EVS26
Los Angeles, California, May 6-9, 2012

The Transformative Impact of Plug-in Electric Vehicles on the Energy Sector

Alina Dini[1]
[1]*Verdant Vision, Director, 47 Henry Street, Greenslopes, Queensland, Australia, alina@verdantvisiongroup.com*

Plug-in electric vehicles (PEVs) are part of a new wave of clean vehicles emerging in global markets. They are widely lauded for their environmental and energy security attributes, but less recognized for their ability to catalyze transformative change in the energy sector. This paper will explore the transformative impact of PEVs on the energy sector as a whole, comparing research predictions with detailed assessment of outcomes from the first global PEV deployments. This review will characterise the transformative change initiated by PEVs, focusing on the areas of stationary/renewable energy, electricity distribution/intelligent grids, electric passenger transport, and household energy behavior.

Keywords: electric vehicle, smart grids, renewable energy, behavior change, policy

1 Introduction

Plug-in electric vehicles (PEVs), unlike any other grid connected device, have initiated a transformation of the energy sector that will lead to enduring evolutionary change. PEVs are well-known for their ability to promote reduction of greenhouse gas (GHG) emissions, improve urban air quality, strengthen local automotive industry R&D, and reduce dependency on petroleum fuels. However, an emergent characteristic of electric vehicles is their ability to catalyze transformative change in the energy sector.

The energy impact of electric vehicles is not lost on decision-makers – many recognize that off-peak, overnight, electric vehicle charging can fill in troughs of energy demand, increasing the utilisation of network assets and driving down aggregate costs. Others note that electric vehicles can support growth of community-level renewable energy deployments whose generation profiles complements most cars, parked at home or at work for many hours in the day. Few recognize, however, that the aggregated impacts of electric vehicles have the potential to affect widespread change across the energy sector, ranging from households to stationary energy generation, more profoundly and systematically than any individual effect.

For decades, researchers have suggested that electric vehicles offer potential to transform existing systems for energy distribution and storage, industry development, and household energy behaviors. But only now, after delivery of the first commercial plug-in electric vehicles to market, can those predictions be observed. Through a detailed literature review, this paper will demonstrate the marked evolution of the energy sector taking place directly as a result of PEV deployment in the global marketplace. This paper will highlight four key areas of impact: (1) stationary energy and renewable generation, (2) intelligent infrastructure, (3) electricity as a transport fuel, and (4) household energy usage. On this basis, the paper will conclusively demonstrate how PEVs are creating an unprecedented widespread and positive transformational change across the entire energy sector.

2 The Energy Sector is Changing

2.1 Evolution of the Electricity Grid

Since its advent in the late 19th century, the electricity infrastructure has evolved into today's modern system, with each iteration adding more capacity for energy transfer, more breadth of reach, more functionality, and in many cases, more cost. However, in the last 10-15 years various technologies have impacted the grid substantially, making its 21st century characteristics markedly different from those in the past.

Increasing popularity of certain appliances (e.g. air-conditioners) and small-scale, distributed energy technologies (e.g. rooftop solar PV) has propelled grid augmentation into the spotlight, making it a common headliner in energy policy discussions and debates. Requirements for new technologies to combine cohesively with the old follow the introduction of these new elements in the system. Some recent examples contributing to the grid's evolution include:

- Distributed generation
- Increasing consumption
- Smart Meters
- Revised tariff structures
- Energy efficient appliances
- Stationary storage
- Broadband grid connectivity
- Demand response technologies
- Increased use/decreased cost of natural gas
- Policy interventions – feed-in tariffs, incentives for distributed generation, smart meter trials, rebates for more efficient appliances
- Plug-in electric vehicles

Given the dynamic pace of technological developments [1] and increasing consumer appetite for new smart services [2], the list of grid interventions with transformational impact is expected to grow with time.

2.2 Key Segments of the Energy Sector

Even though the energy sector is undergoing a rapid modernization through the influence of the technologies and trends listed above, the basic key activity segments in the energy sector remain unchanged. In the author's view, the four key energy sector activity segments include:

- Generation (including Ancillary Services)
- Distribution Infrastructure
- Market Structure (Commercial and Regulatory Arrangements), and
- Consumer Behaviors

These four areas provide a generic framework to characterise the roles and interests of the various stakeholders in the energy system. These four key activity segments are also closely aligned with the four PEV impact areas highlighted by this paper (Sections 3-6). Therefore this framework (Figure 1) allows us to conclusively demonstrate how PEVs are creating a widespread transformational change across all segments of the energy sector.

2.3 PEVs and their Connectivity in the Energy Sector

Electric vehicles stand apart from other 'disruptive' grid technologies because they have managed to catalyze rapid and far-reaching change to the energy system.

Like many new technologies, PEVs offer market innovation, excitement and in this case 'green' branding, making them potentially very popular at a large scale in both popular culture and public policy. However, underlying this enthusiasm for PEVs is a rapid transformational change via a web of unprecedented activity between the electricity and automotive sectors, increasing the proliferation of electricity as a transport fuel. While it is logical that electric vehicles require plugs and sockets, a surprising interplay has developed between the automotive and electricity retail sectors through the formation of an entirely new market for EV recharging networks [3].

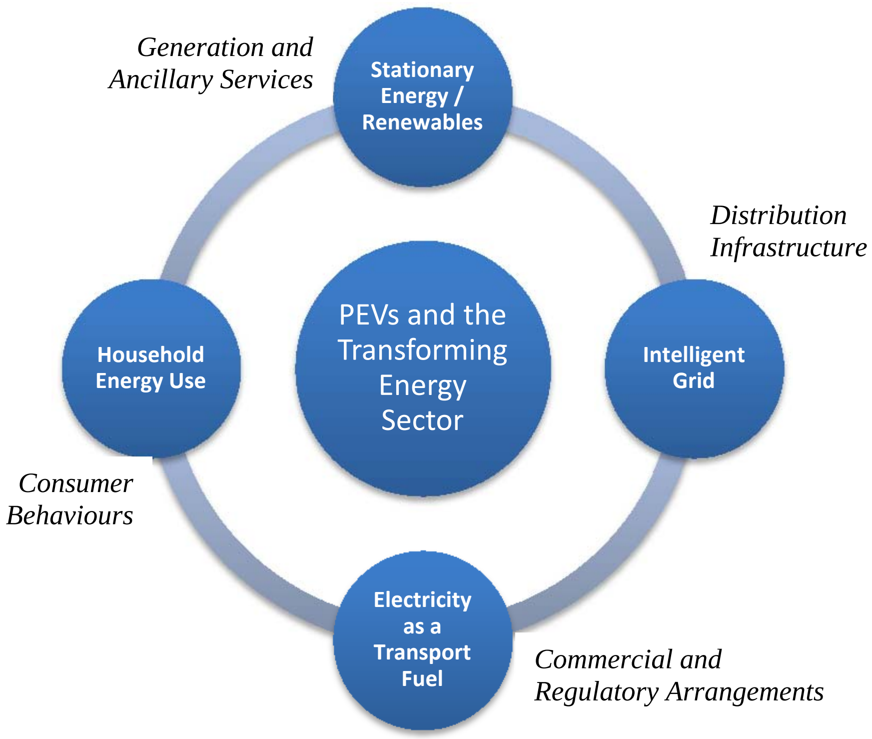

Figure1. Overview of Four Areas of Transformative Impacts of PEVs on the Energy Sector

Electric vehicle connectivity with the grid is often characterised by unknowns – there are risks that insufficient infrastructure will be provided for early PEV adopters (the commonly cited 'range anxiety' issue) vs. the risk that stakeholders will overspend on public infrastructure that ultimately may not be well-utilised once EV behaviors have matured. Furthermore, in the context of EV network loading, there are possible benefits to the network (e.g. increased asset utilisation) as well as possible risks (e.g. impact on peak demand due to coincident recharging loads).

The dividing lines between stakeholders are becoming increasing blurred, as existing players expand into new areas of the market and also as new players emerge. For example, vehicle manufacturers such as Nissan are underwriting new commercial plays like 4R Energy Corporation to trial the feasibility of using old PEV batteries to support grid supply issues [4].

Never before has a single technology succeeded in cultivating change across such a broad range of sectoral activities in the energy sector. And moreover, thanks to the popularity and common use of vehicles in modern society, PEVs are reaching anyone with an interest in driving – and any commercial entity interested in capturing a share of the emerging PEV marketplace.

The pervasive impact of PEVs is truly profound and now, just after the earliest commercial deployments have occurred, can we see how these transformative impacts are being recognized.

3 Stationary Energy and Renewable Generation

The natural partnership between PEVs and renewable energy goes far beyond their thematic similarities. Both are new, clean, low-carbon energy technologies whose partnership results in better utility of both technologies. However, the synergies between PEVs and renewable energy are extending much farther still.

3.1 PEVs Enable Renewable Generation Installations

Central to the environmental argument for PEVs is the 'cleanliness' of the electricity generated to power them. Electric vehicles are often touted as 'zero emission vehicles' but only if their well-to-wheel footprint supports that outcome. In many jurisdictions, PEVs drivers are encouraged to opt into green power schemes or to invest in domestic renewable installations to maximise the environmental synergies between PEVs and renewable energy.

Recognising the obvious opportunity to link PEV recharging with renewable generation, a number of public demonstrations and commercial products have emerged pairing the two. Electric vehicles have filled a missing piece in clean energy marketing campaigns, as PEVs are now regularly included in solar installer brochures and in clean energy campaign materials. New product offerings such as solar PEV parking structures further illustrate the potential for electric vehicles to support growth of community-level renewable energy deployments whose generation profiles complement the availability of parked cars [5].

3.2 Renewable Supply Agreements to Serve the PEV Market

Underscoring the commercial potential of linking the PEV and renewable electricity sectors is an unforeseen partnership between generators and consumers. For example Australian energy producer ActewAGL, who is seeking large scale customers of renewable energy to support industry growth, and EV infrastructure provider Better Place, who are looking for a guaranteed renewable energy supply to support their EV customers, have signed a 10-year supply agreement [6]. Through this commitment Better Place customers are guaranteed a supply of 100% GreenPower® for their entire PEV recharging infrastructure service.

The commercial agreement between charging infrastructure service providers and electricity generators works favourable for both parties. While many markets have not mandated that PEVs be recharged only with renewable energy, it is still fair to expect that the market for renewable energy will grow commensurate with the significant growth of the PEV market over time, as is expected to occur [7].

3.3 Vehicle-to-Grid (V2G) Ancillary Services and Renewables

Utilizing emerging bidirectional features of the electricity grid, PEVs have the potential to enable the use of *even more* renewable energy in addition to the demand for green PEV recharging [8]. The technical relationship between PEVs and the grid is discussed further in Section 4.2 but suffice to say that the intelligent connectivity of some PEV products is providing a new source of market ancillary services that can enable greater renewable energy uptake.

As discussed regularly by Kempton [9] and others [10] the coincidence of PEV connectivity (often most hours of the day) with the intermittency of renewable energy (i.e. solar, wind) opens doors for powerful leverage to increase the uptake of both technologies. For example, in Australia, Simpson has suggested that ancillary services provided by 1 million PEVs (8% of the national fleet) through vehicle-to-grid could enable 45,000GWh of renewable energy generation, equivalent to the entire Renewable Energy Target previously established by the Australian Government in 2009 [11]. Better Place has also determined that smart charging the same number of PEVs would provide over 3,500GWh of equivalent energy storage to the grid [12].

Though plug-in electric vehicles offer lower carbon outcomes than their internal combustion-powered peers, it is also evident in research as well as in the early market place that intelligent pairing of PEVs with renewables accelerates the market growth of both technologies.

4 Intelligent Infrastructure

The topology of today's electricity grid is changing and advanced technologies are upgrading the intelligence of the electricity network. Smart features such as broadband connectivity can enhance the user experience, but may also create additional layers of complexity in its operation as well as market commercial and regulatory arrangements.

Electric vehicles play a significant role in the evolving intelligence of the grid, and their growing participation is expanding the smart network service options for the energy sector, even after PEVs' end of life.

4.1 Plug-in Electric Vehicle Recharging Services

PEVs of all shapes and sizes have one thing in common – they are powered primarily by an on-board battery that is recharged by off-board electricity. While some PEVs only operate in electric mode for part of their driving (i.e. plug-in hybrid electric vehicles a.k.a. PHEVs or extended-range electric vehicles a.k.a. EREVs), all PEVs do simply as their name suggests – they plug in.

Deployment of electric vehicles in the 21st century (as opposed to previous attempts in the early and late 20th century) has spurred the development of a new services market – PEV charging services, also referred to as electric vehicle supply equipment (EVSE) or colloquially, PEV infrastructure or recharging networks. In parallel, the progress of the information and communication technology (ICT) sector has enabled a shift toward smart networks, and this has enhanced the functionality of many EVSEs. They can range from low-tech plugs and sockets, designed only to supply the power requirements demanded by a PEV, or they can provide advanced network services to PEV customers and grid operators alike. Currently nearly 50 different EVSE products are available in the global marketplace at various levels of cost and service offering, some partnered with specific vehicles, but mostly independently available for purchase [13].

To date, the market has demonstrated demand for value-adding EVSE services, as PEV infrastructure products continually enable faster and smarter charging, and many early PEV adopters have demonstrated willingness-to-pay for this convenience. Additionally, grid operators have been sold on the concept of managed PEV recharging, or "smart charging", in which PEV charging can be intelligently scheduled off-peak or at times of excess renewable energy generation. This functionality can fill in troughs of energy demand, increasing the utilisation of existing generation and network assets and delaying the need for augmentation, thereby putting downward pressure on the cost of supply over time [14].

4.2 Vehicle-to-X and Bidirectional Connectivity

In taking PEV recharging services one step further, the EVSE marketplace has also cultivated additional product offerings that further leverage the mobility and connectivity of electric vehicles through bidirectional interfaces for both power and communications. Emerging products in this space tend to combine information portals with some form of energy management system (i.e. user displays and controls), with data collection (i.e. broadband-enabled data logging), and, through the presence of PEVs, active energy storage (i.e. batteries).

The following exemplary products are characterized by cross-industry collaboration between the transport, energy and information technology / communication sectors:

- Tendril is using cloud technology to connect the BMW ActiveE to the home and local utilities [15].
- GM's on-board communication service OnStar [16] is developing a product using grid and internet connectivity to synch timing of Volt recharging with clean energy generation.
- Volvo, Ericsson and Gothenburg Energy's ELVIIS, an integrated software program that allows drivers to control charging of cars to optimise charging (including utilising renewable energy and paying directly for electricity from the car) [17].
- Hohm, the free, internet-based home energy management application developed by Microsoft and used by Ford EV customers [18].
- In Denmark, IBM Siemens, the Danish Energy Association and other partners have collaborated since 2009 on The EDISON Project, an integrated PEV recharging network that leverages intermittent renewable generation [19].

Technological advancements in battery chemistries and management systems have enabled the market for PEVs and also brought to light advanced applications of PEV batteries, such as Vehicle-to-X (V2X), where the PEV battery is utilized to store energy for off-board purposes at a future time. In this manner, PEVs can provide security or support for network operation when:

- electricity supply is not guaranteed (e.g. during service disruption)
- electricity supply costs are unfavourable (e.g. peak period tariffs in a market that includes cost-reflective pricing)
- demand for electricity storage is high and potentially profitable for the vehicle owner (e.g. during periods of excess renewable energy generation)

The introduction of PEVs into the marketplace has further promoted the development of these advanced services, by filling a gap in household and community energy management as vehicles become part of the wider energy ecosystem. The ubiquitous nature of both electricity infrastructure and vehicles in communities has helped pave the road to this greater level of connectivity.

4.3 Second-Life PEV Batteries

In addition to the expanding role of PEV batteries in the vehicle, a market for 'used' PEV batteries has also become evident to automakers such as General Motors and Nissan who have recognized that decommissioned PEV batteries still have sufficient capacity to provide low cost storage for distributed energy and demand management [20]. Additionally, the reuse of second-life PEV batteries 'closes the loop' to boost the overall sustainability credentials of PEVs [22].

Many major PEV stakeholders are involved in investigating the feasibility of this second-life battery market. Some examples include:

- Duke Energy and ITOCHU partnered in 2010 to assess the value of 80 used TH!NK batteries [23].
- In early 2012 Nissan and ABB announced the formation of a consortium to investigate repurposing Nissan Leaf batteries at their end of life [24]. ABB is also working with GM to investigate end-of-life Volt batteries [25].
- The US Department of Energy funded a $1.3 million dollar project in 2011 to explore the best application of PEV end-of-life batteries [26].

While former PEV batteries might be well-suited to the stationary storage sector, question remains about the cost-to-performance ratio of a degraded battery when compared to a new one, such as those provided directly by battery suppliers such as A1234, Panasonic and GS Yuasa [27]. Additionally, battery owners will be forced to compare the residual value of a PEV battery for grid storage against its material value for recycling.

5 Electricity as a Transport Fuel

With the rollout of PEVs, electricity now also serves as a fuel for the vehicle market – a somewhat untraditional role. Since many jurisdictions still don't recognize electricity as being comparable to gasoline, diesel, gaseous fuels or bio fuels, the use of electricity to propel vehicles challenges many long-standing market arrangements in terms of both commercial and regulatory institutions and their roles.

5.1 Electric role transformation – the role of stationary energy service (appliances) vs. the role of mobility (vehicles)

When electric vehicles plug into the electricity network, their philosophical identity is put in question – are they an electrical appliance, a vehicle, or both? The blurring of pre-existing boundaries between the transport and energy sectors is accelerated with the introduction of commercial PEVS, making these devices and their emerging markets complex to regulate. Development of standards and regulations for electric vehicles requires the expertise of electrical, mechanical and chemical engineers, from both the stationary energy and transport disciplines. In fact, in many jurisdictions worldwide, new government agencies[1] and corporate business units have been created to managing matters relating to the burgeoning PEV industry, as no established sector can manage all things PEV-related.

California regulators represent one of the best examples of forward thinking relating to PEV governance. As part of its rulemaking for utilities through the California Public Utilities Commission (CPUC), Californians have endorsed electricity as a transport fuel and are actively working toward resolving policy barriers that do not accommodate this paradigm shift. In July 2011, the CPUC agreed to favour free market development with relation to PEV recharging services – the CPUC voted to avoid regulation of PEV recharging services and to prevent existing CA utilities from owning EVSE infrastructure [28].

The CPUC decision philosophy effectively amends the design function of the electricity grid, redefining it also as a transportation system asset to support electric motoring for the long term. While the CPUC was the first of its kind in the United States to enact substantial reforms to shape the functionality of the electricity grid, many other regulators are expected to follow suit.

[1] For example, the UK Office for Low Emission Vehicles, http://www.dft.gov.uk/topics/sustainable/olev/

5.2 Integration of the Transport and Energy Sector Markets

Exemplary of PEV transformational change is the web of activity between the electricity and automotive sectors, increasing with the proliferation of electricity as a transport fuel. While it is logical that electric vehicles require plugs and sockets, a surprising interplay has developed between the automotive and electricity retail sectors through the formation of electric vehicle recharging networks. Never before have major automotive OEMs and electricity retailers worked together with such calculated coordination – much less shared floor space at an international auto show, as has been the case for Better Place and Renault-Nissan, partners in delivery of the first full-service PEV network.

No other electrical appliance offers this cross-disciplinary market appeal like a PEV – and long term appliance producers such as Bosch, Siemens and General Electric (GE) are keenly aware of this. GE, for example, now has extensive product offerings in the energy sector ranging from household appliances through to PEV charging stations. GE's Capital division has also recognized the finance value of PEVs and have committed to purchasing 25,000 PEVs for use in their global fleets – the largest single EV procurement commitment to date. While GE becomes active in the transport sector, US electric vehicle producer Coda Automotive recently announced the creation of a new business unit – Coda Energy – which will produce and sell energy storage solutions for the distributed energy sector. Citing an anticipated growth in energy storage capacity from 121 megawatts (MW) in 2011 to 12,353 MW in 2021, Coda has sought market share in the energy sector as well as the transport sector. It is increasingly evident that coordination between the automotive and energy sectors is an essential business development strategy for any company wishing to capture a share of the expanding PEV marketplace.

6 Household Energy Usage

PEVs are also catalyzing changes in household energy consumption on the whole. For years, incentive programs, educational campaigns and tariff schemes have been attempted by utilities and regulators as means of influencing household energy behaviors. However, survey results from early PEV trial deployments suggests that new PEV drivers are not only very happy with their vehicles – 86 percent of new GM Volt drivers [29] recommend – but they are also learning a lot more about energy use in general from them.

While several early analyses of initial PEV deployments (such as those done by Accenture) [30] focused on institutional barriers that might shape PEV uptake (e.g. lack of standards), more recent accounts focused on early consumer experiences have illustrate unexpected and beneficial relationships between PEV usage and household energy behaviour. For example, households have been known to demonstrate an '*increased awareness of their individual energy consumption*' as a result of learning how to operate their PEV – an outcome in sharp contrast to some utilities' concerns that PEVs pose a threat to the electricity distribution network if recharging behaviours are not managed [31]. (Note that for the sake of this discussion, transport energy use is considered part of total household energy consumption, regardless of the fuel type.)

6.1 Greater awareness of driving habits

Advanced technology vehicles, many of which provide sophisticated user interfaces to communicate with the operator (i.e. hybrids like the Toyota Prius), have been known to increase awareness of driving habits and their impact on fuel efficiency [32]. Similarly, PEVs have also provided evidence of increasing awareness of travel behaviour and energy consumption, with or without the aid of computerized instrumentation.

Many early PEV adopters are characterized as having well-suited attributes – they are often employed full-time and highly educated; they tend to own their own homes and their first PEV is not their first or only car; and they are attune to new technology developments and favour sustainability products and measures where possible [33]. Early PEV adopters also tend to broadcast their experiences to their peers, suggesting they are not only quite aware of their interaction with the technology, but they also tend to develop well-informed opinions [34].

In contrast, drivers of conventional vehicles are known to give little consideration to their travel habits as a legacy of internal combustion driving and the convenience and high energy density of liquid refuelling. However, PEV motorists are quickly trained to learn where their regular travel destinations are located as well as the round-trip distance and how much energy or range is required to get them there. As discovered by researchers at UC Davis in their 2011 study of the Mini-E trial, unlike conventional motorists, electric vehicle drivers tend to adjust to the electric range limitation of PEVs through increased awareness of their travel habits learned in the early weeks of driving. Over time, these drivers also displayed willingness to push the boundaries of PEV functionality, by driving outside of their normal travel habits and further afield thereby illustrating masterful understanding of the value of energy management and energy efficiency [35].

6.2 Changes to household energy behaviors

Another unsuspected finding of early PEV deployments is anecdotal evidence suggesting a relationship between PEV driver awareness and subsequent behaviour change and their overall view toward total household energy consumption.

In the UC Davis Mini-E trial, more than 67 percent of surveyed drivers admitted to increasing their awareness of their household energy consumption as a result of driving a PEV regularly. While it was not explicitly studied in the Mini-E trial, it could be inferred that PEV drivers transferred their energy behaviour mastery from transport activity to use of other stationary and energy-intensive appliances such as dishwashers, televisions and air conditioners, resulting in a likely reduction in overall household energy consumption. Thematically, this occurrence of 'increased mastery of household energy use' as a result of sustained use of PEVs has emerged in a number of early PEV deployment studies.

7 Emerging Mega Trends in the Energy Sector with PEVs

The introduction of PEVs into the global market place is therefore catalyzing unprecedented change in the energy system and this effect is noticeable in all segments and activities across the energy sector.

Four major 'mega-trends' in the energy sector are aligned with this observation and give rise to the following questions, where more research is considered essential:

(1) Industry Development:
As PEV and renewable energy deployments demonstrate a clear synergy for continued and leveraged market growth, what other synergies in the energy marketplace might arise from the growth of the PEV market?

(2) Economic assessments:
While grid enhancements with the associated costs are inevitable in today's rapidly evolving energy market, how do energy markets differ in relation to localized conditions (i.e. geography, urban density, consumer demographics, market arrangements, etc), and to what degree does consumer willingness-to-pay factor into the growing demand for PEV connectivity in particular and grid intelligence in general?

(3) Policy & Regulation:
Physical integration of the transport and energy sectors is already evident, but to what extent will commercial, regulatory and policy arrangement help or hinder this merger of sectors?

(4) Sociology & human behavior
Early users of PEVs provide anecdotal evidence of positive change in their household energy consumption behaviors. Is this early observation scientifically verifiable and scalable and sustained and, if so, how can this effect be leveraged to promote wider change in household energy use?

8 Conclusion

As demonstrated in this literature review, plug-in electric vehicles are having rapid and far-reaching transformative impacts on the energy sector globally. Unlike no other grid-connected technology, we see evidence that PEVs will accelerate renewable energy uptake, encourage the rollout of smart infrastructure, promote energy awareness and behavior change in consumers, and transform societal understanding of the roles of electricity and vehicles as well as strategic priorities around energy infrastructure. These areas of impact cover all segments of the energy sector according to the framework outlined in this paper. Therefore this paper has conclusively shown how PEVs are creating an unprecedented widespread and positive transformational change across the entire energy sector.

While many questions remain about the breadth and depth and sustainability of PEV impacts on the energy sector, PEVs' potential to bring an unprecedented, positive, transformational change in the broader energy sector is undeniable. Furthermore, thanks to the popularity and common use of vehicles in modern society, PEVs are reaching anyone with an interest in driving – and any commercial entity interested in capturing a share of the emerging PEV marketplace. On this basis, the author contends that PEVs should be embraced as 'force for good' to help advance overall energy sector agendas and that research of these emerging mega-trends should continue. Further research will uncover how to best leverage this powerful impact potential of PEVs.

Acknowledgments

The author wishes to acknowledge Dr. Andrew Simpson, Managing Director of Verdant Vision, for his contributions to this research.

References

[1] Pike Research. "Clean Energy: Ten Trends to Watch in 2011 and Beyond." 2Q 2011.

[2] Ernst & Young. "The Rise of the Smart Customers: What Consumer Think" 2011.

[3] Markel, Tony. "Plug-in Electric Vehicle Infrastructure: A Foundation for Electrified Transportation." National Renewable Energy Lab. NREL/CP-540-47951. April 2010.

[4] Nissan. http://www.nissan-global.com/EN/NEWS/2012/_STORY/120118-01-e.html. Accessed 2012-02-27.

[5] General Electric. http://www.ecomagination.com/portfolio/ev-solar-carport accessed 2012-02-28.

[6] Better Place. http://www.betterplace.com.au/media/media-releases/actewagl-and-better-place-sign-landmark-60m-deal-on-renewable-energy.html accessed 2011-09-30.

[7] International Energy Agency. *Technology Roadmap: Electric and plug-in hybrid electric vehicles.* July 2011.

[8] Short, W. and P. Denholm**.** *A Preliminary Assessment of Plug-In Hybrid Electric Vehicles on Wind Energy Markets.* National Renewable Energy Lab. Technical Report NREL/TP-620-39729. April 2006.

[9] Lund, Henrik and Willett Kempton. *Integration of renewable energy into the transport and electricity sectors through V2G.* Energy Policy 36 (2008) 3578– 3587.

[10] Andersen, Poul H. et al, *Integrating private transport into renewable energy policy: The strategy of creating intelligent recharging grids for electric vehicles.* Energy Policy 37, (2009) 2481–2486.

[11] Simpson, Andrew. *Environmental Attributes of Electric Vehicles in Australia.* Curtin University Sustainability Policy Institute, 2009.

[12] McDermott, Hugh. *Smart Charging.* Proc. Plug-In 2010 Conference and Exposition, San Jose, 2010.

[13] Plug-in Recharge. http://www.pluginrecharge.com/p/evse-vendors.html accessed 2012-02-28

[14] International Energy Agency. *Technology Roadmap: Smart Grids.* 2011.

[15] Tendril. http://www.tendrilinc.com/press/bmw-group-technology-office-usa-partners-with-tendril-to-demonstrate-the-power-of-electric-vehicle-and-smart-energy-home-integration/ accessed 2012-02-27

[16] Gigacom.http://gigaom.com/cleantech/how-to-charge-the-volt-with-clean-power/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+earth2tech+%28GigaOM%3A+Cleantech%29 accessed 2012-02-27

[17] Volvo. https://www.media.volvocars.com/global/enhanced/en-gb/Media/Preview.aspx?mediaid=42537 accessed 2012-02-27

[18] Microsoft. http://www.microsoft.com/presspass/features/2010/mar10/03-31fordhohm.mspx accessed 2012-02-27

[19] EDISON Project. http://www.edison-net.dk/ accessed 2012-02-29.

[20] Green Car Congress.http://www.greencarcongress.com/2011/07/gmabb-20110721.html Last accessed 2011-09-21

[21] Frost & Sullivan. http://www.frost.com/prod/servlet/market-insight-top.pag?docid=216476073 accessed 2012-02-29

[22] Duke Energy. http://www.duke-energy.com/news/releases/2010112301.asp Last accessed 2011-09-30

[23] Nissan. http://www.nissan-global.com/EN/NEWS/2012/_STORY/120118-01-e.html Last accessed 2012-02-27

[24] General Motors. http://media.gm.com/content/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2011/Jul/0720_reuse Last accessed 2012-02-27

[25] Center for Sustainable Energy California. http://energycenter.org/index.php/technical-assistance/transportation/transportation-news/2092-second-life-for-ev-batteries?catid=418%3Acvrp-blog accessed 2012-02-27

[26] Tech On. http://techon.nikkeibp.co.jp/english/NEWS_EN/20120214/204738/ Last accessed 2012-02-27

[27] Doughty, Daniel, et al. *Batteries for Large-Scale Stationary Electrical Energy Storage.* The Electrochemical Society Interface.vFall 2010

[28] California Public Unities Commission. http://docs.cpuc.ca.gov/word_pdf/AGENDA_DECISION/139101.pdf accessed 2012-02-28

[29] Peterson, Rob. GM Volt Plug in presentation. Rob Peterson July 2011

[30] Accenture. *Plug-in electric vehicles. Changing perceptions, Hedging Bets.* May 2011.

[31] Turrentine, Thomas S., Dahlia Garas, Andy Lentz, Justin Woodjack (2011) *The UC Davis MINI E Consumer Study*. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-11-05

[32] Kurani, Kenneth. Impacts of in-car Instrument on Driver Behaviour. IEA, ITF Eco-Drive Workshop. November 2007.

[33] Turrentine, Thomas S., Dahlia Garas, Andy Lentz, Justin Woodjack (2011) The UC Davis MINI E Consumer Study. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-11-05

[34] Axsen, John and Kenneth S. Kurani. *Interpersonal influence within car buyers' social networks: Developing pro-societal values through sustainable mobility policy* .International Transport Forum Annual Summit 2011.

[35] Turrentine, Thomas S., Dahlia Garas, Andy Lentz, Justin Woodjack (2011) *The UC Davis MINI E Consumer Study*. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-11-05

Author

Alina Dini is a director at Verdant Vision, the leading provider of electric vehicle readiness, deployment and evaluation services in Australia. Building on her 5+ years of experience leading policy and business development for clean technology deployment, renewable energy and energy efficiency, Alina created policy frameworks for governments in the US and Australia and worked for Tesla Motors from 2006-2008 where she to create more favorable policy and market conditions for electric vehicles. Alina holds Bachelor's in Political Science and Spanish from the University of California, Davis, and a Master's of Public Policy and Management from Carnegie Mellon University.