Policy*, vol. 37, no. 3, pp. 1095–1103, Mar. 2009.

[6] J. Tomić and W. Kempton, "Using fleets of electric-drive vehicles for grid support," *J. Power Sources*, vol. 168, no. 2, pp. 459–468, Jun. 2007.

[7] B. Lunz, Z. Yan, J. B. Gerschler, and D. U. Sauer, "Influence of plug-in hybrid electric vehicle charging strategies on charging and battery degradation costs," *Energy Policy*, vol. 46, pp. 511–519, Jul. 2012.

[8] J. D. K. Bishop, C. J. Axon, D. Bonilla, M. Tran, D. Banister, and M. D. McCulloch, "Evaluating the impact of V2G services on the degradation of batteries in PHEV and EV," *Appl. Energy*, vol. 111, pp. 206–218, Nov. 2013.

[9] EV Everywhere, "Road to Success," 2014. [Online]. Available: http://energy.gov/sites/prod/files/2014/02/f8/eveverywhere_road_to_success.pdf. [Accessed: 14-Jan-2015].

[10] M.-K. Song, Y. Zhang, and E. J. Cairns, "A long-life, high-rate lithium/sulfur cell: a multifaceted approach to enhancing cell performance.," *Nano Lett.*, vol. 13, no. 12, pp. 5891–9, Jan. 2013.

[11] X. Feng, M.-K. Song, W. C. Stolte, D. Gardenghi, D. Zhang, X. Sun, J. Zhu, E. J. Cairns, and J. Guo, "Understanding the degradation mechanism of rechargeable lithium/sulfur cells: a comprehensive study of the sulfur-graphene oxide cathode after discharge-charge cycling.," *Phys. Chem. Chem. Phys.*, vol. 16, no. 32, pp. 16931–40, Aug. 2014.

[12] K. G. Gallagher, S. Goebel, T. Greszler, M. Mathias, W. Oelerich, D. Eroglu, and V. Srinivasan, "Quantifying the promise of lithium–air batteries for electric vehicles," *Energy Environ. Sci.*, vol. 7, no. 5, p. 1555, 2014.

[13] D. P. Tuttle, R. L. Fares, R. Baldick, and M. E. Webber, "Plug-In Vehicle to Home (V2H) duration and power output capability," *2013 IEEE Transp. Electrif. Conf. Expo*, pp. 1–7, Jun. 2013.

[14] C. Liu, K. T. Chau, D. Wu, and S. Gao, "Opportunities and Challenges of Vehicle-to-Home, Vehicle-to-Vehicle, and Vehicle-to-Grid Technologies," *Proc. IEEE*, vol. 101, no. 11, pp. 2409–2427, Nov. 2013.

[15] Nissan Motor Co., "LEAF to Home Electricity Supply System with Nissan LEAF," 2012. [Online]. Available: http://www.chademo.com/wp/wp-content/uploads/2013/03/14InfrastructureWS/14_infraWS_Presentation_Nissan2.pdf. [Accessed: 22-Dec-2014].

[16] "BMWi ChargedForward Program." [Online]. Available: http://www.bmwichargeforward.com/. [Accessed: 14-Jan-2015].

[17] C. Pang, P. Dutta, S. Kim, M. Kezunovic, and I. Damnjanovic, "PHEVs as dynamically configurable dispersed energy storage for V2B uses in the smart grid," in *7th Mediterranean Conference and Exhibition on Power Generation, Transmission, Distribution and Energy Conversion (MedPower 2010)*, 2010, no. November, pp. 174–174.

[18] "Nissan V2B project." [Online]. Available: http://blog.alliance-renault-nissan.com/blog/nissan-leafs-can-now-power-office-well-home. [Accessed: 24-Oct-2014].

[19] W. Kempton and S. E. Letendre, "Electric vehicles as a new power source for electric utilities," *Transp. Res. Part D Transp. Environ.*, vol. 2, no. 3, pp. 157–175, Sep. 1997.

[20] D. B. Richardson, "Electric vehicles and the electric grid: A review of modeling approaches, Impacts, and renewable energy integration," *Renew. Sustain. Energy Rev.*, vol. 19, pp. 247–254, Mar. 2013.

[21] H. Lund and W. Kempton, "Integration of renewable energy into the transport and electricity sectors through V2G," *Energy Policy*, vol. 36, no. 9, pp. 3578–3587, Sep. 2008.

[22] D. Dallinger and M. Wietschel, "Grid integration of intermittent renewable energy sources using price-responsive plug-in electric vehicles," *Renew. Sustain. Energy Rev.*, vol. 16, no. 5, pp. 3370–3382, Jun. 2012.

[23] K. Knezovic, M. Marinelli, R. J. Moller, P. B. Andersen, C. Traholt, and F. Sossan, "Analysis of voltage support by electric vehicles and photovoltaic in a real Danish low voltage network," in *2014 49th International Universities Power Engineering Conference (UPEC)*, 2014, pp. 1–6.

[24] R. J. Bessa and M. A. Matos, "The role of an aggregator agent for EV in the electricity market," in *7th Mediterranean Conference and Exhibition on Power Generation, Transmission, Distribution and Energy Conversion (MedPower 2010)*, 2010, no. November, pp. 123–131.

[25] J. García-Villalobos, I. Zamora, J. I. San Martín, F. J. Asensio, and V. Aperribay, "Plug-in electric vehicles in electric distribution networks: A review of smart charging approaches," *Renew. Sustain. Energy Rev.*, vol. 38, pp. 717–731, Oct. 2014.

[26] A. Di Giorgio, F. Liberati, and S. Canale, "Electric vehicles charging control in a smart grid: A model predictive control approach," *Control Eng. Pract.*, vol. 22, pp. 147–162, Jan. 2014.

[27] C. B. Harris and M. E. Webber, "The sensitivity of vehicle-to-grid revenues to plug-in electric vehicle battery size and EVSE power rating," in *2014 IEEE PES General Meeting | Conference & Exposition*, 2014, pp. 1–5.

[28] SmartV2G project, "Project objectives," 2012. [Online]. Available: http://www.smartv2g.eu/deliverables.html.

[29] NRG, "eV2g Background," 2013. [Online]. Available: http://www.lehigh.edu/engineering/news/events/ine/pdf/Fisher.pdf.

[30] P. Stith, "EV Grid - Vehicle Grid Integration Services," 2014. [Online]. Available: http://www.energy.ca.gov/2014_energypolicy/documents/2014-06-23_workshop/presentations/06_Stith_EV_Grid_CEC_IEPR_06-23-2014.pdf.

[31] "Grid-on-Wheels Project." [Online]. Available: http://grid-on-wheels.com/. [Accessed: 07-Jan-2015].

[32] P. B. Andersen, O. J. Olesen, G. Poilasne, B. Christensen, E. Cajon, and O. Alm, "The Nikola Project: Intelligent Electric Vehicle Integration," in *IEEE PES ISGT Europe 2013*, 2014, no. C.

[33] Nissan Motor Co., "Nissan Leaf can now power the office," 2013. [Online]. Available: http://blog.alliance-renault-nissan.com/blog/nissan-leafs-can-now-power-office-well-home. [Accessed: 16-Jan-2015].

[34] "Toyota Smart House." [Online]. Available: http://www.toyota-global.com/innovation/smart_grid/. [Accessed: 16-Jan-2015].

[35] "Honda Smart Home." [Online]. Available: http://world.honda.com/news/2014/c140521Real-World-Smart-House/. [Accessed: 16-Dec-2014].