Changing the game

Plug-in electric vehicle pilots

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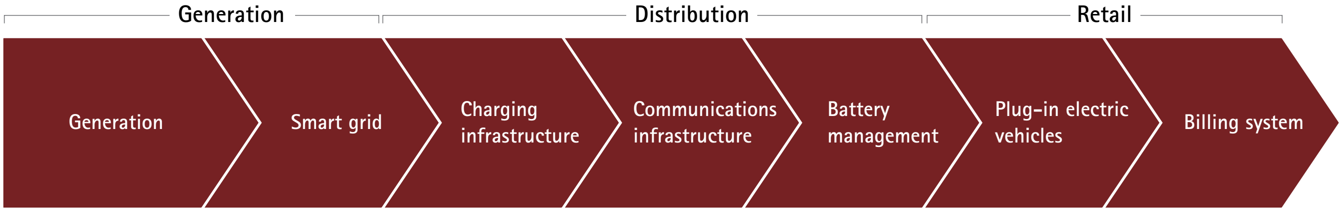
Executive summary

Figure 1. The electrification value chain.



Source: Accenture, "*Betting on Science: Disruptive Technologies in Transport Fuels*," 2009.

Transport accounts for close to 60 percent of global oil consumption and an estimated 30 percent of global carbon emissions.[1] With oil demand projected to grow by 1 percent per year on average from now to 2030—reaching 105.2 million barrels per day in 2030—and the transport sector being the main driver of this growth (accounting for 97 percent[2]), the industry is facing mounting pressure to find alternative fuel options and limit the carbon impact of growth. It is within this context that plug-in electric vehicles (PEVs), estimated to be 40 to 65 percent[3] more efficient than conventional vehicles, have received significant attention, and a number of governments have set ambitious targets for their adoption.

Our previous Accenture report published in November 2009, "*Betting on Science: Disruptive Technologies in Transport Fuels*,"[4] examined 12 potentially disruptive transport fuel technologies, 10 markets and 25 companies trying to bring these technologies to market. Among these technologies, we described PEVs—including plug-in hybrid electric vehicles (PHEVs) and all-electric vehicles (EVs)—leading to the electrification of transport as the industry "game changer," due to its potential to completely disrupt the transport industry, open up the industry to three new industries (battery, utility and charging) and change consumer interaction with the vehicle. Moreover, this potential is being fed by increasing attention from governments across the world. Since the publication of *Betting on Science*, this attention has only strengthened as billions of dollars continue to be invested into the nascent industry to test the technologies through pilots, and to implement subsidies with the aim of kick-starting the market (and overcoming the famous "chicken-and-egg" conundrum—who invests first, industry or consumers?) and scaling up the electrification of transport.

However, despite this investment, the complexity and novelty of the electrification value chain (see Figure 1)—which merges the utility value chain with the automotive, the battery and charging infrastructure value chains—suggest a number of challenges as to how cost-effective business models will be defined and how electrification of the transport industry will be successfully delivered.

We discussed many of these challenges in *Betting on Science*, but as the market evolves, a number of other additional obstacles to address are coming to the foreground. Figure 2 highlights these additional items, which if not addressed, could challenge delivery of electrification of transport.

Figure 2. Challenges to address in delivering plug-in electric vehicles (PEVs).

Area	Challenges to address
Market models and commercial and regulatory frameworks	• Determination of roles and responsibilities across the value chain to develop profitable business models with clarity between the various players. • Development of commercial frameworks to support these business models. • Identification of how PEVs fits into the utilities' regulated industry structure. • Identification of deployment models for PEV infrastructure.
Standardization and interoperability	• Development of standards across charging infrastructure, connectivity to the electricity network, and cyber security and communications security, to ensure interoperability within and across markets, providing customers with security, ease and flexibility. • Development of infrastructure payment standards enabling flexible alignment of costs and payment potentially to be included in a customer's utility bill.
Core PEV technologies	• Development of battery and engine technologies to ensure cost-effective and robust solutions. Batteries account for the large majority of the cost of PEVs, and until the cost per kilowatt-hour (kWh) dramatically decreases (to reach approximately $300/kWh), consumer uptake is likely to be limited to a dedicated and niche consumer market segment. • Specification of charging infrastructure to meet health and safety standards, usage requirements (e.g., installing fast-charging stations where there is not sufficient grid capacity to support the voltage is evidently not feasible), and consumer needs (i.e., location of infrastructure will be critical to determining usage and payback period).
PEV technology enablers	• Development of PEV managed services and fit-for-purpose communication interfaces between the supplier and the charging point, the charging point and the vehicle (and/or the consumer) and the vehicle and the supplier. • Development of back-office support functions, including IT solutions and services, to conduct the various commercial and operational transaction requirements to operate the PEV market on an industrialized and commercial scale (including, for example, the development of software to handle and settle roaming transactions between providers). • Identification of support services required for maintenance of technologies and market structures.
Grid impact	• Detailed investigation into the impact of PEVs. There are a number of studies which have measured this impact at a theoretical level, identifying that high-scale adoption of PEVs could have a substantial impact on the grid if charging is not managed or controlled; however, understanding the real impact on the grid by country is still required. • Definition of a practical approach to grid impact.
Consumer behavior	• Understanding of consumer preferences and behaviors to develop fit-for-purpose PEVs, which cater to consumer requirements and take into account likely trade-offs consumers will be willing to make, if any. • Education of consumers to ensure better understanding of the functionality of PEVs, availability of charging and their positive environmental impact.

While these challenges may seem like significant barriers to PEV market penetration given the range of required considerations, the number of stakeholders they involve and the extensive research still required, the technologies behind PEVs continue to improve. The key to these improvements are pilot projects which provide stakeholders with a safe space in which to develop capabilities, test these technologies and devise a number of creative mechanisms to address these items. As a result, these pilots are integral to determining market scale-up of PEV penetration, business models going forward and "who's who" in the emerging market.

This study aims to highlight the capabilities being developed through PEV pilots, investigate some of the early lessons learned, the creative mechanisms in development and the emerging business models (with a particular emphasis on charging business models) across geographic markets through the lens of these pilot programs. While reading this paper, it is important to remember that electrification remains a nascent industry and that it is constantly evolving. Continuous monitoring of the market will thus be critical to gaining clarity and to identifying the market winners.

While many of our conclusions are applicable to all PEVs, our focus has been on assessing EV pilots versus PHEV pilots. This focus is because our previous studies, *Betting on Science* and *Biofuels Time of Transition: Achieving High Performance in a World of Increasing Fuel Diversity*,[5] had a strong focus on PHEVs. In addition, EVs have more significant business model implications due to the required changes in consumer behavior and to the extensive potential strain on the grid. The study highlights five primary conclusions:

• Capabilities required to deliver electrification of transport will be the same across markets, but the players that choose to develop these capabilities will vary by geographic market, resulting in the development of a number of market models (with their own regulatory policies) across the globe.

• Early lessons learned from PEV pilots identify that many of the assumed challenges can be overcome through testing and market awareness, but three key challenges require further time for development: cost, scale and grid management. For example, PEVs are likely to meet the daily driving requirements of the average city user and therefore the infamous "range anxiety" is perhaps not the primary barrier to consumer adoption, but testing of core PEV technologies (and their impact) is limited by low penetration rates and will need continuous monitoring as the electrification of transport market scales.

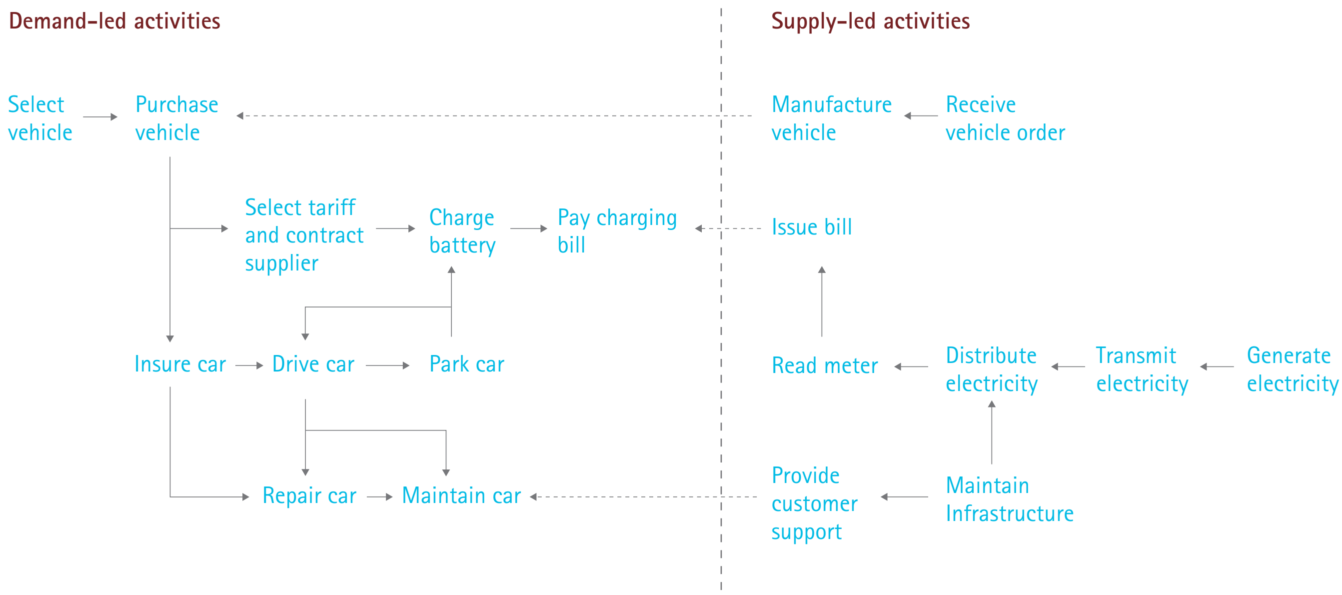
• Creative mechanisms are being devised to overcome key challenges related to technology cost, scale and grid management such as the disaggregation of the battery cost from vehicle ownership.

• A variety of business models are emerging across the three value chains: automotive, battery and charging, with different players taking the lead in different markets. Early success of these business models will determine "who's who" on the electrification of transport landscape.

• The consumer challenge is one that remains pertinent, with market uptake difficult to estimate. Better understanding the consumer and who will buy PEVs will be critical to anticipating scale and the success of electrification of transport.

Delivering plug-in electric vehicles

Figure 3. PEV-related activities.



Capabilities required

The merging of the electrification value chain with both the automotive value chain and the battery value chain evidently creates new capability requirements. An assessment of both demand-led and supply-led activities (see Figure 3) that PEVs require enable identification of what these capabilities are.

On the demand side, consumers will be coping with three traditional value chains: automotive (the vehicle), battery (the vehicle battery pack) and energy (the electricity supply). Ensuring consumers are able to appropriately maintain their batteries, easily charge their vehicles at home and/or in public locations and at their convenience, and be accurately billed will be critical to the consumer experience and the successful uptake of PEVs.

On the supply side, activities will expand traditional value chains—creating opportunities for incumbents and new market entrants. This includes managing and delivering the electricity supply, operating and maintaining the associated infrastructure, and providing the necessary support services, e.g., customer support, tariffs and billing. Some suppliers see access to the consumer in the car (because of the need to access state-of-charge information and to bill for charging) as an opportunity to provide other content and services. We expect to see significant innovation in this area.

As previously mentioned, new capabilities need to be developed to support this demand-side and supply-side activity and integrate it with the traditional value chains; at the same time, integration may sometimes require upgrades to existing capabilities. These new capabilities can be separated into three main areas: hardware, software and support services. Figure 4 provides a high-level overview of these capabilities—with a more thorough explanation thereafter.

Figure 4. PEV required capabilities.

Hardware →	Network distribution reinforcements	Electric vehicle supply equipment		
Software →	Network software	Charging software	Customer-facing software	
Support services →	Infrastructure maintenance	Back-office systems	Customer support	Additional services

Hardware

Developing the physical charging infrastructure is critical to the success and scaling of PEVs. This includes two key components:

Distribution network reinforcements

The need to reinforce existing distribution substations will heavily depend on the current capacity of the substations and the level of PEV penetration. While high penetration is not likely to occur on a large scale for a number of years, PEV take-up is likely to be concentrated in the same areas (e.g., within the same city neighborhoods), meaning that the same substations will be impacted and will require reinforcements.

Electric vehicle supply equipment (EVSE)

Brand new infrastructure will be required for charging PEVs. EVSE will need to be located at homes, on streets and in private/commercial locations (e.g., offices, shopping centers and parking bays) to provide charging capabilities for consumers with differing requirements. These requirements include different levels (or speeds) of charging, such as fast charging at supermarkets or on motorways. These charging stations, regardless of level, will all need to be open architecture to ensure interoperability, and to contain payment devices which will enable accurate billing/membership schemes. The number of EVSE required will be subject to the level of PEV penetration—at full scale, two EVSE per vehicle is expected.

A number of questions remain as to how many and which substations to upgrade, where to locate the EVSE and what level of charging is required and where. The answers will rely on extensive testing and research through pilot projects determined by those companies that develop these capabilities.

Software

The integration of these new capabilities will rely extensively on the development of supporting software to ensure all elements of the value chain communicate with one another and with the end consumer. There are three key areas of software capability:

Network software

The network software platform will enable utilities to measure and manage grid demand through recognition of the number of PEVs on the network. This software will facilitate network planning and management, helping to determine where reinforcement is needed.

Charging software

This software manages communication between the PEV and the grid. It communicates with the PEVs, establishing state of charge and when the PEV needs to be fully charged. This data is cross-referenced with the state of the grid to manage PEV demand with the rest of the demand on the network (thus minimizing network strain, particularly at peak times). This is called managed or controlled charging. The software will further have roaming capability to be able to match consumption with billing and is normally integrated in the PEV.

Customer-facing software

The customer interface maximizes the customer experience by providing necessary and useful information regarding the consumer's PEV and the supporting infrastructure. The interface is located either on the PEV itself or on a portable device and details the vehicle state of charge, as well as the location of EVSE.

These software platforms will be critical to the successful integration of these new capabilities, enabling communication across the value chain.

Support services

Support services are the capabilities that will underpin the functioning of the market. They are essential to maintaining the infrastructure and managing the high volumes of data that will come online, ensuring accurate billing and a positive consumer experience.

Infrastructure maintenance

A small field force will be necessary to maintain the EVSE and repair any malfunctions, when they cannot be done remotely. The need for maintenance is expected to be more extensive in the first few years of market development.

Back-office systems

These systems will build on currently existing capabilities but will need to manage much higher volumes of data, given the higher volumes of energy consumed at a multitude of different points and the need to align this to billing. These systems will need to communicate directly with the charging infrastructure to gather and aggregate the appropriate data needed for billing. While these high volumes of data will be a challenge to manage, they will provide the opportunity for extensive data analytics, further developing the technology. The level of development and the system requirements will depend on which company is operating the infrastructure and whether the data feeds into existing utility back-office systems or require new systems.

Customer support

Providing robust customer support will enhance the customer experience. This support will encompass queries relating to the EVSE, to tariff structures and/or to billing. An important item of note is to minimize the number of consumer interfaces for ease and simplicity.

Additional services

A wide range of additional services could be offered to the consumer, taking customer-facing software a step further. This includes add-ons such as electronic maps with the location and charging state of EVSE, details of energy consumed and carbon dioxide (CO_2) savings, among others.

In parallel to the development of hardware, software and support capability, the integration of these capabilities will be instrumental and a defining differentiator for market players. The number of capabilities required to support PEVs provides evidence of the wide range of opportunities open to incumbents and new market entrants. These capabilities will require continued testing and development, both to improve the technology and to devise cost-effective business models, but already present an early indicator of the key roles and responsibilities that the market requires.

In focus: The Chevrolet Volt and the Nissan LEAF™

Plug-in electric vehicle (PEV) is a catch-all phrase to include both plug-in hybrid electric vehicles (PHEVs) and full electric vehicles (EVs). While this catch-all phrase is often used and little distinction made between the two vehicle types, when it comes to consumer demand, these vehicles have very different implications. Understanding the implications and which type of vehicle is likely to be more popular—at least in the short to mid term—is critical to better understanding how the market will develop, as well as infrastructure requirements and the need for grid reinforcements (i.e., the impact on the grid). However, automotive manufacturers seem to have anticipated the market and drawn a line in the sand favoring one vehicle type over the other, with GM putting its money behind the PHEV, and Renault, BMW and Nissan hedging their bets on the EV. This debate between the PHEV and the EV is one that is most transparent in the market race between GM's Chevrolet Volt and Nissan's LEAF, both released in the United States in late 2010. In many ways, the initial success of one over the other is likely to shape the market going forward. Indeed, manufacturers and consumers are awaiting in anticipation, and behaviors and decisions are likely to be impacted by the initial success of one over the other.

The Chevrolet Volt is a PHEV, or extended-range vehicle, meaning it can run on both electricity and gasoline. This feature dampens consumer "range anxiety," providing optionality and flexibility. The Nissan LEAF is an EV, running solely on electricity. Figure 5 provides an initial comparison of the vehicles.

While certain statistics and facts can be compared, the pros and cons of the vehicles are largely subjective and will appeal to different customers with varying needs and expectations for their vehicles. The question then is: Which consumer group will prove more powerful and dominate the market?

Looking at anticipated production numbers, the story is a difficult one to decipher. Targeting 10,000 vehicles in the first year of production, GM recently announced that they are doubling their 2012 production targets, taking them to 45,000. This increase is due to the high level of consumer interest already expressed, with more than 25,000 consumers adding their names to the list of "Volt enthusiasts."[6] Nissan, on the other hand, has been even more optimistic in its target, aiming to produce 50,000 vehicles in the first year of production.[7] At the time of this report's publication, Nissan further expected 25,000 orders for the vehicles in the United States before the end of December 2010.[8] How much these numbers are based on consumer surveys and studies and how much comes down to marketing and publicity is anyone's guess, but it does emphasize the strong signal Nissan is trying to send.

Taking a different approach, Autoblog conducted a consumer survey to see whether the PHEV, the EV or the regular internal combustion engine (ICE) would prove more popular. The results were interesting, with 44.1 percent of respondents saying they would prefer to purchase the Volt, 27.2 percent saying they would prefer the LEAF and 28.7 percent opting for a conventional ICE.[9] Therefore, the survey would assume that the Chevrolet Volt will have more buyers than the Nissan LEAF.

Again, however, these comparisons cannot be viewed in black and white. Looking more broadly, the truth is while PHEVs and EVs share a similar grid relationship, they are very different vehicles and will appeal to different consumer segments. Both vehicles will appeal to green-conscious consumers, but while EVs are likely to be mostly city cars, PHEVs may appeal to city, suburban and country drivers, given the dual fuel optionality. As infrastructure becomes more widespread, this appeal may change and EVs may become more widespread. Until then, the PHEV may provide an interesting transition. This is particularly true with respect to fleets. For example, GE recently committed to converting half of their global fleet to PEVs by 2015, starting with an initial purchase of 12,000 GM PEVs in 2011.[10] The Chevrolet Volt/Nissan LEAF debate is most interesting in this respect—if the Volt surpasses or even reaches expected consumer demand, it may conjure a greater market wave of PHEVs; if not, EVs may have the winning tickets.

Figure 5. Comparison of Chevrolet Volt and Nissan LEAF™.

	Chevrolet Volt	Nissan LEAF™
Price US$	$41,000 or possibility to lease for $350/month for 36 months	$33,720 or possibility to lease for $379/month for 36 months
Range	40 miles (60 km) on all electric; 300 miles (450 km) on gasoline	100 miles on all electric
Battery size	16 kWh lithium-ion battery pack	24 kWh lithium-ion battery pack
Battery life	Eight-year/100,000-mile warranty	Eight-year/100,000-mile warranty
Charging time	Fully charged in between four hours (240 V) and 10 hours (120 V)	Fully charged in eight hours (220/240 V)
Pros	• Possibility to drive only on electric miles, and therefore potential to be a zero-emission vehicle • Dual-fuel engine provides extended range and greater flexibility • Tax credits and subsidies	• Zero-emission vehicle • Tax credits and subsidies
Cons	• High cost compared to similar vehicles • Inefficiency of having two engines • Limited infrastructure available to support electric charging, and long charging times	• Limited infrastructure available to support electric charge, and long charging times • Limited vehicle range

Note: Price (US$) does not include or incorporate subsidies or tax incentives.

Sources: "What Makes the Chevrolet Volt a Better Electric Vehicle?" July 21, 2010, www.chevroletvoltage.com/index.php/Volt/the-value-of-the-chevrolet-volt.html; Nissan LEAF™ electric car, www.nissanusa.com/leaf-electric-car/index#/leaf-electric-car;

Roles and responsibilities

In addition to the production of batteries and vehicles for consumer purchase, the capabilities required bring to light key roles that the market requires to support the electrification of transport. While these roles will be replicated across geographies, the market players that take on these roles will vary by market, and indeed a variety of players may take on the same roles within one market, leading to a hybrid of solutions. Figure 6 describes these roles and the players that we are seeing take on the resultant responsibilities.

The variety of companies and organizations that fulfill these roles implies the need for strong collaboration between them. This collaboration and the accompanying set of agreements (regulated and nonregulated) will form the basis of a market model, facilitating market entry and supporting the scale-up of the electrification of transport.

While collaboration between the various players will be important across the board, in some geographies, a market model may arise more organically than in others. For example, where utilities are more actively engaged in the electrification of transport, they may encourage consensus around creating a market model to better mitigate any of the potential risks, namely excessive strain on the grid. In other markets, while managing the impact on the grid will be equally as important, the creation of a market model may be more evolutionary, driven by the competitive dynamics of the market and consumer preferences.

A number of considerations and decisions will need to arise, including:

- Who the key players in the market are.
- The nature of the exchanges between these players, and what sort of rules and regulations support these exchanges.
- The variety of customer interfaces and who manages them.

While considering these decisions, lessons learned from the development of other new markets, such as the mobile telecommunications market or unified processes market in banking can further accelerate market development of the electrification of transport. Particular insights to take into account are:

- The single point of customer contact in the telecommunications market: mobile operators settle the costs for customers that make and receive phone calls abroad with a contract phone through a concept known as roaming. The roaming principle could be applied to charging in the electric transport market; e.g., charge point operators settle costs among themselves to retain a single point of customer contact.
- The ability to use multiple systems in banking: whereby automated teller machines (ATMs) can be used by all consumers, without the need to be a customer of a particular bank, further facilitating customer flexibility. Again, this could be applied to the electric transport market, whereby consumers would be able to use multiple charge points, no matter the operator or their potential providers.

Supporting both of these examples is a set of market agreements between the relevant parties which will facilitate market entry for new players and ensure a customer-friendly solution. The establishment of these types of agreements in the electric transport market will be the underpinning of a market model.

Figure 6. Roles and responsibilities.

Role	Responsibilities	Examples of market players
Electricity retailer	• Provide electricity to charging stations • Identify licensee	• Utility companies • New market entrants; e.g., Google
Charge point owner	• Pay up-front investment cost for charging point • Enable access to charge point operators	• Municipalities • Utility companies • Automotive companies
Charge point operator	• Operate and maintain charging point • Align billing system	• Municipalities • Utility companies • Automotive companies • New market entrants; e.g., end-to-end solution providers, charge point developers
Charging services provider	• Provide charging services—charging and billing	• Utility companies • New market entrants
IT service provider	• Provide customer service • Provide billing services	• IT companies • New market entrants; e.g., end-to-end solution providers, charge point developers, automotive companies, telecom operators

Creating a PEV market model in the Netherlands

In the Netherlands, EnergieNed, the Dutch organization for energy producers, traders and suppliers, and Netbeheer Nederland, the Dutch organization of grid operators, commissioned an Accenture study to design the market model for PEV charging infrastructure in the public domain (but could also be applied to the commercial domain). The market players involved realized the importance of stakeholder input (from traditional utility players to car manufacturers and fleet owners) to create a widely supported market model. Therefore, they conducted the study, consulting 43 companies and organizations from eight different industries, to gauge their preferences and insights.

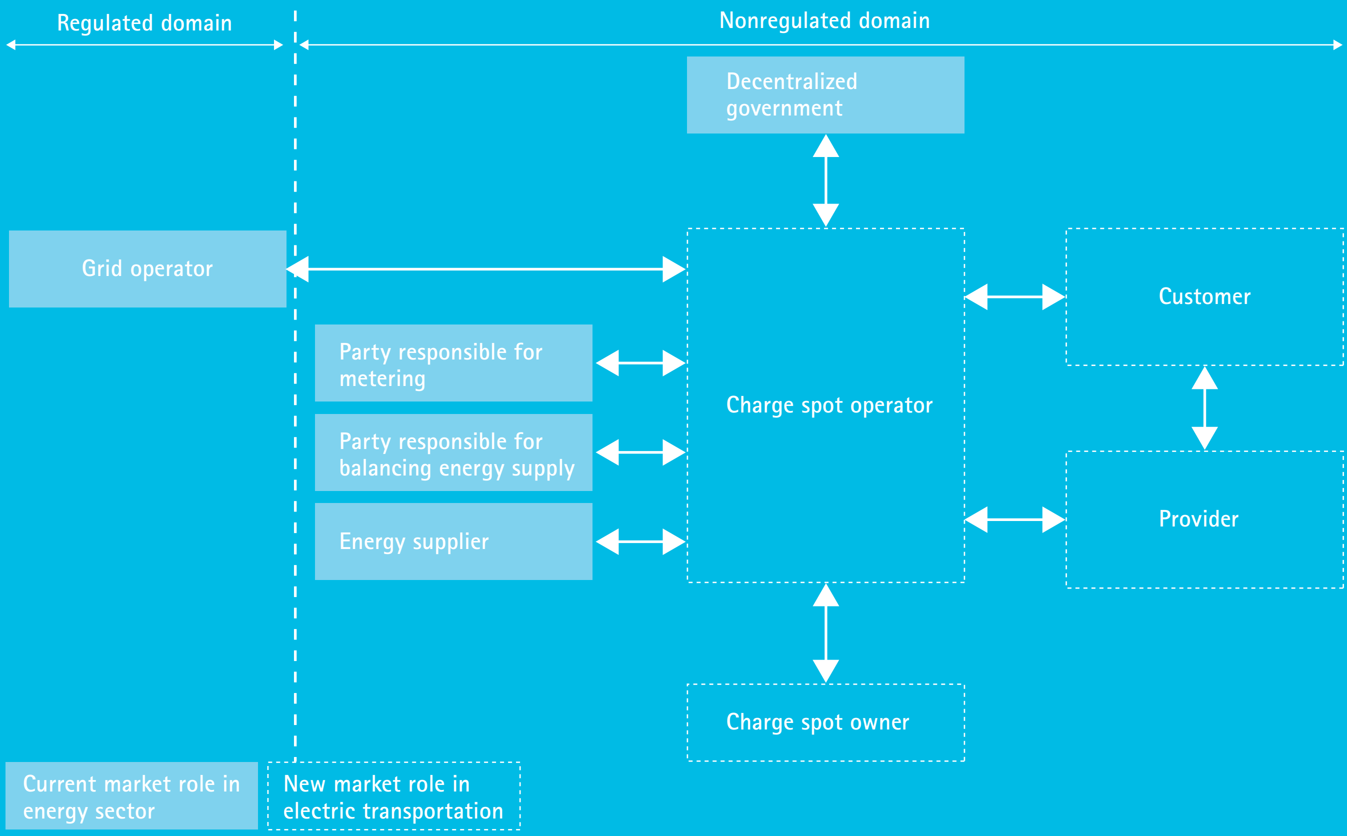
Important outcomes from the broad consultation included:

- The widely accepted condition that customers must have easy and full access to charging spots in the public space.
- Customers from abroad must have access to those charging spots.
- A strong preference for an open market, which would include giving a variety of providers access to one charging station and would enable wide customer choice with regard to payment methods, including ATM cards, "cash-on-a-card" (pre-paid payment cards) and other methods.

Based on the information gathered, three potential market models were created. These models were then evaluated along a set of criteria that included customer-friendliness, market facilitation, regulatory implications, and technology and cost implications. From this evaluation, a preferred market model was selected. The preferred market model is in many ways comparable with the market model used in the telecommunications industry. It describes the segregation between ownership, local operation (operator) and charging services (provider) at the charging spot. These new market roles are expected to evolve in the free commercial domain.

Figure 7 depicts the preferred market model and the interactions of the various players. Within this market model, the **charge spot operator** is responsible for operating the charging point and for settlement. The operator also is responsible for granting access to the charging station. The **provider**, in turn is (as in the telecommunications industry), responsible for the customer. The provider has a contract with the customer offering full access to charging spots, and is responsible for cost settlement with both the customer and the operator.

Figure 7. Preferred market model in the Netherlands.



The preferred model, as previously described, is an extension of the current market model in the Dutch energy sector, which offers optimal service and freedom of choice of energy supplier for the customer. It is expected to stimulate new market entrants to participate in the electrification of transport as it supports access to all, therefore supporting competition and innovation. Underpinning this free market structure, local governments will lay down certain conditions for charging infrastructure including location, safety and accessibility.

Further detail behind the various responsibilities, as well as the relationship between the different parties are available on EnergieNed's website,[11] with necessary adjustments to existing law and regulations, new agreements and commercial arrangements currently being determined. The results of the study, "*Market Model for Electric Vehicle Charging Infrastructure*," published by EnergieNed in May 2010,[12] therefore act as a conversation starter to develop a mature PEV market in the Netherlands. The study concludes with several recommendations to ensure model implementation and to accelerate market developments; they include:

- Engage all relevant parties in the determination of the final market model.
- Further detail the market processes to set uniform requirements on a national level; e.g., request for a charging station.
- Utilize knowledge and experience from other pilots to further develop the model.
- Encourage standardization to facilitate an open-access market.
- Investigate the necessity and feasibility of centralizing essential functions—lessons learned from other industries include centralization of functions once the market has reached a certain level of maturity.
- Participate in international forums to ensure the Netherlands is aligned to European technical standards and to encourage information exchanges between different market players.

Testing and development through pilots

Pilot landscape

PEV pilot projects have continued to grow exponentially since the release of our previous *Betting on Science* study in late 2009. Figure 8 provides a very high-level overview of some of this activity.

Interesting to note is the expansion of activity across geographies, with a particular increase in the number of pilots running in Asia Pacific. This is in part due to the attention and funds provided by governments across the region, including the Chinese government and the Ministry of Economy, Trade and Industry in Japan. Another point to note: while players operating in the space have not changed substantially, they have expanded their geographic footprint, with Better Place gaining ground in the likes of Japan and BMW replicating its US pilots in the United Kingdom and Germany. This expansion highlights the importance of testing the technology in different geographies, as the political and economic environments as well as the consumers will shape success of each individual market.

The pilots identified here are testing various capabilities required for PEVs under varying circumstances and market conditions. Figure 9 highlights some of the capabilities being tested against the potential PEV challenges we identified in Figure 2.

The breadth of capabilities being tested indicates research and development across the electrification value chain, from generation to distribution through to retail. Interesting to note is that this expansion in the number and breadth of pilots also has resulted in greater focus downstream. While, to date, the majority of pilots have been concentrated on testing technology components and their integration, the rise in the number of governments and automotive companies involved in pilots has led to a greater focus on understanding the consumer. However, early lessons learned here remain minimal and thus results from those pilots having focused on understanding the consumer early on are interesting to note. For example, BMW tested consumer expectations and behavior in its 2009 US pilot, partnering with the University of California (UC) Davis. The latter included leasing of 450 MINI Es to consumers in California, New Jersey and New York. Results from the pilot were released in a study by the UC Davis in January 2010,[13] key findings were as follows:

- The MINI E met the average daily requirements of a driver, with a range of 100 miles being largely sufficient.
- As such, users found that charging at home was sufficient, with additional charging demand generally being at work.
- Users participating in the pilot tended to be men in their mid-30s to early-40s, with a penchant for new and green technology.
- Users often seemed to have more than one vehicle.

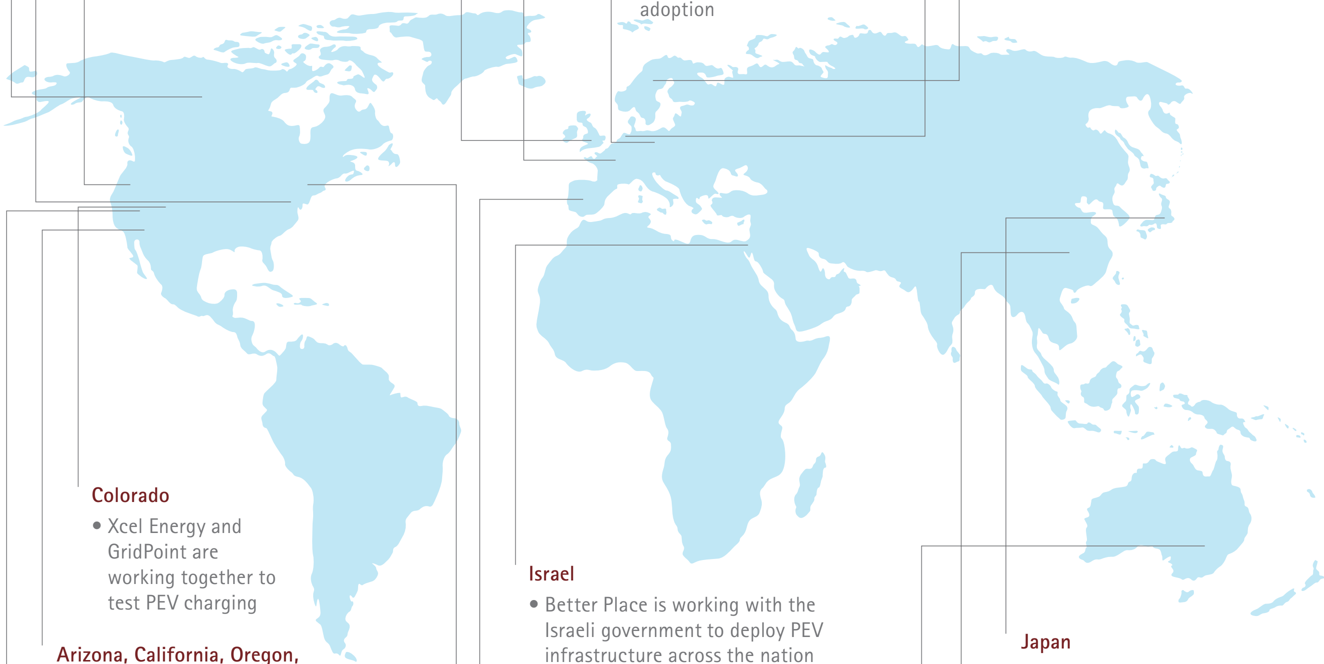
BMW conducted similar pilots in the United Kingdom and Germany and is currently assessing the results. Furthermore, the company has plans for other MINI E pilots in China and Japan, as well as Active E pilots in the United States in 2011.

Nissan, GM, Mitsubishi and Toyota are among other original equipment manufacturers (OEMs) closely examining this question to enable them to develop cost-effective and sustainable business models. In a similar vein, government pilots, such as the United Kingdom's "Plugged in Places Infrastructure Pilot" have a strong consumer angle, as the government tries to extract the greatest public good from its investment.

The results of these pilots will lead to technology improvements, facilitate market acceptance and help develop cost-effective and sustainable business models to support market scale-up. While we are still in the early stages of this exploration, continued monitoring of the market and sharing of early findings will enable steadier progress, as well as an indication of what the future market landscape will look like, both in terms of structure and major players.

For the purposes of this study, we have selected a few pilots to provide some food for thought, demonstrate the breadth of players involved at this early stage and provide early indication of some of the developments we are likely to see over the next five or more years. The pilots we have selected are testing some of the core PEV capabilities and technologies. However, we have not assessed pilots that are more focused on the grid opportunities that PEVs bring; for example, distributed storage or vehicle-to-grid technology. It is our view those pilots will become more significant as the technology and business models begin to stabilize.

Figure 8. PEV pilots.



Canada
- City of Vancouver working with BC Hydro and Mitsubishi to demonstrate and evaluate first mass-produced, highway-capable EV
- Ontario government announced partnership with Better Place

North Carolina
- GridPoint and Duke Energy have partnered to test smart charging

Oregon
- Nissan testing LEAF plug-in model in conjunction with eTec
- Hotspot for battery research ($40 million for research and grants)

Colorado
- Xcel Energy and GridPoint are working together to test PEV charging

Arizona, California, Oregon, Tennessee, Washington
- eTec and Nissan are partnering for the largest deployment of EVs and EV infrastructure, following a $99.8 million grant from the U.S. Department of Energy

California
- Coulomb Technologies is working with the Bay Area to roll-out charging stations
- In October 2010, Better Place announced, with support from the U.S. Department of Transportation via the Metropolitan Transportation Commission, that they will bring a switchable-battery, electric taxi program to the Bay Area in partnership with the cities of San Francisco and San Jose
- Southern California Edison is working with Mitsubishi and Ford to test EVs and PHEVs
- San Diego Gas & Electric is testing a mobile car charging device

United Kingdom
- Office of Low Emission Vehicles working with consortia to roll-out infrastructure
- EDF Energy working with Toyota
- BMW is working with the Technology Strategy Board, Scottish & Southern Energy and Oxford Brookes University to test 40 MINI Es

Paris
- ERDF and Renault are working together to roll out charging stations within Paris

Berlin
- BMW and RWE are providing vehicles and charging infrastructure for wide-scale adoption

Israel
- Better Place is working with the Israeli government to deploy PEV infrastructure across the nation

Spain
- "Project Movele" piloting EV rollout in Madrid, Barcelona and Seville

California, New Jersey, New York
- BMW rolled out 450 MINI Es (through a leasing model) to consumers with consumer behavior analyzed through a partnership with the University of California Davis

Amsterdam
- E-laad.nl (E-Charge) foundation rolling out 10,000 charging stations by 2012
- City of Amsterdam integrating PEVs into its "Smart City"

Scandinavia (Denmark, Sweden)
- Dong Energy is working with Better Place to use wind to power PEVs
- Vattenfall and Volvo are working together in Sweden to test PEVs

Japan
- The Ministry of the Environment is working with Better Place, Subaru and Mitsubishi to roll-out PEVs and to test fast charging in taxis
- Showa Shell Sekiyu is working with Nissan to pilot off-grid fast-charging stations at petrol stations using solar energy

China
- Nissan is working with the Chinese government to roll-out electric vehicles in Wuhan

Australia
- AGL Energy and Macquarie Bank are working with Better Place to use renewable energy resources to power the PEVs

Note: Representative sample only—non-exhaustive.
Source: Accenture analysis.

Figure 9. Pilot capabilities currently being tested.

Area	Capabilities being tested	Pilots discussed in this study
Market models and commercial and regulatory frameworks	• Optimum charging tariffs to meet consumer requirements and minimize capital expenditure, developing cost-effective business models	• All pilots covered in this study are testing different business models to support scale-up
Standardization and interoperability	• Integration of various cities and the ability to drive between cities	• The One North East pilot is heavily focused on standardization and is part of the Plugged in Places (PiP) program in the United Kingdom
Core PEV technologies	• PEV technology, including safety, reliability and power • Battery management and reusability of batteries • Electric vehicle supply equipment (EVSE), including safety, reliability, power and charging times • Optimum location of EVSE • Robustness and feasibility of battery switching technology to address extended range	• One North East and Alliander are each testing the requirements for charging infrastructure in a city environment • Better Place is testing the battery performance and durability of battery switching technology under an extreme use case scenario (that of EV taxis)
PEV technology enablers	• Use of renewable energy to provide power to PEVs, including wind and solar energy • Managed or controlled charging, including software and integration with PEVs and EVSE • Optimum charging tariffs to meet consumer requirements and minimize capital expenditure	• Showa Shell Sekiyu's pilot in Japan is testing the ability to use solar power for fast charging
Grid impact	• Impact of varying PEV penetration levels on the grid • Distributed storage to lessen impact on the grid • Vehicle-to-grid technology to use vehicles as storage and provide power back to the grid	• The Alliander pilot is testing the impact on the grid to determine where/when reinforcements might be needed
Customer behavior	• Customer behavior, including reactions, preferences, consumption and charging patterns	• The BMW pilot in the United States assessed customer behavior

Alliander: E-Laad Pilot, The Netherlands

Pilot overview and objectives

Alliander is one of the largest grid companies in the Netherlands and has been very active in leading electrification initiatives throughout the country. The largest initiative pursued to date is the company's involvement in starting a foundation called E-laad.nl. This foundation is an initiative of several distribution companies and the national grid company/system operator. Together, the participating companies represent around 75 percent of the total distribution grid in the Netherlands. The aim of the foundation is to roll-out 10,000 charging points throughout the country by 2012. The key objective is to "solve the chicken-and-egg problem by providing basic infrastructure for electric vehicles," said Richard de Vries, manager of technology infrastructure at Alliander. This early-stage deployment will further enable a better understanding of how people use the infrastructure, what is expected of the infrastructure, the actual impact on the grid and the market model required for successful scale-up of the electrification of transport.

The creation of a market model for PEVs will be a particularly interesting development as, currently, the meter connection point in the Netherlands is part of the grid companies' regulated domain, whereas the charging point infrastructure and its communication systems (known as electric vehicle supply equipment [EVSE]) remain part of the nonregulated domain. Where responsibility will lie for this infrastructure in the future will be heavily dependent on the findings of the pilot research. To build on the pilot, the Dutch grid companies and electricity suppliers are working on a separate study, in conjunction with market regulators, to help define the most suitable market model for PEV scale-up in the Netherlands.

For the purposes of the pilot infrastructure rollout, procurement of the EVSE has been accomplished through a tendering process. The up-front investment for this infrastructure has been paid for by E-Laad.nl and the infrastructure has been fitted with a meter that can be read remotely. Smart metering and two-way communication flows, however, are not being tested at this stage.

To utilize the foundation's charging infrastructure, customers must sign up to an annual membership. For a flat fee of €100, customers are able to utilize the charging infrastructure as much or as little as they want throughout the year. Customers who sign up to the scheme are further able to select a location to place a charging point—this is done in conjunction with local municipalities to ensure the infrastructure is effectively utilized. While these conditions are unsustainable in the future, they provide a beneficial and simple environment in which to gather key lessons learned.

These activities are all run and managed by the foundation, which has a set of employees "on loan'" from each of the grid companies. These "loaned" employees are considered employees of the foundation and are thus independent of their actual employers and their business agendas. The foundation is then overseen by a board, composed of representatives from each of the grid companies, which ensures the foundation runs smoothly.

The pilot is expected to run for a period of three years, until the end of 2012, after which time lessons learned will be aggregated and the role of the grid companies in the electrification of transport market will be more precisely determined.

Initial lessons learned

Six months into the pilot, 45 charging points have been deployed (eight within Alliander's territory) and a number of lessons have already been recorded.

Infrastructure and software

While the technology behind the electrification of transport is largely proven, there are a number of practical challenges that remain. First, with regard to the infrastructure, the current cost of EVSE is unfeasibly high for large-scale rollout. This realization has led to a re-evaluation of much of the infrastructure design, and companies are looking into lower cost options for a wider-scale rollout. Second, the physical architecture of this infrastructure is very important, as it needs to contribute to an attractive urban setting. The foundation is working with a number of design companies to build more attractive infrastructure that is discreet but meets the requirements and needs of customers.

The pilot has further paid credence to the importance of standardization. Currently, every grid company has different policies regarding the meters and the connection points, resulting in a total of eight different policies. These policies need to be standardized and extended to the charging points to facilitate interoperability and market access.

With regard to the software embedded in the EVSE, the foundation has found it to be prone to many small outages. Although these outages can usually be fixed remotely, it becomes costly when site visits are required. This software needs to be further developed and tested to avoid these malfunctions and added costs.

Customer behavior

The foundation records meter consumption every five minutes and stores it on a daily basis; data is then distributed to the various grid companies for analysis.

Another interesting lesson learned is that charging infrastructure is fairly equitably distributed across the grid, resulting in no substantial impact on the grid. Given the small numbers currently operating in the pilot, this might be expected to change upon scale.

The lessons being learned from the pilot rollout are still very much in their infancy. As the pilot grows, the lessons learned will be more impactful and telling of future market developments.

Business implications

The impact of the pilot and the work being carried out in parallel on market model design will be paramount to how PEVs are rolled out in the Netherlands and what market rules and regulations envelop it.

As previously mentioned, grid companies and electricity suppliers, in conjunction with market regulators, executed a study to design a possible market model to charge and pay the electricity for electric transportation in the Netherlands. Based on a market consultation (interviewing about 40 key stakeholders) three different variants of market models were identified. Based on criteria such as customer, market facilitation, regulatory, technology and costs, a preferred market model has been selected and developed in further detail. The final report[14] contains an extensive description of the preferred model. This includes a description of the responsibilities of and relationship between market roles. For example, the high-level processes to charge an electric vehicle, to pay the charging services or to request a charging spot, have been described. The results of the study, including the preferred market model, are the starting point for a dialogue to develop a mature electric vehicles market in the Netherlands.

Within these options, the role of local governments will be critical, as electrification of transport will contribute to the wider aim of carbon-reduction targets. Therefore, it is crucial to ensure support and partnership along the way.

Better Place: Tokyo Taxi Battery Switching Demonstration

Following a successful demonstration of the battery-switching concept in Yokohama in 2009, Better Place received a grant from Japan's Ministry of Economy, Trade and Industry's Natural Resources and Energy Agency to introduce the battery-switch technology into taxi fleets for commercial demonstration. This grant resulted in a partnership between Better Place and Nihon Kotsu, Tokyo's largest taxi operator, to demonstrate the concept feasibility and commercial applicability of a battery-switch station. The pilot consists of three switchable-battery electric taxis, available for hire in a dedicated taxi line on the first floor of the Roppongi Hills Complex in Tokyo.

The key pilot objectives are to:

• Generate greater insights and lessons learned around battery performance in a heavily-used electric vehicle such as taxi, in a controlled charging and temperature environment.

• Demonstrate the technical feasibility of the switchable battery vehicle, marking the next major milestone in the testing of all of Better Place's electric vehicle solution components before the end of 2010 and prior to full rollout of the solution in Israel.

• Collect data to better understand consumer behavior.

• Serve as a catalyst to accelerating mass adoption of electric vehicles.

The taxis are fitted with A123 Systems lithium-ion batteries, each with its own identification number to enable data to be collected from the batteries throughout their lifetime. This creates a unique "history" for each battery, which is then taken into account during battery operation to ensure optimal conditions to prolong battery life and performance; e.g., temperature and speed of charging. The Tokyo switch station includes charging technology behind the scenes, enabling both slower and faster charging when necessary (although slower charging is usually used, given fast charging's detrimental impact on battery life) and supported by optimum thermal management capabilities. With Better Place owning the batteries and leasing them to customers through a subscription fee, they have ultimate responsibility for the battery. As a result, it is evidently in their business interest to ensure that the batteries are properly maintained. Not having ownership of the battery further simplifies the customer experience.

When a battery needs recharging, the taxi driver will drive up to the battery switch station, where an automatic mechanism detaches the battery from the vehicle, loading a fully charged battery in its place so the driver is able to drive away. The removed depleted battery is then recharged under optimal conditions to minimize degradation. The switch process only takes 59.1 seconds, thus making it viable for taxi business operations.

A final important consideration for the pilot is battery health and safety. The battery itself has been designed using safe chemistry and packaging technologies. Each battery contains a battery management system which acts as the "brain" of the battery, monitoring and controlling it to ensure safe operation. The battery-switch station adheres to high health and safety regulations, with protective measures taken to store the battery and to ensure that the battery is never overheated during the charging processes and has sufficient cool down time prior to usage.

In order to ensure lessons are learned from the pilot and to further develop the battery-switch model, data was continuously collected, both at drive, charge, switch and at park times, for a period of 90 days. The data collected was then used to test:

- The duration, durability and robustness of the battery switch process.
- Battery resistance to degradation under actual operating conditions—and in extreme circumstances—in vehicles that operate at a significantly higher rate than the average consumer vehicle.
- Driver and consumer reaction to the battery-switch technology.

Initial lessons learned

The battery-switch model for taxis has received a very positive response and has generated high levels of public interest. To date, 3,020 customers having ridden in the taxis; and customers are seeking out the Better Place taxis and asking the taxi drivers to go to the battery-switch station to experience the switching process themselves. Hundreds of visitors also have come to the center to watch the switch in action.

The driver experience also has been positive. The three taxis have together driven 40,311 kilometers and gone through the battery-switch process 2,122 times, switching their batteries several times a day. The process is easy and convenient, with an average switch time of 59.1 seconds. Moreover, initial driver concerns with regards to battery durability were eased within the first few days of driving.

To gather more lessons learned, the pilot has been extended for another three months. In addition to gathering more data on battery performance and consumer feedback, the battery-switch station will have new programming to make it possible to speed up or slow down recharging automatically to enable an optimum charging process which extends the battery life span and performance.

Business implications

The Tokyo taxi pilot represents a major milestone to prove Better Place's battery-switch model and is likely to be replicated in other geographies. Furthermore, the hope is that it will provide a wider incentive to join the race to electrification of transport. As Kiyotaka Fujii, President of Better Place Japan, highlighted, "Tokyo has more taxis than London, Paris and New York combined, with approximately 60,000 vehicles, representing a high-mileage and high-visibility segment that can serve as the catalyst for this technology to transfer to the mass market."

Better Place's model is one of mass deployment, and the battery-switch process is one component of this model. Ideal for taxis or fleets given its speed and convenience, it addresses range limitations and anxiety, both of which are major barriers to electric vehicle adoption. Charge spots will complement, and indeed outnumber, battery-switch stations to make sure consumers have a wide range of options for charging at their convenience and to suit their needs. It is anticipated that consumers will still do their charging at home or at work more than 90 percent of the time. What Better Place is trying to do with this optionality is to remove all adoption barriers and create a sustainable, customer-friendly model that supports mass deployment of electric vehicles. "It is increasingly recognized that fast charging is not a sustainable method of charging given its detrimental impact on battery life and the strain it places on the grid. Better Place is developing creative ways to get around this problem and still give customers the flexibility they require," says Dr. Michal Wolkin, Director of Energy Storage Technologies at Better Place. This optionality will be supported by software for battery and energy management and customer service support to ensure a positive and seamless driving experience.

With charge spots, and supporting software already being deployed in Israel and Denmark along with 100,000 Renault electric vehicles ordered, the early success of the Tokyo battery switch pilot gives greater confidence to the rollout of the battery-switch stations, helping to test the full Better Place model at scale.

One North East: Plugged in Places Pilot, Northeast United Kingdom

Pilot overview and objectives

One North East, the regional development agency (RDA) in the Northeast of England, is leading one of the consortia that have been awarded funding by the UK government's Plugged in Places Infrastructure Scheme, to roll-out 1,300 public charging posts across the region.

This proposition was built upon an initial pilot developed by the RDA with Newcastle City Council, which installed 40 charging points throughout the city to test the technical and legal challenges associated with the rollout of infrastructure. The lessons learned with regard to the change requirements on the grid, the difficulty in finding convenient places in which to install charging points, the requirements around insurance and maintenance of the posts and the challenges associated with lack of regulation, impacting the timing and cost of implementation were all aggregated to build a case for a larger-scale rollout of charging points across the region. This Plugged in Places pilot is seeking to test:

- Fast charging and its impact on the grid.
- Optimum location of charging stations.
- IT systems required for communications between charging posts.
- The wider communications and consumer engagement required.

The 1,300 charging posts that will be rolled out over the next few years will include a combination of 3-kW and 7-kW posts, both with a built-in upgrade path, as well as 12 50-kW fast-charging stations. These charging posts will be procured competitively, with the first 700 posts being procured immediately and the remainder in a second phase, to account for technology upgrades. The program's targets include a rollout of 620 posts by the end of March 2011, with the remaining posts to be rolled out by 2013.

To implement this program, One North East is working with 60 businesses and councils across the region to ensure a cooperative and collaborative rollout of charging posts. Notable partners include:

- Nissan—One North East has an ongoing partnership with the auto manufacturer,[15] which is contributing deep expertise on fast-charging technology through a "loaned" individual employee. The company is further contributing to the market growth with the build of its battery plant in Sunderland.
- Nissan/Learning and Skills Council (LSC)—supporting the development of an £8 million training college to train individuals on technical and safety requirements associated with PEVs.
- Centre of Excellence for low carbon and fuel cell technologies (Cenex)—the RDA is working with Cenex to analyze findings from a six-month user test case, which saw the rollout of smart cars to a variety of users. This research and analysis will provide detailed input on consumer behavior and uptake potential.

• Newcastle City Council Traffic Management Division—the skills and technology associated with traffic management are very similar to those needed to roll-out PEV infrastructure. Newcastle City Council's Traffic Management Division will be rolling out the pilot infrastructure.

Initial lessons learned

As previously mentioned, the Newcastle pilot provided a number of lessons learned which were built into the RDA's case for Plugged in Places. Notable lessons learned from the pilot are focused on the practical challenges of rollout and include:

• The importance of understanding the legal requirements ahead of a rollout—the legal aspect is often underestimated, but can have significant implications on rollout timeline. It is even more important as there is currently a lack of regulation supporting PEV implementation.

• The importance of insurance and maintenance—the complexity of a PEV rollout is often underestimated with unaccounted insurance/ maintenance.

• The importance of understanding public infrastructure ahead of a rollout—issuing a survey of the site for the charging point is essential ahead of implementation, as the connection charge can be astoundingly high (up to £3,000) if the charging point is installed in the wrong place.

Thus far on the Plugged in Places pilot, One North East has been amassing more lessons learned, particularly around the difficulty in bringing market scale. These include:

• Lack of standards—standards will be critical to scale-up and rapid implementation and the lack of standards is currently severely delaying market progress due to high risk of rollout ahead of common standards.

• Lack of interaction with smart communications—the focus currently is on charging, consumer behavior and the impact on the grid, but more attention needs to be paid to ensuring integration with communications, as these will be fundamental to the success of PEV pilots.

As the pilot advances, the RDA expects to develop a number of additional lessons learned. However, at the moment, the focus is on understanding the process associated with a rollout of this size.

Business implications

According to Dr. Colin Herron, manager for manufacturing and productivity at the RDA, the key challenge to the business model behind nationwide scale-up of electric transportation is the cost of the charging infrastructure. With level II charging posts (charging vehicles at 240 volts or in between four to eight hours) costing about £5,000/post, fast-charging posts (charging vehicles in about 30 minutes) costing about £30,000/post and utilization by charging point being very low (due to lack of market scale as well as the popularity of home charging), the case for public infrastructure is difficult to make. To break even, public charging posts would need to have cars being charged for approximately 10 hours a day; even then it would take approximately eight years to pay back initial capital.

The question for policymakers and businesses then goes beyond encouraging the purchase of PEVs to one of encouraging consumers to using public infrastructure over home charging points. While some consumers will not have a choice as they do not have access to at-home charging facilities, a high proportion of early adopters are expected to primarily charge at home. The incentives or value-add services that can be developed to encourage a greater share of public charging will be incremental to driving down the cost of infrastructure rollout and supporting scale-up. These incentives could include use of charging infrastructure for software/media downloads, for example, whereby consumers would view plugging in as having greater value than simply recharging the vehicle's battery.

These questions will need to be addressed by policymakers and businesses alike. However, while a break-even economic state might be acceptable in the public world, private businesses will need to show a return on investment to be considered worthwhile. It is conceivable to posit that public infrastructure will remain a public domain, while businesses will concentrate on private infrastructure, which are likely to have higher rates of return.

Showa Shell Sekiyu: Fast Charging Pilot, Japan

Pilot overview and objectives

Showa Shell piloted fast-charging stations in Japan to test the technology and identify potential business models. The pilot was funded by the Japanese Ministry of Economy, Trade and Industry, and was one of the government's 10 funded pilots to promote and invest in electric vehicle-charging infrastructure throughout Japan. The Showa Shell pilot had five principle objectives:

- Develop optimum charging and renewable energy supply systems to ensure customer needs are met while minimizing capital expenditure.
- Identify value-added services for PEV users.
- Evaluate the viability of a car-sharing business.
- Evaluate a green certificate point system for PEV users and charging service providers.
- Develop IT systems to support a membership charging service business.

Within this framework, Showa Shell worked with Nissan and jointly studied the development of a fast-charging system for PEVs using Showa Shell's CIS (copper indium selenium) solar panels (manufactured by Solar Frontier, Showa Shell's 100-percent subsidiary company) and Nissan's lithium-ion batteries for automotive use, both of which enable off-grid fast charging, thus minimizing grid impact. In addition, Showa Shell extensively researched (and continues to research) viable business models to support the development of this new service. The pilot began in November 2009 and ran through to the end of July 2010.

The pilot consisted of three Showa Shell petrol stations and one hydrogen station (for fuel cell vehicles [FCVs]) fitted with currently available fast-charging PEV technology, enabling those stations to charge vehicles between 15 and 30 minutes to 80 percent capacity, depending on the battery capacity and its state of charge. All of these stations adhered to very strict safety standards, given the risks associated with having gas and electricity on the same site; e.g., sufficient separation between gas and electric output. Given the small power supply capacity size (usually less than 50 kW) of petrol stations and the high power requirements of fast-charging systems (usually 50 kW per unit), the stations need to be further fitted with additional stationary batteries and solar panels, enabling less expensive nighttime charging (with minimal grid impact) and maximum use of renewable energy by ensuring sufficient power capacity during daytime periods.

Out of the four functioning stations, two were fitted with solar panels (5 kWH each) to provide zero-emission power. While these panels did not fully support fast charging and were supplemented by electricity, they provided an interesting test ground to assess the viability of zero-emission charging.

The pilot further provided charging services for PEV users (less than 100, and mostly business users) with dedicated systems to support the pilot,

such as user identification and real-time data communication between the stations and a data center. These services were offered to PEV users through a membership scheme, meaning that real pricing of these services had yet to be determined. The core objective of the pilot was first to determine a number of basic elements around the charging infrastructure, namely, the technology around fast charging and the optimum charging level, given significant consumer demand for fast charging and the capital intensity this implies. Data was, however, systematically collected from the pilot to subsequently set appropriate tariffs/rates for consumers.

Initial lessons learned

At the time of interview, the pilot was still in early stages and thus lessons learned were minimal. While the pilot has now ended, we were not able to get further insights at this stage. What we do know is that the fast-charging technology is functioning but, currently, there are too few PEVs on the road in Japan to properly test the technology under strain and viable business models. With Nissan having released PEVs at the end of 2010, demand for fast-charging stations is expected to increase, enabling a greater number of lessons learned to emerge.

Business implications

Showa Shell has been very interested in the developments around PEVs, given their stake in the solar industry and in the petrol station business, i.e., service provider for car users. However, the company is finding the identification an economic business model behind these ventures to be very difficult. Given the high capital expenditure required, ranging from $50,000 to $100,000 per unit and significant operational costs, a minimum of 100,000 PEVs on the road would be required to make the economics attractive. This is further constrained by the fact that at the moment, government is the main driver behind adoption.

With automotive manufacturers ramping up production (Nissan is expected to produce more than 50,000 PEVs per year), Showa Shell sees significant change luring in the automotive industry. Not only will this mean greater availability for consumers, but the ramp-up also is likely to bring down battery costs, which will further improve the economics. There also are a number of creative ways to make the economics work; for example, looking at the reuse of batteries at service stations. These workarounds are currently being studied, meaning that the next few years will see interesting market developments, and will further provide support for Showa Shell's early-stage involvement in this industry.

Despite this potential, Showa Shell expects it to "take between five and 10 years before the business case behind PEVs becomes really interesting," according to Matsukawa Takeaki, external relations manager, Showa Shell.

Implications of PEV pilots

Early lessons learned

The market landscape and case studies demonstrate a varied and dynamic PEV market, with a number of different players, ranging from utilities to oil companies to government agencies, taking on similar roles and investing in the early PEV market to try to develop cost-effective business models and kick-start the market. When reviewing the early lessons learned, principle lessons that emerge include:

- **By and large, the technology to support electrification of transport works.** Continued focus should be on testing of the integration of electrification capabilities versus technologies in isolation. This integration will further need to be closely monitored as PEVs scale, given that higher penetration is likely to have a significant impact on these technologies.

- **Grid impact needs to be closely monitored as PEVs scale.** While some pilots are demonstrating minimal impact on the grid, higher penetration may tell a different story. Focus should remain on the development of managed charging and off-grid charging to ensure a more controlled impact as electrification scales.

- **While there may be differences by geography, consumers are likely to prefer home charging.** Consumer preference tends to be for home charging over public charging, indicating that the pool of users may be limited to those with at-home charging facilities. The likely limited use of public charging further makes for a more difficult infrastructure business case.

Figure 11 summarizes some of the wider lessons learned.

Figure 11. PEV pilots: lessons learned.

Area	Early lessons learned
Market models and commercial and regulatory frameworks	• Public PEV infrastructure is currently too costly for a viable business model to be developed—more cost-effective infrastructure will need to be developed and utilization rates will need to significantly increase. • Planning and rollout of PEV infrastructure is a complex and time-consuming process—all elements (site surveys, planning permission and insurance) need to be considered at the start of the project for realistic planning to be done.
Standardization and interoperability	• Lack of standards is holding back PEV development—they need to be developed across the value chain to encourage greater take-up and investment.
Core PEV technologies	• Current low levels of PEV penetration make it difficult to really test technologies and understand their constraints/limitations. • Fast-charging stations work, but the optimum balance between cost and customer expectations needs to be struck. • The charging infrastructure to support PEVs needs to be attractively designed to fit into the urban environment. • Battery-switch technology provides instant range extension without impacting the grid. This option also minimizes battery degradation, as charging is done under controlled environment.
PEV technology enablers	• Software implementation tests need to be conducted "in the field" as there are currently a lot of technical challenges (e.g., communication failures between charging points and back-office systems do not allow for remote monitoring/ maintenance of the charging infrastructure). • Pilots to date have not focused enough on the integration of communications between charging infrastructure, support services and back-office systems, leading to technical failures and an inability to provide an end-to-end package to customers.
Grid impact	• Low PEV penetration levels seem to have limited impact on the grid, but will depend on the state of each local grid.
Customer behavior	• Typical PEV users found to be males in their mid-30s to early-40s. • Most PEV users own a second vehicle. • PEVs are able to meet daily driving requirements of consumers, tempering range anxiety. • Home charging is sufficient to meet daily driving requirements. • PEVs do not need to be charged daily.

Figure 12. Creative mechanisms in the electrification of transport.

Challenge	Creative mechanisms
Scale	• Consumer purchase subsidies and tax incentives to encourage PEV take-up • Work schemes encouraging employees to purchase PEVs and providing them with the required charging support
Cost	• Reuse of batteries at service stations • Provision of in-vehicle services to recoup some of the investment cost • Disaggregation of cost of battery from initial purchase price
Control	• Provision of in-vehicle services to encourage connectivity to the grid • More competitive tariffs for managed charging

The insight from the lessons learned further highlights areas that require greater research, testing and the development of creative mechanisms to overcome them. The three key areas likely to represent the greatest challenges going forward include:

Scale
Low PEV penetration levels leading to artificial testing grounds and difficulty in developing cost-effective business models.

Cost
High infrastructure costs, paired with limited usability, indicating the business model for public infrastructure is not attractive today. With level II charging stations (charging batteries at 240 volts or between four and eight hours) costing approximately $5,000/ unit and fast-charging stations costing approximately $50,000/ unit, striking a balance between consumer needs for public charging (most likely fast charging) versus cost will further hamper the equation. If public infrastructure is to become an important market focus, then these costs will need to be dramatically reduced.

Control
Limited charge frequency inhibiting the viability of managed charging. If consumers only plug in their vehicles every two days, the impact on managed charging will be significant, and the ability to control power flows and time of charge will be limited.

Creative mechanisms devised

Although the three challenges of scale, cost and control are emerging as the most significant by the pilots, industry players are working to resolve them. Some of these challenges will be overcome naturally as the market develops; i.e., scale will enable robust testing of the technologies and help to drive down cost. However, to support market scaling, creative mechanisms need to be devised to force down costs and develop sustainable business models. Figure 12 highlights some of the mechanisms that we are seeing emerge in the market, both being developed by governments and businesses, and how they will help overcome these challenges.

These mechanisms will develop along with the business models, so it is important to analyze the different emerging business models to better understand what mechanisms are being developed and how the market is tackling these issues. The next section, **Emerging business models,** focuses on these business models, which we see emerging across the automotive, battery and charging industries.

Emerging business models

The variety of pilots and the number of stakeholders involved highlights the emergence of different business models from the three merging value chains—automotive, battery and charging infrastructure.

In automotive, electrification of transport is forcing auto manufacturers to expand their supply chains and develop key strategic relationships with battery manufacturers, as batteries are the heart of the vehicle. These strategic partnerships are critical to decisions as they relate directly to the chemistry of the battery (resulting in automotive manufacturers favoring one technology over the other and taking us back to the PHEV/EV debate, see "In focus: Chevrolet Volt and the Nissan LEAF" on page 12) and the associated cost, impacting the go-to-market model. Two primary models are emerging today:

• **Direct vehicle sale to the consumer,** indicating the relationship between consumer and automotive manufacturer does not change drastically, and the automotive manufacturer relies on vendors to sell the vehicle to the consumer as done with conventional vehicles. This model indicates a high vehicle purchase price and is thus likely to only appeal to those green consumers who can afford it. It further strengthens the focus on the warranty of the battery as the expected lifetime of the vehicle is today less than a conventional vehicle (eight years quoted by GM and Nissan versus the typical 10 to 15 years for a conventional vehicle).

• **Leasing of vehicle,** indicating a change in the way a consumer purchases a vehicle but rendering PEVs more affordable. Indeed, this model avoids the high up-front purchase price by spreading it out over a determined period of time. Both GM and Nissan are offering this as a payment option for the Volt and the LEAF, enabling consumers to spread the cost out over 36 months. BMW has followed a similar approach in its pilots (although given the pilot conditions, consumers do not lease the vehicles for a sufficient period of time to own the vehicle at the end of the lease), leasing the MINI E to consumers for a period of 12 months.[16]

Emerging business models around the battery also are interesting. Widely recognized is the fact that the battery pack accounts for the highest proportion of cost in a PEV. This high cost is often quoted as a barrier to consumer adoption and to the scale-up of PEVs. Industry stakeholders, however, are not letting this defeat them, and are instead developing creative business models around the battery to lower the cost and make the PEV more affordable. The key model of note here is:

• **Battery leasing,** indicating a change in the way a consumer purchases a vehicle by disaggregating the cost of the battery, making the vehicle more affordable, and by rendering the issue of battery warranty a negligible point to consumers. This is the Better Place business model, as Better Place is maintaining ownership of the batteries and leasing them through a subscription service model (which also enables consumers to have access to Better Place's charging infrastructure) and selling the consumer "miles" versus electricity.

Charging infrastructure is a final area which deserves attention. Here, again, cost and scale are key issues as the infrastructure is expensive and consumer demand still uncertain, raising challenges of how many charging posts to install and where to install them. This strengthens the importance of pilots in identifying how often consumers will charge their vehicles, when and where. From the case studies detailed in this paper, three key business models to manage charging infrastructure are emerging:

• **The public infrastructure model,** which focuses on providing charging infrastructure for the public space and particularly tries to bridge a gap for those consumers who do not have access to home charging.

• **The private infrastructure model,** which responds directly to consumer demand as opposed to anticipating it, and focuses on installing charging stations in homes or at private sites (e.g., office parking lots and shopping malls) to ensure higher usage and gain greater return on investment.

• **The end-to-end solution,** which provides a full solution to consumers, combining charging with battery/vehicle maintenance and value-add consumer services to minimize the number of interfaces the consumer has to manage and therefore simplify the solution.

These emerging business models across the value chains will continue to develop as pilots accumulate more lessons, consumer interest increases and the market scales. This makes the market and evolving landscape ever more interesting to watch as some of these business models (and the players supporting them) will prove successful in attracting scale and profit, while others will have to bow out of the electrification market. Watching these pilots provides interesting indicators for what roles different companies and organizations will play.


ELECTRIC
VEHICLE
CHARGING
STATION

In focus: Charging infrastructure operating models

Through our analysis, three primary charging business models seem to be emerging: the public infrastructure business model, the private infrastructure business model and the end-to-end solution. As the drivers behind each of these models are very different, their structure and implications significantly vary. Figure 13 compares the three business models—identifying their implications on cost, the grid and the customer.

The public infrastructure business model's primary driver is to act as a market starter and ensure consumers have the infrastructure support they need to purchase PEVs. As a result, this model requires significant up-front investment for the purchase and installation of charging stations, and will have an extended payback period as the price charged to consumers for recharging their vehicles will have to be low, to guarantee usage. Infrastructure usage is likely to be unpredictable and the impact on the grid more volatile, and the model could increase peak load. This impact will be dependent on scale, but highlights the important role of the utilities within this model in managing the impact on the grid and ensuring each site is appropriately reinforced. While the model is a "no-return" model and therefore unattractive to the majority of market players (it will primarily be driven by municipalities and local governments as an investment into the public good), it is expected to incentivize consumers and accelerate the market's development. This is a model that we are seeing across many geographies; for example, in the Netherlands with the E-laad.nl rollout and in the United Kingdom with the Plugged in Places infrastructure rollout.

The private infrastructure business model represents an investment decision and, therefore, seeks a return. The cost charged to the consumer will be at a premium over public charging, but is expected to offer additional benefits; for example, convenience of location and/or integrated IT services. The convenience of location is a particularly important point to raise. As highlighted by results from initial pilots, home charging is likely to be the preferred charging method—if consumers are willing to have charging points installed in their homes, it is to be expected that they would pay a premium.[17] However, this will be an interesting business model in itself, as consumers could pay for the charging point straight out, or could pay for a whole service (integrated IT services, charging and billing) and pay for the charging point over time. A number of different models are likely to emerge to cater for home charging—these models also could be replicated for charging at work. Fast charging also is expected to be a regular feature of a private business model, providing greater flexibility and convenience to consumers. As previously discussed, the cost of fast charging far outweighs that of regular charging, indicating an even higher premium for customers that choose to use this service. This also indicates significant grid impact, which will need to be managed.

As such, within a private model, managed charging and precharged batteries are likely to be important features. This will enable regular and fast charging without heavy strain on the grid. A wide range of different players are pursuing varieties on the private business model, ranging from oil companies and utilities to automotive providers. The manner in which they seek to recoup the investment costs (in addition to the cost premium charged to the consumer) will vary by player and can include recycling of batteries and/or provision of additional services, such as integration of vehicle into home energy management system and in-vehicle services. Xcel Energy's pilot in Boulder, Colorado, for example, seeks to integrate PEVs into the wider "smart world."[18] Consumers are provided with an in-home management system, which enables them to monitor and control their energy usage—from their lighting to their in-home appliances to their PEVs. Finally, the end-to-end solution is an alternative to the private infrastructure model, as it offers the customer a single point of contact and provides an end-to-end service from the vehicle purchase through to its operation (charging) and maintenance (battery and vehicle). The market player here is Better Place. In our previous *Betting on Science* report, we discussed that Better Place has disaggregated the cost of the battery from the vehicle purchase cost and offers customers a contract (similar to that of a mobile phone) where they will pay a set fee each month for the running and maintenance of their vehicle. Contracts will vary but include in-vehicle services, managed charging and battery swap. Battery swap is one aspect of this model unique to Better Place, and provides PEV consumers with extended range, when required, while limiting grid strain. Because Better Place owns the batteries, consumers do not have to worry about liability/warranty and Better Place, in turn, has full control over the maintenance of the batteries—enabling them to ensure they are optimally maintained. Better Place then recoups its investment and makes a profit over the vehicle's lifetime. This business model provides customers with a cheaper clean-car option, but relies on other players in the value chain cooperating.

These three business models are likely to evolve with the market and as battery and infrastructure costs come down. Moreover, while there is likely to be a mixture of business models by market, the key determinant to their success really is the customer.

Figure 13. Comparison of emerging business models.

Business model	Public infrastructure model	Private infrastructure model	End-to-end model
Description	• Provision of infrastructure alone • Public charging infrastructure installed to support market scale-up and minimize the "chicken-egg" conundrum • Open access to all consumers at very low cost • Costs borne by municipalities	• Provision of infrastructure alone • Private charging infrastructure installed as a business investment • Access to those subscribing/ paying for the service • Costs borne by investors with expectations of a particular rate of return	• End-to-end solution including provision of infrastructure, vehicle maintenance, and support services • Private charging infrastructure installed as a business investment • Access to those subscribing/ paying for the service • Costs borne by investors with expectations of a particular rate of return
Cost model	• Infrastructure for the public good (and to support market scale-up) so little, if any, return on investment, indicating low cost to charge for customer and heavy public investment	• Return on investment will be required for continued operation (particularly for fast charging)—will need to obtain significant market share for this • Premium cost for use over public infrastructure to ensure return on investment	• Return on investment will be required for continued operation—will need to obtain significant market share for this • Subscription fee which disaggregates cost of battery from purchase price and instead focuses on total cost of ownership throughout vehicle lifetime
Impact on grid	• Charging stations will be accessible 24 hours a day/seven days a week, indicating poor understanding of usage patterns (at least initially) and, therefore, unpredictable impact on grid and potential increase of peak-load	• Off-peak usage and/or managed charging to ensure low electricity costs and disaggregation of grid impact • Fast charging likely to be key to success of model—will need to be managed off-grid; e.g., use of pre-charged batteries to power individual vehicles	• Off-peak usage and/ or managed charging to ensure low electricity costs and disaggregation of grid impact
Customer-friendliness	• Supports customer trust and flexibility as charging stations are widespread and accessible to all	• Private infrastructure to be rolled at a customer's preference; e.g., work sites, homes (planning permits and safety restrictions allowing)	• One point of customer contact for all PEV-related services

Conclusion

PEVs have received increasing amounts of attention from policymakers, business and the media. This attention also has put a lot of pressure on the technology to deliver, as governments have set ambitious targets and huge levels of investment have been poured into the development of pilots to test the various technologies and the supporting business models, to bring PEVs to life.

Nonetheless, pilots provide an interesting bed of research to investigate, enabling several conclusions to be made with regard to market progress and emerging business models, and therefore have been the focus of this study. As previously mentioned, we have focused on pure EV pilots, as the implications of EVs over PHEVs are expected to be more significant—both in terms of consumer behavior and the impact on the grid. Nevertheless, the conclusions drawn are largely applicable to all PEVs. The pilots highlighted here are interesting for several reasons:

- They are being supported by a wide variety of industry players, including utilities, municipalities, oil companies and new market entrants.
- They are testing a variety of factors, including customer preferences, core and enabling PEV technologies and the requirements for infrastructure.
- They are testing the viability of different business models across value chains, automotive, battery and charging infrastructure.

However, it is important to note that these highlighted pilots are only a sample of pilots being run across the globe. Our focus has been to identify those pilots that are testing core PEV capabilities and technologies. Thus, the pilots here are less focused on additional grid opportunities, such as distributed storage or vehicle-to-grid technologies. The exception here is the focus on the integration of renewables, with Showa Shell assessing the ability to integrate renewables into charging. We expect these grid-related opportunities to become more significant as the market evolves.

Through assessment of these pilots we have highlighted, we have made five key conclusions:

1. PEV market models will vary by geography.

Capabilities required to deliver electrification of transport will be the same across markets, but the players that choose to develop these capabilities will vary by geographic market, resulting in the development of a number of market models (each with their own regulatory policies) around the globe.

The evolution of different market models is natural, but needs to be carefully managed and international cooperation strongly pursued.

This is particularly true given that standardization on a regional if not international level is important in supporting scale-up of PEVs.

2. Many of the assumed PEV challenges can be identified through pilot testing, but three key challenges require further time for development.

While there are still many lessons to be learned, the early results from the pilots indicate that the technology works. However, three key challenges remain.

Cost
The technology is still too expensive for consumers to purchase vehicles at scale and for a return on infrastructure investment to be made.

Scale
While the technologies function in an isolated environment, there are too few PEVs on the road to robustly test the technologies.

Control
Managed charging will be fundamental to protecting the grid and to permit managed charging, consumers will need to be incentivized to plug in to the grid whenever parked.

3. Creative mechanisms will be critical to overcoming key challenges related to technology cost, scale and grid management.

Industry players need to be proactive about market developments to stimulate demand and be creative in the mechanisms that they develop to support mass commercialization of PEVs—this end goal will then further help to overcome the barriers previously identified. For example, consumer uptake will be limited by the current cost of PEVs, at a significant premium to conventional vehicles, but if the cost of the PEV is spread out over the vehicle's lifetime, higher consumer uptake is likely.

4. A variety of business models are emerging across the three value chains—automotive, battery and charging—with different players taking the lead in different markets and working to resolve the challenges presented by PEVs. Early success of these business models will determine who's who on the PEVs landscape.

As an example, the charging infrastructure business models identified in this study—the public infrastructure business model, the private infrastructure business model and the end-to-end solution—will continue to develop and will work to resolve these challenges in slightly different ways. The public infrastructure business model primarily seeks to resolve the issue of scale by providing market reassurance of support for PEV owners; the intent is to act as a market starter to support commercial models going forward. The private infrastructure business model is focused on cost and control and seeks to identify the appropriate balance between affordable prices for customers, convenience and minimal capital expenditure and impact on the grid. In this model, consumers would need to accept a cost premium and focus is likely to be on managed charging. Finally, the end-to-end solution seeks to resolve all three by disaggregating the cost of the battery from the initial purchase price, but by recouping the investment through a longer-term contract and additional support services; for example, in-vehicle services, access to charging network, battery leasing and battery switching for range extension. Furthermore, the model looks to managed charging to reduce the impact on the grid and ensure a more predictable load.

The number of players involved in the market at this early stage is overwhelming. As the market evolves, so will the players in this space. Currently municipalities, oil companies, utilities, automotive companies and new market entrants (from start-ups to companies such as Google, which are diversifying) are all assessing the viability of their business models. While markets are likely to have a mixture of solutions, and players, there will be clear winners by market. In the short term, public infrastructure business models will be an essential part of the landscape to support market scaling, but longer term, PEVs will need to become a profitable commercial model to be sustainable. The automotive business models, the private infrastructure business models and end-to-end solutions are likely to be the most interesting ones to watch.

5. The likelihood of consumer uptake remains difficult to estimate.

Determining the success of these models is, in large part, the consumer. This is one area that we did not explore as deeply in this study, and it has surprised us that, aside from the BMW pilots, few lessons learned to date have emerged regarding the consumer and who will actually buy PEVs. Therefore, it is an area that requires a greater degree of attention, as the consumer remains at the heart of the debate, and will truly determine how fast PEVs scale in the commercial domain. The pilots and studies focusing on the latter will be particularly interesting to watch.

In focus: Who will buy PEVs?

Customer preferences are at the heart of the electrification of transport. Whether the public market scales will depend on vehicle uptake (the commercial market will have more rational business drivers, so will follow a different uptake path) and the customer perception of the PEV. These will further determine which business model is most successful in the different markets. To hypothesize on this point and gain some insight on the short-term nature of the market, it is important to understand who are the consumers buying PEVs today. Given the current premium of PEV technology, today's PEV consumer will likely be middle class with a high interest in new technology and who owns a second vehicle. This is evidently a small segment of the consumer market and one not driven by price. It would thus be possible to assume that these consumers would also be willing to pay a premium for charging their vehicles, and that in the short term the private infrastructure model has the potential to be successful. Further supporting this point is that, while there will be differences by market, home charging and work charging are expected to be the primary charging methods used.

However, in the longer term, if PEVs are expected to reach a wider segment of the population, costs will need to be reduced. Whether this will be met by a competitive market or by the public infrastructure model is another question, and will be better informed by more insight into the customer psyche, what customers want and their current perceptions of PEVs. This study does not seek to answer this question but highlights its importance. Accenture is currently researching and analyzing this question and will release the results of a global customer survey in mid-2011, which will aim to shed more light on this question and enable greater speculation as to which business models are likely to scale more rapidly.

Footnotes

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