Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems

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Produced for the ISO/RTO Council in conjunction with Taratec

Acknowledgements

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Executive Summary

Introduction

The arrival of plug-in electric vehicles (PEVs) to the North American light vehicle market marks the first time since the earliest days of the automotive industry that electricity could be considered a major transportation fuel. The introduction of PEVs also marks a major point of departure for the management of the North American electricity grid with the introduction of a significant new charging load.

While PEVs present a significant new load, they also represent an opportunity to develop existing and potentially new products and services for grid management. In the near term, managed charging of PEVs, coordinated among megawatts of charging load, could help provide ancillary services or emergency reliability services. By using the PEVs' capability to support two-way power transfers (charging and discharging to the grid), PEVs will serve as a large distributed energy source.

Purpose

The purpose of this study is to identify products and services that PEVs could provide under existing market and reliability structures of the North American independent system operators (ISO) and regional transmission organizations (RTO). As such, the project team focused on identifying those products and services that could be implemented by ISO/RTOs in the near term. The PEV products and services considered in this study include those related to treating PEV battery charging as a demand resource (by regulating charging) to provide energy, ancillary services and other reliability-related services for the market. The project team recognizes that PEV demonstrations of two-way interactions with the grid (known as "vehicle-to-grid" or "V2G" interactions) are underway. Ultimately, the ability to discharge battery energy back into the grid could make PEVs a valuable distributed asset for the grid. The National Institute of Standards and Technology (NIST) in January 2010 issued the *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0.* It referenced the development of data standards for PEV charging, as well as the use of PEV energy storage for demand response purposes.

This analysis makes no projections about the likely implementation or schedule of implementation for these products and services. As such, while the report recognizes ISO/RTO variation and projects PEV penetration regionally, it speaks generally to the likelihood of near-term PEV products and services. In the process of this research, the project team identified additional products and services that are less certain in their feasibility but are worth continuing to explore.

Objectives

This study had five primary objectives:

1. Identify operational, load, and price impacts to the North American electricity grid from light-duty PEVs as their adoption increases;
2. Identify potential PEV products and services;
3. Ascertain the market design adaptations that might be necessary to incorporate PEV services into existing markets and provide a standardized approach to mobile loads;
4. Determine key technologies, communications, cybersecurity, and protocols required to enable PEV products and services; and
5. Determine the types of investments in Information Technology (IT) infrastructure needed to integrate PEVs, and estimate their costs.

As with hybrid electric vehicles before them, PEVs are not likely to be distributed evenly across North America during the early years of market development. Furthermore, the driving characteristics of various PEV classes imply that initial target markets may be relatively focused. In projecting passenger and fleet PEV market growth, and their resulting load and market price impacts, researchers addressed the following questions:

- What are likely patterns of adoption among North American states, cities, and ISO/RTO regions?
- What PEV loads might develop given likely charging profiles?
- What are the implications of PEV loads in ISO/RTO regions and metro areas?

To understand the products and services aggregated PEVs could offer the ISO/RTO markets, researchers addressed the following questions:

- What sort of aggregated PEV load concentrations might be available for demand-response services?
- What are the technical capabilities of PEVs?

To assess the ability of existing markets to integrate potential PEV services, the project team addressed the following questions:

- What role might the aggregators and ISO/RTOs play in integrating PEV resources?
- What common rules for ISO/RTO market operations would facilitate participation?
- What common communications and IT requirements, if any, would facilitate participation?

To assess IT and communication infrastructure needs, researchers addressed the following questions:

- Do existing standards or protocols meet the unique needs of PEV resources?
- What tools are needed to address the mobile aspect of PEV resources?
- What are the likely costs of communication and IT infrastructure needs?

Methods

The project team began the analysis by projecting PEV penetration in regional markets. To model early PEV market development, the project team examined historical records of early adoption of hybrid electric vehicles. Specifically, the project team used historical records of Prius sales. The project team also estimated total sales according to public-sector and private-sector goals and population estimates. Using PEV forecasts, the project team then estimated regional PEV load impacts under a set of charging scenarios. The three scenarios considered average charging loads over one-hour, eight-hour and twelve-hour time periods. Finally, the project team estimated regional price impacts using system market models and projected PEV loads.

Next, the project team examined potential PEV-related products and services by identifying PEV capabilities and mapping them to existing products and services. The project team assumed that an aggregator would coordinate the use of multiple vehicles to meet commitments to the grid operator while achieving targeted charge levels for the vehicles. To identify possible modes of interaction with the ISO/RTOs, the project team developed value chains for each of the PEV products and services, with the aggregator as an intermediary between the retail entities and the ISO/RTOs.

Then, the project team identified operational and technical requirements necessary to integrate potential PEV products and services. Because PEVs are mobile loads and may travel across market boundaries, the project team considered diversity among markets when identifying integration needs.

Finally, based on the potential benefits and expected consumer desire for PEV products and services, the project team recommended a subset of potential PEV-related products for initial development. Though integration costs will likely vary across regions, the project team developed high-level average estimates to identify a likely range of expenditures. These costs include market upgrades as well as incremental investments in IT infrastructure.

Outcomes & Recommendations

Projected Impact of PEVs

The project team estimates that one million PEVs could be deployed in North America within a five- to ten-year timeframe. In analyzing the history of the Prius' early adoption, the project team observed a "coastal effect" where initial sales tended to cluster on the West Coast and Northeast rather than in the Midwest and Southeast. Apparent similarities between Prius and PEV adoption indicate that such clustering will likely also occur in the initial stages of PEV sales and early PEV adoption will not be proportional to population size alone. Furthermore, researchers believe that PEV sales are likely to be heavily concentrated in large urban areas. Available capacity for demand reduction depends on the number of PEVs available locally, charging energy, and likelihood that the vehicle is charging. Therefore, based on PEV load projections, major cities appear to offer the greatest opportunity for ISO/RTO products derived from PEV load management.

With regard to wholesale-energy price impacts, the effect varies greatly by ISO/RTO, based on the penetration and concentration of PEVs. Initial research indicates that the short-term wholesale energy price impact of one million PEVs ranges from near zero to up to 10%, depending on the region, available resources, and load (both time of day and day of the year). The greatest estimated impact would occur if high concentrations of vehicles charge over a short period of time on a peak day. As the time duration over which charging occurs increases, the effects of PEV charging decrease to minimal impacts. It appears that exposing customers to some mechanism, such as dynamic pricing, special tariffs, or managed charging, that would reduce charging over a higher-demand, concentrated time period, might help self-regulate the potential problem of price impacts from PEV charging. Such mechanisms will likely become critical as the PEV market grows beyond one million vehicles and represents a significant fraction of the vehicles on the road. Additional research to detail the regional price impacts of PEVs over time will help inform the selection and implementation of new products and services.

PEV Products and Services

As a result of its assessment of PEV capabilities, several products or services are recommended for initial deployment based on a combination of their potential usefulness to the ISO/RTO and the likely response from aggregators and end consumers. In the phased implementation approach, the initial products and services are characterized by minimum infrastructure required and support of grid reliability. They include:

- **Emergency Load Curtailment (ELC)**—PEVs are able to provide a quick-response load-curtailment resource for emergency events, and may be aggregated for maximum effect. Due to relatively simple mechanisms for engaging this resource, and the large benefit of doing so, emergency load curtailment of PEV charging is a likely near-term product. It could serve in a reliability-based or economic demand response capacity.
- **Dynamic Pricing (DP)**—Dynamic pricing might be a way to accomplish charging of PEV batteries in off-peak hours. However, further research on consumer behavior is necessary to understand how a PEV owner will respond to retail price differentials. In addition, PEV-specific dynamic pricing may be one way to introduce dynamic pricing to consumers while avoiding political sensitivities regarding dynamic pricing for existing retail loads.
- **Enhanced Aggregation (EA)**—The potential for high concentrations of PEV loads in the evening makes managing charging over the day a priority for the ISO/RTOs. Some aggregators, automakers and information management groups appear to be proactive in developing scheduling capabilities, possibly using additional information provided by the ISO/RTO. This product would be complementary to planned time-of-use (TOU) programs typically offered by the retail utilities. It also could be potentially linked to a dynamic-pricing product.

As the PEV penetration increases and additional infrastructure is installed, the following market products can provide value to the ISO/RTOs and aggregators:

- **Regulation**—Expected PEV load in the next few years will not likely have a large impact on the amount of total regulation in the ISO/RTO markets or on regulation market prices. However, the regulation market is attractive to PEV stakeholders since it can generate fairly predictable revenues. In addition, the relatively simple but new communication requirements for this product make it a good trial for subsequent PEV products and services.

- **Reserves**—PEVs are able to provide reserve resources with relatively simple control of PEV charging. Furthermore, this product appears to complement upcoming developments in demand response (DR) resources as a result of smart grid developments.

Other PEV products and services may evolve and eventually become part of the offerings available to the market. Such second-tier products and services include energy and capacity.

The project team recommends a future re-evaluation for the products that did not make the first-tier selection to better assess needs, timing and value provided. Additional details on these products and services are available in the body of the report.

Integration Requirements

The integration of PEV resources into existing ISO/RTO systems will require changes to market rules and investments in IT infrastructure. Such changes and investments will enable ISO/RTOs to meet the unique needs of PEV resources and facilitate commonality across ISO/RTO systems, which is important for a mobile resource.

The *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0.* sets forth an action plan that includes drafting common information models in Unified Modeling Language (UML) for use by different Standards Development Organization (SDO) projects.

To enhance commonality in communication standards, the IRC project team recommends Distributed Network Protocol 3 (DNP3), Inter-Control Center Communications Protocol (ICCP), and Extensive Markup Language (XML)/Hypertext Transfer Protocol Secure (HTTPs) as standard communication interfaces. Recommended encryption standards include secure ICCP, secure DNP3, and HTTPs with digital certificates. Other integration requirements either not covered or partially covered by existing standards or developing standards include:

- Scan rate and visibility;
- Continuity of operation;
- Telemetered data requirements;

- Metering requirements;
- Availability; and
- Reliability requirements.

The project team recommends continued and expanded participation in standards development efforts by standards organizations, including:

- the Society of Automotive Engineers (SAE);
- the National Institute of Standards and Technology (NIST);
- the International Electrotechnical Commission (IEC);
- the North American Energy Standards Board (NAESB); and
- the Institute of Electrical and Electronics Engineers (IEEE).

For PEV aggregators to participate in ISO/RTO products and services, the ISO/RTOs must ensure that the aggregators have the ability to identify PEV locations, ISO/RTO systems can support a validation process for PEV transactions, and aggregators can provide a sufficient amount of aggregated load. Regarding aggregation size, existing and evolving DR products and services using load as a resource appear to be a good starting template for new rules and processes for PEV-related services. Currently, DR products and services provide a variety of functions in the ISO/RTO markets including energy, reserves, capacity, and regulation.

The infrastructure investments required to enable PEV participation vary depending on the complexity of PEV aggregator interactions with the ISO/RTOs. In the initial stages of PEV participation, the project team expects that investments, such as in IT infrastructure to forecast PEV loads, will be required for the ISO/RTOs. Local government, utility, or homeowner investments to charge vehicles and handle new load are likely to be the predominant investments. As experience accumulates and stakeholder interactions become more sophisticated, additional ISO/RTO investments will be necessary as:

- PEVs transform from reliability assets to market assets;
- Aggregators manage more complex charging schedules and communicate more frequently with ISO/RTOs; and
- ISO/RTOs start forecasting resources and validating transactions.

These investments include increased communications capacity to handle larger data amounts, more market product and service offerings, and an increased number of aggregators.

Ultimately, the integration of PEVs into ISO/RTO markets and systems will incur additional cost. The project team estimated that each ISO/RTO will require:

- A one-time incremental cost between $0 and $265,000 to upgrade systems to support PEV aggregators;
- Annual staff labor costs of approximately $600 to $3,000 per PEV aggregator;
- A one time incremental cost of $80,000 to upgrade software and improve reliability; and
- Monthly costs of $480 to $2,080 for secure communications.

The project team also estimated a one-time incremental cost per aggregator of around $70,000 to support the connectivity between the aggregator and the ISO/RTO.

Final Comments

Overall, the projected electrification of light-duty vehicles in North America poses a challenge to the electricity grid while also offering unique opportunities. The management of PEV charging, at a minimum, can limit the impact of new PEV loads and, at its best, provide new resources. To gauge the potential impacts, services and needs of PEVs, this study conducted an interdisciplinary analysis based on the best available information. As the market progresses and technologies develop, users of this study should check observed trends against analysis assumptions. Conducting near-term studies will help demonstrate concepts presented in this paper and gather new information before the PEV aggregate load grows larger. Testing might also assist in the ongoing development of relevant standards. Furthermore, better understanding of driver behavior is needed to help gauge which tools are appropriate for managing PEV loads and mitigating potentially negative impacts. For example, it is not clear to what extent electricity price signals can solicit sufficient driver responses, especially where transitions to PEVs result in significant fuel cost savings. Experience with smart grid technologies and use of load as a resource in tandem with such testing and demonstrations will be invaluable in preparing for the unique changes predicted to arrive with PEVs.

1. Introduction

Utility and automotive experts expect PEVs to join the mass market for light-duty vehicles. Recent actions by policymakers, automotive manufacturers, and investors indicate that such growth may not be far off. Over the course of the next three years, for example, most major domestic and international original equipment manufacturers (OEMs) will bring PEVs to market. This study is one of several initiatives to prepare the North American electric system for widespread adoption of PEVs, with the goal of optimizing PEV-grid integration.

The purpose of this study is to identify products and services that PEVs could provide under existing market and reliability structures within the markets of the North American ISO/RTOs. As such, the project team focused on identifying those products and services that could be implemented by ISO/RTOs in the very near term.

The study makes no projections about the likely implementation or schedule of implementation for these products and services. Each ISO/RTO is unique in terms of the products and services it currently offers, ease with which it might integrate PEVs into existing markets, and likely penetration of PEVs. As such, while the report recognizes ISO/RTO variation and projects PEV penetration regionally, it speaks generally about the likely near-term PEV products and services. In the process of this research, the project team identified additional products and services that are less certain in their feasibility, but are worth continuing to explore.

Section 2 of the report reviews PEV characteristics and summarizes the results of a market penetration, load impact, and price impact projection by region. Section 3 describes how PEVs might integrate with existing ISO/RTOs, determines potential products and services, identifies likely interactions with the ISO/RTOs, and discusses the potential role of a PEV aggregator. Section 4 highlights the technical and operational requirements for enabling PEV products and services. Communications infrastructure, settlement and scheduling needs, and market commonalities are considered. Finally, Section 5 presents a summary of the analysis, recommends initial products and services, notes infrastructure needs, and defines incremental IT cost.

2. PEV Characteristics and Impacts

2.1 PEV Characteristics

PEVs constitute a variety of vehicle types with different battery capacities, vehicle ranges, and vehicle drive trains. Such differences are important to the electric industry because of their influence on daily vehicle electricity consumption. This, in turn, influences the size and duration of charging loads. Vehicle characteristics also have an impact on PEV purchase patterns, influencing the location of PEV charging loads. Generally, three different kinds of vehicles make up the PEV fleet:

- **Plug-in Hybrid Electric Vehicles (PHEVs)** are hybrid vehicles that run on an internal combustion engine with batteries that can be recharged by connecting a plug to an external electric power source. They have larger batteries than traditional hybrid vehicles (e.g., 5-22 kWh), allowing for a longer all-electric range. Because they have hybrid engines, they effectively have an unlimited driving range.
- **Extended Range Electric Vehicles (EREVs)** are electric vehicles with relatively large batteries (e.g., 16-27 kWh) capable of relatively long all-electric ranges (e.g., 40-60 miles). An on-board internal combustion engine provides an unlimited driving range by recharging the battery when needed.
- **Battery Electric Vehicles (BEVs)** are pure electric vehicles with no internal combustion engine and require recharging at the end of their designed driving range. Of the PEVs, BEVs generally have the highest all-electric range (e.g., 60-300 miles) and the largest battery capacity (e.g., 25-35 kWh).

Due to their battery size and sole reliance on electricity, BEVs have the greatest charging load and their initial adoption may be limited to urban centers. However, as technology advances, the 100-mile BEV range could extend to 300 miles. Such advances are not likely until at least the third-generation vehicle is introduced. However, rapidly evolving technology makes the timing difficult to predict. PHEVs and EREVs, on the other hand, depend on an internal combustion engine to provide the range extension necessary to serve all of the vehicle owner's needs.

2.2 Driving Characteristics

Transportation data for U.S. driving patterns indicates that 60% of domestic average daily driving is 30 miles or less, and approximately 70% of driving is 40 miles or less.[1] Upcoming EREVs have been designed to drive 40 miles in all-electric mode. As such, EREVs could accommodate 70% of driving in all-electric mode with a single over-night charge. Combining daytime charging using public charging or at-work charging obviously extends these vehicles' effective all-electric driving ranges.

Given the expected cost declines of lithium-ion batteries during the initial market entry stage, the suburban market has daily driving patterns that can take maximum advantage of the decreasing cost of PHEV and EREV batteries. In particular, the PHEV and EREV configurations can accommodate suburban driving patterns in all-electric mode without concern about driving-range limitations.

In major U.S. metropolitan areas, the average miles driven do not vary greatly and is typically about 33 miles per day;[2] an exception is the New York metro area, where the average is 17 miles per day. To the extent that BEVs have a limited driving range before extended charging is required (e.g., a 40-60 mile battery, or even a 100-mile battery), urban and close-in suburban areas are the ideal target market.

2.3 Charging Characteristics

Initially, PEVs are expected to charge at either 120 VAC or 240 VAC. Charging voltage along with battery size determine the required charging time.[3] The differences in PEV designs and battery capacity imply different charging requirements and charging times. The total energy required to charge a battery, and the average energy required per day, depend on the miles driven and the vehicle energy consumption per mile. PEVs typically require 150-400 watt-hours per mile (Whr/mile) depending on weight, for propulsion. Additional power may be required for accessories and air conditioning during summer months. Air conditioning energy requirements can be substantial, and depend on climate and the time that the vehicle is occupied rather than miles driven.

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[1] Generated by the Center for Transportation Analysis, Oak Ridge National Laboratory.
[2] Ibid.
[3] As an example, charging at 120 V, a 16 kWh PEV will require approximately eight hours to fully charge. This compares to four hours at 240 V.

Level 1 first-generation chargers supply 120 VAC and 30 Amps or less with a typical household plug.[4] As such, coordination of vehicle purchase with charging infrastructure is necessary, and it will be even more important with Level 2, 3 or DC chargers, coordination becomes more important. Level 2 chargers are specified as 240 V at up to 70 Amps,[5] while Level 3 chargers are still being defined.

A PEV acting as a controllable load is able to modulate its charging rate up (increased charging) or down (decreased charging) in response to near real-time control signals that originate at the grid operator but may be processed at an intermediary aggregator, such as a private- or public-parking garage or utility. Alternatively, a PEV may modulate its charging rate "on" (full charging at normal rate for the vehicle) or "off" (no charging) in response to near real-time control signals emanating from the grid operator via an intermediary. Either way, PEV charging can be interrupted in large scale almost instantaneously assuming the necessary communications capabilities are available. Controlling the charging load is not simply a demand resource; however, it can be thought of that way. It is also a time-shifting resource since, in general, whatever is not supplied "now" must be supplied "later but soon." PEVs can be connected at any time of day. However, the expectation, based on various surveys, is that PEVs will mostly be connected in the evening hours. Whether or not they are charging depends on the state of charge of the battery and the external control by the utility or aggregator.

PEVs will likely have onboard communications, computing capabilities, and the other functionality in the near term that will enable them to be "smarter" than most end-use loads. However, PEV batteries may have warranty restrictions on how frequently the battery charging can be regulated until the manufacturers validate the warrantable usage via lab tests. For example, the charging to not-charging state cannot be cycled more frequently than normal city driving charging and discharging cycles today (e.g. 2-10 seconds). Current feedback from the PEV manufacturers is that they will warrant the batteries for normal stop-and-go city driving. They do not have sufficient experience to address a higher frequency of charging/discharging of the batteries as might occur in grid applications. As technology advances over time, PEVs are likely to have increased battery capacities and higher charging rates, and management protocols could optimize participation with battery performance.

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[4] These definitions for Level 1, 2 and 3 charging are derived from communications with parties involved in ongoing standards development.

[5] Ibid.

2.4 PEV Market Penetration Forecast

2.4.1 Introduction

The Obama Administration has set a goal of achieving one million PEVs on the road in five years. Recent government incentives and stimulus investments to accelerate market acceptance, including grants and loans to manufacturers and tax credits to consumers, indicate movement towards this goal. As such, the project team used the goal of one million PEVs on the road in five years as a basis for its scenario development.

To frame the forecast of PEVs over time, the project team defined three PEV market development phases:

1. Initial market entry,(2009–2012);
2. Market development and growth (2013–2017); and
3. Mature market development and expansion (2018–2030 and beyond).

The following describes each phase in more detail.

Initial Market Entry (2009–2012)

Most major manufacturers will introduce PEVs during this time period (see Appendix A for a summary of recent OEM announcements). The OEMs will begin mostly with limited production levels and will closely monitor consumer use of the vehicles and vehicle performance. The consumers that purchase these PEVs will be largely early adopters. As PEVs become available, government and private fleet owners will begin to buy them and accumulate performance data.

Market Development and Growth (2013–2017)

During this period, additional PEVs are likely to be introduced and production capacity and output will increase. As output increases, battery manufacturing costs will decrease, making some manufacturers profitable. Government incentives will probably still be needed to assist market growth. In the middle to the end of this period some manufacturers will likely introduce second-generation PEVs while all manufacturers will likely introduce evolutionary improvements. PEV owners are expected to be mostly early adopters though by 2017, when market acceptance is projected to reach the point where mass-market customers are beginning to consider the purchase of a PEV. Consumer and private fleet acceptance will depend on many factors beyond government incentives, including gasoline prices, the perceived importance of environmental issues, and the availability of acceptable charging options.

Mature Market Development and Expansion (2017–2030 and beyond)

This period is considered as the beginning of the mass-market. Additional PEV models are likely to be introduced and additional manufacturers may enter the market. New technologies, advanced features, and new charging capabilities likely will be available. Third-generation PEVs are likely to begin appearing on the market. Most importantly, the vehicles will likely have appeal to mainstream automotive customers and become mass-market products. Government incentives may still be necessary in this time period but should be reduced and phased out. Production levels will be geared to market requirements.

2.4.2 Methodology

The analysis defines three scenarios: a *Target Case* in which the President's one million PEVs goal is met in five years, a *Fast Case* in which the target is met earlier, in less than four years, but with a more rapid rate of PEV introduction than appears likely at present, and a *Slow Case* in which the target is not met until eight years into the market development. In all cases, OEM announcements were used as the basis for estimating initial market entry (with validation from the OEMs), and for the "Initial Market Entry" phase (2009-2012) stated production plans provided a starting point.

The first of the three projections assumes that the five-year period begins at the end of market introduction in 2012 and that the goal is achieved in 2017. The second projection is significantly accelerated and achieves the goal of one million PEVs by 2015. The third and final projection assumes that market forces slow adoption and the one million PEVs goal is not achieved until 2019.

To forecast the geographic distribution of PEV passenger vehicle adoption in the Market Development and Growth phase, the project team examined data on early Prius adoption. Generally, early adopters are different from the established mainstream market. Early Prius adopters can be characterized by their interest in new automotive technology, fuel economy improvements, and environmental benefits. They also appear to have been motivated by a vehicle that visually "made a statement." They were willing to pay a price premium to obtain these objectives even when the economic justification was not compelling. These consumer behavior characteristics appear relevant to early PEV adopters. As such, to forecast PEV passenger vehicle sales in the early adopter period, the project team gathered data on Prius registrations in the U.S. from 2000 through 2007.

The project team expects that Canadian PEV adoption trends would be similar to the U.S., though not necessarily of the same magnitude. In particular, a lack of national incentives and the impact of colder temperatures on battery life are likely to affect adoption totals. However, there appears to be significant interest in PEVs in Canada because of environmental concerns, high gasoline prices relative to electricity, and provincial-level incentives in Ontario province, such as customer rebates and the target increase for passenger PEVs is 5% by 2020. To forecast Canadian adoption trends, the project team estimated total PEV penetration and adopted similar regional patterns (such as urban/rural splits and, to a lesser degree, coastal tendencies) as observed in the U.S.

To forecast fleet adoption of PEVs, researchers assumed that fleets would be motivated by public policy and fuel cost reduction. The largest number of these vehicles may be owned by governmental entities (including postal service vehicles), utilities, and package delivery services. These types of PEVs tend to be distributed somewhat evenly on a per capita basis. In addition, utilities tend to distribute their light vehicle fleet by population throughout their service territories. As such, the project team used population as a guide for how market growth would split regionally. The project team confirmed that these assumptions are reasonable through private communications with electric utilities and the U.S. Postal Service. Furthermore, the miles driven by these fleets in urban centers are relatively low and predictable. The vehicles also tend to “come home” each evening which fits the PEV use model quite well.

Figure 1 illustrates the total U.S. sales of Prius from 2000 to 2007. Sales were relatively low in 2000, 2001, and 2002. After the second-generation Prius was introduced in 2003, sales grew more rapidly. The project team believes that between 2005 and 2006, sales growth was hampered by manufacturing issues. Sales growth resumed in 2007.

Figure 1. United States Annual Prius New Registrations

(Prius data provided by R. L. Polk)

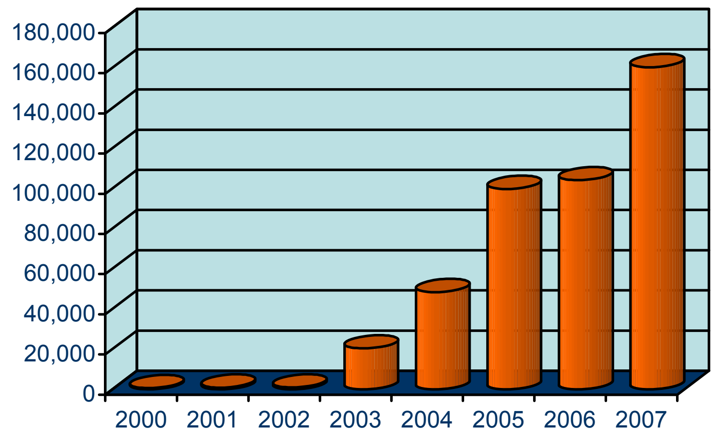


Figure 2 illustrates the geographic distribution throughout the U.S. of Prius sales from 2000–2007. Prius sales were generally concentrated in states with the highest population, but not always. Table 1 illustrates that Maryland and Massachusetts, for example, had higher Prius registrations than other states with higher populations, such as Ohio.

Table 1 illustrates Prius new registrations per capita in the period from 2000-2007.

Figure 2. Total Prius Sales, 2000–2007

(Prius data provided by R. L. Polk)

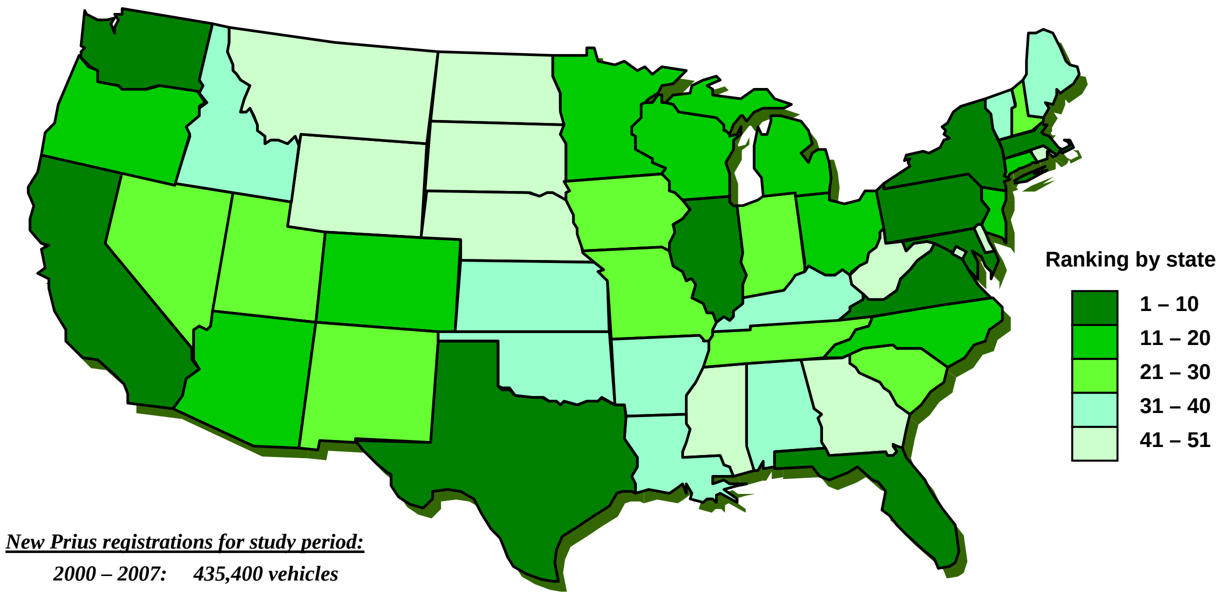


Table 1. Buyer Demographics: Locations of New Registrations

States With Highest Population, 2000–2007		
Rank	State	Population (Millions)
1	CA	36.8
2	TX	24.3
3	NY	19.5
4	FL	18.3
5	IL	12.9
6	PA	12.5
7	OH	11.5
8	MI	10.0
9	GA	9.7
10	NC	9.2

States With Highest Prius Sales, 2000-2007		
Rank	State	Total New Registrations
1	CA	123,989
2	FL	20,596
3	TX	18,297
4	NY	18,033
5	VA	17,828
6	WA	16,459
7	PA	14,791
8	IL	14,660
9	MA	13,723
10	MD	12,040

Figure 3. Prius Registrations Per Capita, 2000–2007

(Prius data provided by R. L. Polk)

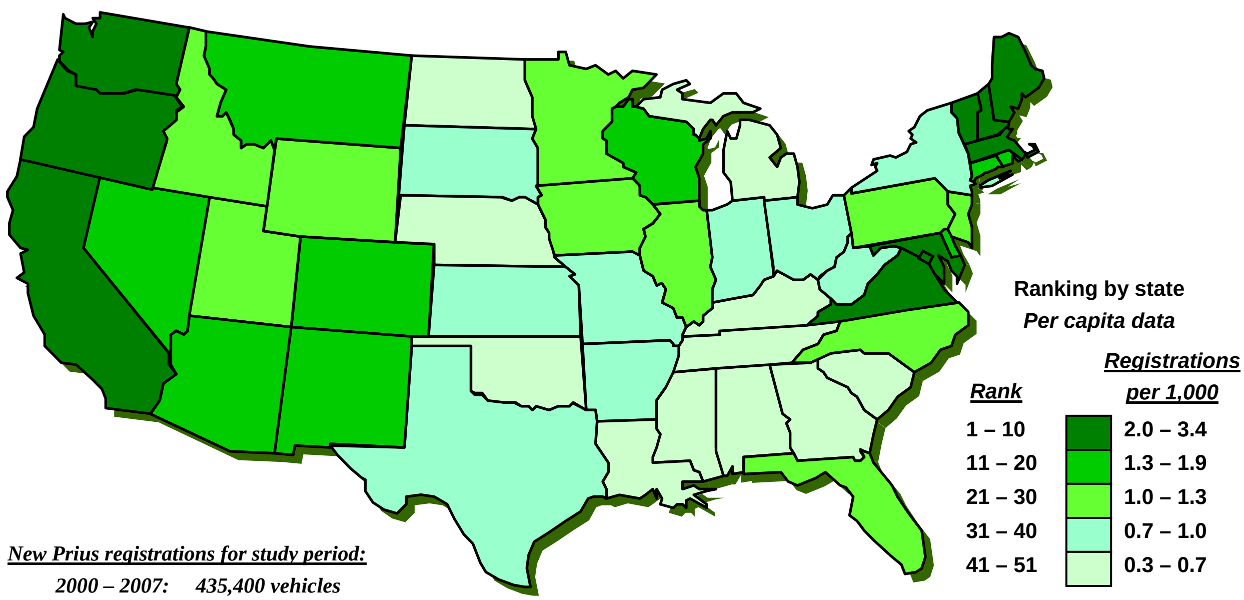


Table 2 shows the states ranked by Prius registrations per capita and also shows the ten largest metro areas in the U.S. and their total Prius registrations. The data illustrate that the demographics of the Prius customer has a strong "coastal" character. In addition, sales were heavily concentrated in the largest urban areas, which account for 31.6% of total U.S. sales.

Table 2. Buyer Demographics: Urban Concentrations

States Where Prius Was Most Popular			Metro Areas Where Prius Was Most Popular			
Rank	**State**	**Registrations** per 1,000 Residents	**Rank**	**Metro Area**	**Total New Registrations**	**% of U.S.**
1	CA	3.37	1	New York	18,622	3.7%
2	VT	3.21	2	Los Angeles	52,700	10.4%
3	OR	3.04	3	Chicago	9,400	1.9%
4	NH	2.54	4	Wash., D.C.	15,100	8.4%
5	WA	2.51	5	San Francisco	42,900	8.4%
6	DC	2.46	6	Philadelphia	6,300	1.2%
7	VA	2.29	7	Boston	13,200	2.6%
8	MD	2.14	8	Detroit	3,000	0.6%
9	MA	2.11	9	Dallas	3,200	0.6%
10	ME	2.03	10	Houston	3,900	0.8%

Note: "Most Popular" = highest per capita sales

The project team's review of historical trends in Prius adoption illustrated the following:

1. Early adopters were not proportional to population size alone.
2. There were significant differences in per capita sales between states and regions.
3. Some regions showed strong preferences for the Prius while others did not.
4. Total numbers (vs. per capita numbers) were driven by overall population.
5. The "coastal" phenomenon showing preference for the Prius among early adopters on the West Coast and the Northeast is very clear in both the per capita and total sales numbers.

The conclusion from this analysis projecting the distribution of consumer-owned PEVs is that the early adopters for this type of vehicle technology have a clear demographic locational component. A number of utilities have recently used similar demographic analysis to attempt to forecast locations of PEV load within their service territories. As a result of this analysis the project team believes that there will be significant differences in PEV concentrations among ISO/RTOs.

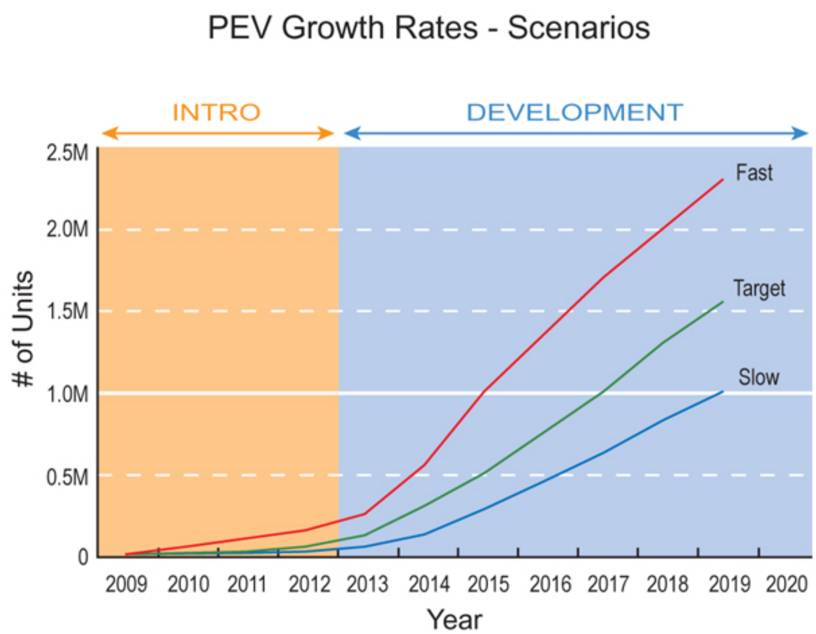
2.4.3 PEV Projected Concentrations

The key from the ISO/RTO perspective is to locate the concentrations of PEVs that can provide significant capacity for demand response resources. The project team applied the Prius example to anticipate consumer buying behavior of PEVs. The project team anticipates that consumers will initially buy PHEVs and EREVs and a lesser number of BEVs.

Error! Reference source not found. illustrates the projections of PEV penetration rates through 2019. Total PEV penetration forecasts for each of the ISO/RTOs are provided in Appendix B. The target curve meets the Obama Administration's goal of one million PEVs in the U.S. in five years, by 2017. The fast case meets the goal of one million vehicles by 2015, while the slow case meets the goal in 2019. The penetration curve in all cases is based on the Prius model for consumer behavior, with an increase due to fleet introductions after initial market entry in 2012. In addition, the 2006 stall in Prius sales growth was smoothed in the PEV forecast.

The projections in this report assume a smooth transition in market growth. However, the project team realizes that these transitions are not necessarily smooth and those manufacturers who improve their product more rapidly will gain market share while others leave the market. Also, the projections in this report are based on extrapolations of first-generation vehicles though the project team recognizes that game-changers in cost and power density can have dramatic impacts on the penetration rate.

Figure 4. PEV Growth Rates—Scenarios



The fleet PEV estimates were based on applicable federal government vehicles from all departmental and agency purchases of sedans, station wagons, SUVs, and light trucks, representing about 80% of the federal vehicle fleet. The estimates are consistent with Obama Administration targets of a 50% rate of U.S. Government purchases of PEVs starting in 2012. While such a scenario may appear optimistic, potential purchases by utility companies and private fleets would make up for any actual shortage in government fleet PEV purchases. Therefore, the project team believes that a total estimated impact of about 12,500 vehicles per year with about 80% concentrated in the major metros is a reasonable estimate. Overall, the fleet data do not materially affect the shape of the curves in Figure 4.

Table 3 illustrates the projected distribution of consumer, fleet, and total PEVs in the top 20 most populous metropolitan areas at the one-million-vehicle target. PEV projections are consistent with the Prius data where the overwhelming majority of PEVs are located in metropolitan areas. The New York metro area data include a minor assumption that some of the area PEVs will commute into New York City and be available at some point during the day or evening for charging.

Table 3. PEVs in the Top Twenty Most Populous Metropolitan Areas

City	Consumer PEVs	Fleet PEVs	Total PEVs
New York	40,000	14,069	54,069
Los Angeles	105,000	14,069	119,069
Chicago	20,000	7,892	27,892
Washington, DC	31,000	6,520	37,520
San Francisco	85,000	6,005	91,005
Philadelphia	13,000	5,319	18,319
Boston	27,000	4,976	31,976
Detroit-Ann Arbor	6,000	4,718	10,718
Dallas-Fort Worth	6,500	4,461	10,961
Houston	8,000	4,032	12,032
Atlanta	4,500	3,517	8,017
Miami	8,000	3,346	11,346
Seattle-Tacoma	23,000	3,088	26,088
Phoenix	13,000	2,831	15,831
Minneapolis	8,000	2,574	10,574
Cleveland-Akron	6,000	2,574	8,574
San Diego	20,000	2,445	22,445
St. Louis	3,500	2,230	5,730
Denver-Boulder	9,000	2,230	11,230
Tampa-St. Pete	7,000	2,059	9,059

Note: Metro areas located within the ISO/RTO study are **bold**; other metro areas are in gray

Table 4 shows estimates for the vehicles "living" in the ISO/RTO regions. This table excludes vehicles "living" in the New York metropolitan area that are external to the NYISO.

Table 4. PEVs in the ISO/RTO U.S. Regions

ISO/RTO	Consumer PEVs	Fleet PEVs	Total PEVs
ISO-NE	50,780	10,294	61,074
NYISO	28,194	15,544	43,738
PJM	103,124	41,048	144,172
Midwest ISO	65,022	29,622	94,644
SPP	18,466	11,993	30,459
ERCOT	27,276	15,493	42,769
CAISO	237,698	29,956	267,654
TOTAL	**530,560**	**153,950**	**684,510**

Appendix C provides maps of each of the ISO/RTO regions showing the estimated major concentrations of consumer vehicles within the regions.

Looking separately at two major Canadian metropolitan areas, Toronto and Calgary, the project team can scale a maximum number of PEVs based on population assuming that Canada follows a similar adoption curve to the U.S. The project team estimated 15,700 PEVs for Toronto and 3,700 PEVs for Calgary.[6] These numbers assume that Canada or the provinces will adopt similar incentives as the U.S.

2.5 Projected Aggregate PEV Loads by Area

2.5.1 Introduction

The available capacity for demand reduction depends on the number of PEVs available locally, the charging energy, and the likelihood that the vehicle is charging. The total energy required to charge the batteries depends on the miles driven and the vehicle energy consumption per mile. PEVs can be connected at any time of day. However, the expectation based on various surveys is that PEVs will mostly be connected in the evening hours, though not necessarily at times of low load. Whether or not they are charging depends on the state of charge of the battery, the owner's preference and the incentives, and the external control by the utility or aggregator.

2.5.2 Methodology

The availability of daytime charging is important to the commercial success of PEVs. However, there are substantial survey and vehicle use data that suggest that 80% to 90% of charging will occur in the evening or at night. The project team examined two cases, one where the vehicles all charged during a 12-hour period and another where the vehicles all charged during an 8-hour period. In using the data, it is not necessary to consider that the charging periods are contiguous. In other words, if 10% daytime charging is appropriate for a region, then a portion of the charging time can be distributed in the daytime. The project team made no attempt to analyze specific utility service area expected charging schedules.

OEM-produced vehicles are expected to be capable of either Level 1 or Level 2 charging initially. The project team believes that the majority of vehicle owners will require Level 2

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[6] These estimates were calculated on the same basis as U.S. estimates made under the assumption of 1 million vehicles deployed. The number of projected vehicles is a maximum estimate, with Toronto modeled on Chicago and Calgary modeled on Minneapolis.

charging or higher because of shorter charging times. Utilities also are likely to encourage Level 2 charging because of the control flexibility that it provides. In some cases, BEV owners may desire Level 3 charging but the installation expense of Level 3 will be prohibitive to most PEV home-charging owners.

Rather than attempt to analyze each metro area and estimate weather and traffic conditions—factors that impact PEV consumption—the project team assumed for the purposes of this analysis that the vehicles consumed approximately 300 Whr/mile. The project team also assumed that, at the time that a million vehicles were on the road, all of the PEVs could deplete at least 10 kWh from daily commuting.

With the above assumptions, Level 1 chargers (with a PF of 0.8) would require 6.88 hours per day to charge a PEV. Level 2 chargers operating at 30 Amp (with a PF of 0.9) would require 1.51 hours per day for the 33-mile drive cycle. Given the advantages of Level 2 charging, the project team assumed for purposes of this analysis that 20% of the vehicles were charged at Level 1 and 80% at Level 2. A stochastic analysis to determine the likelihood of a certain number of vehicles charging at a specific time is beyond the scope of this project. Instead, the project team used average number of vehicles connected.

Finally, the project team recognizes the variations among utility load profiles. Here again, the project team made no attempt to customize charging profiles in order to level utility loads. In presenting the results of the analysis, the project team provided the maximum load if all chargers were operating simultaneously. This is only for comparison since the project team recognizes that local distribution constraints will not allow simultaneous charging of the entire fleet.

2.5.3 Regional Load Results

Table 5 shows the number of projected vehicles and the resulting estimated aggregate PEV load by city metro area. Three estimates are presented based on three average charging times for the PEV population: concurrent charging within 1 hour, staged charging over eight hours, and staged charging over twelve hours. Los Angeles stands out as the largest load potential with San Francisco close behind. The numbers are based on the portion of the load within their primary ISO/RTO.[7]

Table 5. Load and Charging Projections for the Top Twenty Metropolitan Areas

City Metro Area	Total PEVs	Load if everyone charged at the same time (MW)	Load if charging is staged over 8 hours (MW)	Load if charging is staged over 12 hours (MW)
New York	**54,069**	**299**	**33**	**22**
Los Angeles	**119,069**	**658**	**147**	**98**
Chicago	**27,892**	**154**	**34**	**23**
Washington, DC	**37,520**	**207**	**46**	**31**
San Francisco	**91,005**	**503**	**112**	**75**
Philadelphia	**18,319**	**101**	**23**	**15**
Boston	**31,976**	**177**	**40**	**26**
Detroit-Ann Arbor	**10,718**	**59**	**13**	**9**
Dallas-Fort Worth	**10,961**	**61**	**14**	**9**
Houston	**12,032**	**67**	**15**	**10**
Atlanta	8,017	44	10	7
Miami	11,346	63	14	9
Seattle-Tacoma	26,088	144	32	21
Phoenix	15,831	88	20	13
Minneapolis	**10,574**	**58**	**13**	**9**
Cleveland-Akron	**8,574**	**47**	**11**	**7**
San Diego	**22,445**	**124**	**28**	**18**
St. Louis	**5,730**	**32**	**7**	**5**
Denver-Boulder	11,230	62	14	9
Tampa-St. Pete	9,059	50	11	7

Note: Metro areas located within the ISO/RTO study are **bold**; other metro areas are in gray

[7] As the number of PEVs per metro area is assumed to be a fixed fraction of the total deployed fleet based on demographics and population, aggregate load projections to 2019 are scalable based on the vehicle market penetration curve. For example, a 50% increase in the number of PEVs deployed nationally would proportionally raise all of the load estimates. Alternatively, if 20% of the charging is performed during the day, then the same scaling can be performed to estimate the megawatt load for an 8- or 12-hour daylight period.

Using the same analysis as described for Table 5, the project team estimated that the 8-hour charging average load for Toronto will be less than 19 MW and for Calgary will be less than 5 MW as shown in Table 6.

Table 6. Estimate Loads for Two Canadian Cities*

City Metro Area	Total PEVs	Load if everyone charged at the same time (MW)	Load if charging is staged over 8 hours (MW)	Load if charging is staged over 12 hours (MW)
Toronto	15,700	86	19	13
Calgary	3,700	22	5	3

*Calculated on the same basis as U.S. at 1 million vehicles deployed. Number of vehicles projected is a maximum with Toronto modeled on Chicago and Calgary modeled on Minneapolis.

Table 7 provides the total PEVs and loads for each ISO/RTO based on vehicles "living" in the ISO/RTO and includes vehicles outside the major metro areas. The project team does not believe that isolated vehicles outside of the metro areas offer a significant opportunity for ISO/RTO load management during the time period that the project team studied. However, the numbers of vehicles represent both the "coastal" effect in adoption rate and also a strong dependence on population.

Table 7. Load and Charging Projections in the U.S. ISO/RTO Regions

ISO/RTO	Total PEVs	Load if everyone charged at the same time (MW)	Load if charging is staged over 8 hours (MW)	Load if charging is staged over 12 hours (MW)
ISO-NE	61,074	338	75	50
NYISO	43,738	242	27	18
PJM	144,172	797	178	119
Midwest ISO	94,644	523	117	78
SPP	30,459	168	38	25
ERCOT	42,769	237	53	35
CAISO	267,654	1,480	331	221
TOTAL	**684,510**	**3,785**	**819**	**546**

2.6 Projected Aggregate PEV Price Impact by Area

2.6.1 Introduction

In addition to estimating PEV load impacts by region, the project team estimated the regional wholesale price impacts from the first million PEVs. In particular, the project team estimated the expected incremental load by ISO/RTO due to each region's share of the first million PEVs. (For example, researchers estimated an additional 242 MWh of load in NYISO due to 42,738 PEVs).

2.6.2 Methodology

The project team estimated regional, wholesale price impacts using ISO/RTO market models and projected PEV loads, as described in Table 7. The anticipated load varies considerably from one ISO/RTO to another, with the highest densities of anticipated PEVs occurring in Los Angeles, San Francisco, and New York. The project team assumed that the PEV load "comes on" at 6:00 PM in each market and persists. The actual charging time and duration are a function of commuter driving patterns and PEV charging levels. The analysis here assumes three scenarios. These scenarios are:

- Scenario 1: Peak charging profile; all PEVs attempt to charge in 1 hour (simulated the worse-case scenario for unconstrained charging)
- Scenario 2: 8-hour charging; load spread evenly over an 8-hour period
- Scenario 3: 12-hour charging; load spread evenly over a 12-hour period

In the worst-case scenario, Scenario 1, all PEVs charge at the same time. In scenarios 2 and 3, the durations over which vehicle charging occur increase, spreading out the load over time. See Table 7 for the assumed PEV loads by region.

2.6.3 Price Impact Results

Results indicate that even at a market penetration of one million vehicles, PEVs have the potential to increase wholesale prices, depending on the time of day and day of year. However, the wholesale price impact varies greatly by ISO/RTO, based on the penetration and concentration of PEVs and on whether PEV charging occurs simultaneously. California shows the largest maximum price impact considered, followed by New York. The short-term price impact of one million vehicles ranges from near zero to up to 10%. (Appendix D contains detailed results tables). The 10% impact seen in Scenario 1 assumes a high concentration of PEVs charge over a short period of time on a peak day. Estimated impacts in scenarios 2 and 3, where PEV charging is spread over several hours, shrink to less than one percent across all regions. This indicates that as the time period over which charging occurs increases, the short-term price impacts decrease to minimal amounts. Using some mechanism to prevent charging over a concentrated time period—such as dynamic pricing, special tariffs, or managed charging—appears likely to help mitigate potential price impacts caused by PEV charging. Such tools will likely become critical as the PEV market grows beyond one million vehicles and represents a larger fraction of the total vehicles on the road.

2.7 Conclusions

The following conclusions can be drawn from this analysis:

- It is feasible that one million PEVs might be deployed in the U.S. by 2017.
- Prius adoption data indicate that there are concentrations of early adopters in the coastal regions.
- Assuming that historical Prius adoption trends are a good proxy for estimating regional PEV penetration, the project team estimates that PEVs will be distributed more densely on the West Coast and Northeast than in the Midwest and Southeast, and that metropolitan areas will have higher concentrations than rural areas.
- Load projections illustrate the need for managed control of charging in areas of high concentration of PEVs.
- Since the number of PEVs per metro area is assumed to be a fixed fraction of the total deployed fleet, based on demographics and population, megawatt load projections are scalable based on the vehicle market penetration curve.
- The wholesale energy price impact of PEVs varies greatly based on the penetration and concentration of PEVs. Initial research indicates that the short-term price impacts of one million PEVs range from near zero to up to 10%, depending on the region and time of day.
- The greatest estimated impact occurs where high concentrations of vehicles charge over a short period of time on a peak day. As the time period over which charging occurs increases, the short-term price impacts decrease to minimal amounts.
- Exposing customers to some mechanism, whether it be dynamic pricing, special tariffs, or managed charging, could help self-regulate the potential problem of price impacts from PEV charging.
- Additional research to detail the regional price impacts of PEVs over time will help inform new tools.

3. PEV Interface with the ISO/RTO

3.1 Role of PEV Aggregator

This study assumes than an aggregator will coordinate the application of multiple PEVs to meet product or service commitments to the ISO/RTO while also achieving targeted charge levels per commitments to the vehicles. A broad array of aggregators is anticipated, many stemming from existing, knowledgeable utility organizations (e.g. distribution utilities, municipalities, existing demand response integrators, scheduling coordinators), and many with little or no experience in interfacing with the bulk power grid (e.g. independent system providers [ISPs], automotive OEMs, and retail establishments).

As with any load resource, an aggregator will need to sign up a sufficient number of PEVs to provide the product or service and meet the requirements specified by the ISO/RTO to participate in the market. Aggregation for energy or ancillary services (A/S) to participate in the ISO/RTO market is viable if participation has a value for the PEV owners. PEV owners will need to balance the desire for payments associated with participating in ISO/RTO-related products against concerns about battery life impacts or charging convenience. Future customer preferences, energy rates, social pressures, and other factors will foster or discourage the growth of PEVs as a participant in the ISO/RTO markets.

A key issue regarding the provision of market services by PEV loads is that the PEVs have to be charged to target levels (normally, fully charged) by a defined time. Thus, if a vehicle providing services reaches a point where it must charge at its maximum rate to achieve the targeted charge level at the targeted time, it would discontinue providing grid services. The charging control must be capable of anticipating that condition and not offer services for a given hour if that is reasonably anticipated to occur during the hour ahead. Some products, like regulation, will require two-way communication with the ISO/RTO within the latency requirement defined in the NERC reliability standards.

3.2 Potential PEV Products and Services and Adaptations Required

This section describes services that PEVs could provide as a managed load. The project team first focused on what services PEVs could possibly provide today under existing market product definitions. Then, by examining the PEV technical capabilities, the project team suggested new market products and services specific to capabilities provided by the PEVs. The project team developed common definitions appropriate to all the North American markets, and outlined specific data requirements for today's market resources, such as response time requirements, duration requirements, and control and visibility requirements. V2G capabilities are outside the scope of this study. Therefore, products and services are focused on demand response-type services only.

As noted earlier, two types of managed charging are feasible for PEVs. The first is a simple on and off type of charging where charging occurs at the full charging rate when on and demand appears in increments. An alternative charging control would modulate the charging rate over time, providing a smoother continuation of load. In the event that the PEV is able to modulate its charging rate the following terminology applies:

- **Normal charging level:** the charge rate (somewhere between maximum and minimum) at which the PEV charges absent any control signal from the grid
- **Duration:** the time it takes the PEV to achieve full charge (from a fully discharged state) at the normal charging level.
- **Maximum charge rate**: the maximum rate at which the PEV can charge when signaled to do so.
- **Minimum charge rate:** the minimum charge rate (probably zero) at which the PEV charges when signaled to do so.
- **Rate of change**: the maximum rate of change in charging rate (in % /sec) that the PEV can withstand.
- **Maximum charge energy:** duration times normal charging rate.

In the event that the PEV is only able to switch charging on or off then the following terminology applies:

- **Normal charging rate**: the average charge rate of the PEV when it is controlled on and off in some (not necessarily symmetric) pulsed fashion by a control signal.
- **Charge cycle duty:** the % of the total connection time that the PEV is charging.
- **Duration:** the time it takes to charge the PEV fully at the normal charge rate
- **Maximum charge rate**: PEV inherent charging rate = the rate at which the duty PEV charges absent any control signal to do otherwise.
- **Minimum charge rate**: zero; the charge rate at which the PEV charges when signaled to do so. (The PEV now looks like a load resource capable of being controlled at a rapid rate automatically)

- **Rate of change**: the maximum rate of change in charging rate (in %/sec) that can be applied to the PEV to alter its effective charging rate.
- **Maximum charge energy:** duration times normal charge rate

Mathematically, pulsed charging can be transformed effectively into the modulated charging if the pulse rate is faster than approximately four times the control signal.

In the sections below, the potential grid services from PEVs are described in two cases: that individual PEVs provide services, or that aggregators provide services. Key questions and issues are identified for both cases.

3.3 Traditional Services and Products

Scheduled Energy

Scheduled Energy is a service available in today's markets where a market participant offers to provide energy or demand for a period of time. To make it applicable to a PEV, an individual PEV driver could communicate to an aggregator on the amount of energy needed by a given time and the aggregator would develop an energy schedule defining the energy and time period that the PEVs would charge. For example, a PEV owner might schedule evening charging for a total of 5 kWh. The information required would be the amount of energy necessary to reach the target charge state at the target time, in addition to maximum and normal charge rates, and maximum charge level. The parameters afford a number of ways to communicate this information, as energy and time or as current charge level and time. Standards would be required for models for this information.

Regulation

A PEV providing regulation service is capable of adjusting its effective charge rate net of modulation or pulse duty cycle adjustment up or down by a regulation amount equal to the regulation capacity offering. The aggregator providing regulation must be able to adjust the PEV charge rate by the regulation amount at a rate of *R kW / minute*. The regulation amount offered through PEV-charging reductions, *R*, is constrained by the capacity of the associated charging infrastructure. The charging rate of change in *% / sec* must be sufficient to meet regulation service response requirements. It must be able to begin changing its charge rate (response time) within SR seconds (6-30 seconds). Currently, *R*, as determined by the required response rates, is roughly 10 minutes. However, future response rates for PEVs might be in the 6- to 30-second range. The response time is a key requirement for aggregators and may restrict systems in use by an aggregator if sufficient communication capability does not exist. To participate, the aggregator must meet the imposed minimum response times. The aggregation of PEVs providing regulation response must be able to sustain its regulation contribution (up or down) for a specified period of time. In many of today's markets, this duration is assumed to be one hour. Some ISO/RTOs have allowed for 15-minute sustained duration for limited energy devices.

An aggregator providing regulation services from PEVs must be able to meet the requirements for regulation services (regulation up, regulation down, or symmetric up and down) as required by the individual ISO/RTO and as defined for conventional generators or limited energy resources. It is expected that an aggregator would provide regulation services by combining the responses of a number of PEVs. It is the responsibility of the aggregator to have sufficient rate of change and amount of change in aggregate PEV charging load so as to meet its regulation commitments to the system operator.

In order for the aggregators to be able to provide regulation services to an ISO/RTO, they will need to implement two-way communications with the PEVs and demonstrate they can meet the obligation to participate in the regulation market, or otherwise demonstrate the real-time control and validation requirements of these services.

Reserves

An aggregation of PEVs providing reserves must be able to reduce its charging level by *SR kW* near instantaneously (with *SR / sec*) on receipt of a control signal. As with regulation, the amount of reserves offered by the aggregation of PEVs' charging reduction is dependent on the charging infrastructure. The typical required response time is 10 minutes, but might change in the future. A PEV not capable of modulated charging or pulsed charging is nonetheless able to provide a component of the aggregate PEV reserve by simply stopping charging, assuming that the vehicle would remain "off" for a sufficient period of time so as not to violate any vehicle pulse duty cycle restrictions. An aggregation of PEVs which responds to a reserve actuation signal must remain "off" for the minimum of *SRM* minutes or until the reserve signal is rescinded. Today, *SRM* is typically 60 minutes.

An aggregator which sells reserves from its PEV base is responsible for having sufficient PEV response available to reduce load by the reserve amount offered, above and beyond any capacity offered for regulation services. In co-optimized markets, an aggregator could submit into both regulation and reserve markets and the ISO/RTO market could determine which one to schedule. The aggregator must be able to deliver the reserve amount from PEV response within *SRS* seconds when requested. In today's markets, this is within 10 minutes.

For aggregators to provide reserve services in an ISO/RTO market, they will need two-way communications with the PEVs and meet the audit requirements to participate in the regulation market, or will have to otherwise demonstrate the real-time control and validation requirements of these services.

Emergency Load Curtailment

The aggregation of PEVs which are not providing reserve or regulation, but are scheduled to be charging, may be able to shed load in emergency situations, providing additional capacity when needed. Such an aggregation of PEVs must stop charging in response to a load shed signal from the grid operator or the utility. An aggregator providing load shed service to the grid operator must have scheduled charging available in excess of regulation and reserve so as to be able to reduce aggregate load by the load shed amount. Aggregators would be responsible for managing ramp schedules on hourly boundaries on the same basis as other scheduled resources.

This capability is not a current ISO/RTO product or service and it is usually performed by the transmission owners or retail entities that interface with the ISO/RTO.

Balancing Energy

An aggregator capable of altering PEV charging on a real-time basis may offer changes in total PEV charging load into the balancing energy/real-time dispatch market. The aggregator must be able to adjust PEV aggregate charging load down (selling energy) or up (buying energy) in response to dispatch signals. The aggregator must be able to affect PEV charging and respond in aggregate on time scales identical to that of conventional generation.

Table 8 summarizes the existing products and services that PEVs in aggregation might provide. For all ISO/RTO products and services, an aggregator would act as an intermediary between the ISO/RTO and individual PEVs.

Table 8. Traditional Products and Services Summary

Services Provided by PEVs	Description of Service Requirements	Map to existing ISO/RTO Products/Services	PEV Possibilities	Complexity 1-easy 5-complex
Scheduled Energy	▪ An aggregator providing scheduled energy shall be able to reduce its charging level by "Scheduled Energy schedule" ▪ An aggregator with an accepted energy bid must reduce its aggregate PEV load by the scheduled amount for the period of the award ▪ An aggregator which sells energy from its PEV base is responsible to have sufficient PEV response available to reduce load by the scheduled amount offered, above and beyond response offered for market products or services ▪ An aggregator must be able to deliver that energy scheduled from PEVs' response and adhere to the required ramp rates ▪ An aggregator shall have sufficient governor response available to demonstrate compliance to the obligation, if required	There are existing scheduled energy products/services at most ISO/RTOs ▪ Obligation-based bilateral contracts: and/or market-based awards ▪ ISO/RTO opens the market for scheduling ▪ Telemetry measurement requirements on the resources (MW) Existing services may need modifications to accommodate PEVs	PEVs could provide scheduled energy by simply interrupting charging in response to a signal from an aggregator. The aggregator might have to limit sales in the final hours of the night, for instance, in order to meet commitments to PEV owners for a full charge the next day.	3
Regulation	▪ An aggregator providing regulation service shall be capable of adjusting its charge rate up or down by an amount equal to the regulation amount offered ▪ An aggregator providing regulation must be able to adjust its charge rate by the regulation amount at a rate of R kW/minute. Its rate of change in %/sec must be sufficient to meet regulation service response requirements ▪ An aggregator providing regulation service shall provide a sustained kW contribution (up or down) for RM minutes ▪ An aggregator shall have sufficient regulation service response available to demonstrate compliance to the obligation	There are existing regulating products/services at most ISO/RTOs: ▪ Obligation-based (allocation of Reg requirement) and/or market-based awards ▪ ISO/RTO issues signals for Req Up or Reg Down via telemetry (2-6 sec range) ▪ Typically resource-specific ▪ Telemetry measurement requirements on the resources (MW, Status) Existing services may need modifications to accommodate PEVs	Battery makers are unsure what level of modulation the battery charging can support. Initial feedback is that a roughly 15-second rate is the best they would agree to. Thus PEVs could not provide regulation without very sophisticated algorithms and vehicle-unique communications via an aggregator that ensured this constraint was met. A simple broadcast signal would not suffice unless the regulation signals used were adjusted to avoid more rapid cycling.	3

Services Provided by PEVs	Description of Service Requirements	Map to existing ISO/RTO Products/Services	PEV Possibilities	Complexity 1-easy 5-complex
Reserves	▪ An aggregator providing reserves shall be able to reduce its charging level by SR kW near-instantaneously (with SR/sec) on receipt of a control signal. Note also that a PEV not capable of modulated charging or pulsed charging is nonetheless able to provide reserve by simply stopping charging ▪ An aggregator which responds to a reserve actuation signal must remain "off" for the minimum of SRM minutes or until the reserve signal is rescinded ▪ An aggregator which sells reserves from its PEV base is responsible to have sufficient PEV response available to reduce load by the reserve amount offered above and beyond response offered for regulation services ▪ An aggregator must be able to deliver that reserve from PEV response within SRS sec when requested. ▪ An aggregator shall have sufficient governor response available to demonstrate compliance to the obligation	There are existing reserve products/services at most ISO/RTOs: ▪ Obligation-based (allocation of reserve requirement) and/or market-based awards ▪ ISO/RTO issues calls if more/less reserves are needed ▪ Telemetry measurement requirements on the resources (MW) Existing services may need modifications to accommodate PEVs	PEVs could provide reserves (and other reserve products) by simply interrupting charging in response to a signal from an aggregator. The aggregator might have to limit SR sales in the final hours of the night, for instance, in order to meet commitments to PEV owners of a full charge overnight. The requirement that SR be provided for at least one hour is typical of ISO/RTOs today.	3
Emergency Load Curtailment (ELC)	▪ Aggregators which are not providing reserves or regulation but which are scheduled to be charging may be able to provide load shed capabilities ▪ Such PEVs must accept a signal to stop charging in response to a load shed signal from the grid operator ▪ An aggregator providing load shed service to the grid operator must have scheduled charging available in excess of regulation and reserve so as to be able to reduce aggregate load by the load shed amount	Similar to the demand response energy services and will require adaptation to accommodate PEVs. Telemetry will be required.	The ability to accomplish fast demand response as a form of emergency load shed at a level below the distribution feeder is interesting. This would vary from many existing DR products in that the ISO/RTO, via an aggregator, would be able to accomplish the emergency load shed rapidly and with certainty. This is a kind of second- stage reserve.	3

Services Provided by PEVs	Description of Service Requirements	Map to existing ISO/RTO Products/Services	PEV Possibilities	Complexity 1-easy 5-complex
Balancing Energy	▪ An aggregator capable of altering PEV charging on a real-time basis may offer changes in total PEV charging load into the balancing energy/real-time dispatch market ▪ The aggregator must be able to adjust PEV aggregate charging load down (selling energy) or up (buying energy) in response to dispatch signals ▪ The aggregator must be able to affect PEV charging and respond in aggregate on time scales identical to that of conventional generation.	Some components of this service are similar to existing services but will require modifications to accommodate PEVs. Telemetry will be required.	Conceivably this is a good fit for PEVs at periods when the balancing demands are "balanced" up and down as opposed to long periods when all balancing is in one direction only (such as when the load forecast is off). Hourly schedule transitions are an example of this in many markets and cause balancing price spikes especially at nodes where generation is restricted. PEVs' ability to provide this service could be valuable.	4

3.4 Evolution of ISO/RTO Systems and Information

Due to their unique technical performance, users' behavior, and expected market penetration, PEVs offer new possibilities to the ISO/RTOs. In the process of examining PEV capabilities, the project team identified areas where the ISO/RTOs could enhance their ability to effectively and efficiently interact with PEV aggregators. Considering the current and projected capabilities of PEVs, the project team identified the following potential areas for future development.

Enhanced Aggregation (EA)

Aggregation of PEVs will allow interaction directly with the wholesale electricity markets. Aggregated PEVs would provide the ISO/RTO with a high degree of flexibility in delivering power. To better enable the efficient and economic scheduling of aggregated PEVs, the ISO/RTO would provide pricing information to the aggregator who would schedule the delivery of power to the PEVs with a defined amount of energy over a defined time period. Unlike scheduled energy delivery, for example, EA would provide information to the aggregators so they can decide how much charging occurs in each hour. A PEV which is "off charging" due to scheduling would not be capable of providing regulation or reserve services. This precludes "off" PEVs from providing "down" regulation service.

Aggregators would be responsible for aggregating a cohort of participating PEVs, by zone or node as appropriate for the market. Here, it would be the aggregator's responsibility to manage individual PEV charging to meet committed schedules. A PEV capable of EA must be able to communicate to the aggregator information sufficient to schedule and manage charging. Information required might include the amount of energy required to reach the target charge state at the target time. In addition, other parameters such as maximum and normal charge rate and maximum charge level would be necessary. The parameters afford a number of ways to communicate this information as energy and time, or as current charge level and time, and so on. Standards would be required for models for this information. The PEV then must be able to accept charging control signals to manage its charging to schedule.

There is a consensus building that with large enough PEV penetration, managed charging of some sort will be essential for PEVs capable of Level 2 and Level 3 charging. Whether it is simply a "schedulable demand", as with EA, or an automatic price response, as discussed below, is unknown.

Dynamic Pricing

An alternative to EA is autonomous PEV price response. Under this scenario, the PEV would be exposed to the retail-equivalent hourly prices and the PEV would autonomously determine whether or not to charge given the price in response to an on-board application or some remotely provided signal from an aggregator or charging station. Dynamic pricing is not available to retail loads in today's market, though some ISO/RTOs are pursuing it. Participation will require separate metering for PEV charging or a revenue meter on the vehicle. Vehicle manufacturers are currently designing second- generation PEVs which will have considerable on-board computing power. The applications and level of accuracy (on-board meters) are still in design and this information is not available at this time.

3.5 Likely Modes of Interaction

3.5.1 Introduction

For each of the potentially new products or services that a PEV may provide, the project team developed a business process to examine the interaction between the PEV and the ISO/RTO, and other intermediary parties. In the models analyzed here, a retail entity would not directly interact with the ISO/RTO, but would interface via a registered market participant. This third party could either be a utility or an aggregator who would provide the interface between the ISO/RTO and the end PEV owner. Though the business processes discussed include new offerings, the models are grounded in the current market. As the markets evolve, new participants, such as information management experts, will likely enter the market and interactions may adjust. Given the current emphasis and need for third parties, however, this study assumes their participation when discussing the business processes.

Since the PEV interface to the ISO/RTO is the aggregator, there needs to be a standard interface defined so the ISO/RTO can validate the aggregator and the PEV performance to the awarded product or service. The aggregator and the PEV instruction/charging data will need to be available in a standard model and format for validation and settlement purposes. Actually, this is an important standards concept for both PEVs and DR on how the data will be reported and collected. Additional description of the roles of all stakeholders is provided in Appendix E.

Reserves

The expected interactions for this PEV service would be like interactions for existing reserve products. An aggregator would need to sign up for reserve products with the ISO/RTOs to participate in the market. As such, the aggregator would have to meet obligations as outlined by the ISO/RTO. For many markets, the ISO/RTO will require two-way communication with the aggregator and validation that the reserve award obligation is being met. In return, the ISO/RTO would open bids for A/S products, run the market, and post results to inform the aggregator of any reserve awards. Once the ISO/RTO validates the reserve has been provided, the settlement process is initiated. The ISO/RTO would pay the aggregator, and the aggregator would pay the PEV owner in return.

Regulation

As with reserves, an aggregator would need to sign up for regulation products with the ISO/RTOs and meet obligations to the PEV owner and to the ISO/RTO. For most markets, the ISO/RTO will require two-way communication with the aggregator and validate the regulation award obligation is being met. The ISO/RTO market would open bids for regulation products. The market submittal period then would close, and the IRO/RTO would run the market and post results, informing aggregators of any regulation awards.

The aggregator would receive signals from the ISO/RTO and send charge or stop-charge signals to the participating PEVs. It is expected that the aggregator would continually monitor the obligation versus the actual regulation up and regulation down (i.e., start/stop charging). Any penalties for non-commitment would be assessed by the ISO/RTOs in the settlement process. Here, the ISO/RTO would validate provision of the regulation service. The ISO/RTO would also pay the aggregator, and the aggregator would pay the PEV owner in turn.

Emergency Load Curtailment

For this service, aggregators combine the quick response of individual PEVs to offer larger-scale load curtailment resources for emergency events. Such resources might be contracted by utilities or by the market. Participation by PEV owners might be voluntary. However, mandatory models are also feasible.

As with the other products, aggregators would register with the ISO/RTO or utility to offer a bundled package of demand capacity available for emergency alerts. In turn, the ISO/RTO or utility would provide the ELC. If implemented by the ISO/RTO, a new product would be required that could be bid-based. Before scheduling resources with the utility or ISO/RTO, the aggregator must have an initial estimate of driver usage patterns to forecast the availability of demand as a resource. Initial driver scheduling estimates would facilitate this forecast. Another approach would be for the utility to implement a PEV emergency load reduction program where PEV owners get a break on their electric bills (since the car can move and be charging somewhere else) by signing up for this program. When the need arises for emergency load curtailment, the utility would shed PEV load by sending a signal for the PEV to not charge.

As it does now, the ISO/RTO would monitor system reliability and notify market participants of impending emergency events. In this model, aggregators would then monitor which resources are available for curtailment, possibly notifying drivers. With voluntary ELC, aggregators could confirm commitment from drivers. With mandatory ELC, the aggregators could simply prepare for automatic curtailment.

Barring rectification through other means, the ISO/RTO would then call upon market participants (aggregators or utilities) to activate load curtailment resources. At this time, the aggregator would shut off PEV charging. Where curtailment is mandatory, shut-off would be automatic. Where it is voluntary, drivers could override attempts to limit charging.

With aggregators as the primary interface between PEV owners and the ISO/RTO or PEV owners and utilities, settlements could be arranged with a single load-resource entity. As such, ISO/RTOs or utilities would directly reward aggregators, who would pass on earnings to PEV owners through a variety of means (e.g., single up-front payment, subscription price reduction, follow-on payments). Such settlements could entail payments for service, or even a penalty for non-commitment.

Enhanced Aggregation (EA)

Collecting information on aggregate regional "installed" PEV capacity is vital for forecasting potential demand and procuring the required amount of energy for PEV charging. Data collection can happen through a number of possible paths, such as via PEV sellers, state departments of transportation, aggregators, or charging station installers. Nevertheless, coordination with the ISO/RTOs is key for correctly allocating geographic information to each of the ISO/RTO territories.

As generic PEV schedule forecasts are updated over time to reflect actual PEV preferences, such as pre-planned schedule changes by drivers, aggregators would need to inform the ISO/RTOs. Updated aggregate schedules, for example, could be submitted to the ISO/RTO as bid products. ISO/RTOs could provide pricing signals to permit the aggregator to perform managed charging for its suite of PEVs. Under this paradigm, generation schedules to provide the energy are cleared and established, and the ISO/RTO scheduled transactions at the wholesale level are finalized. Once the ISO/RTO validates that the energy as scheduled has been provided, the settlement process is initiated.

Dynamic Pricing

The utility or the ISO/RTO might serve as the price provider for dynamic pricing. The aggregator would need to register with the utility and the utility or aggregator would inform the ISO/RTO that they want to participate in dynamic pricing. The ISO/RTO could open bids for energy products, run the market, and post results. The dynamic prices would be sent to the utility or aggregator to send to the price-sensitive PEV. If the price is favorable, the PEV participates by not charging the PEV until the price drops or some other owner preference becomes more important.

4. PEV Integration into the ISO/RTO Markets and Systems

4.1 Communications and Information Technology Infrastructure

To help identify technologies for integration of PEVs into the ISO/RTOs, researchers examined the functional requirements for common PEV products. The goal is to derive the common set of functional integration requirements that would be consistently applied to all ISO/RTOs, if feasible, understanding that for existing products the implementation is already defined.

These functional requirements are documented in Table 9. The following requirements are defined:

- Frequency of Communications
    - Command or Instruction From ISO/RTO to the Aggregator
    - Telemetry Reporting from Aggregator (status and validation) to the ISO/RTO
- Latency (delays tolerated) in the communications
    - Aggregator to ISO/RTO
    - PEV/EVSE to Aggregator (EVSE is the Electric Vehicle Supply Equipment)
    - Aggregator to PEV/EVSE
- Energy Usage Reporting
    - Meter Data Reporting Interval (validation)
    - Meter Read Frequency
- Auditing Requirement—identifies if there is a need to verify the identified product is available as advertised.

The assumption for an aggregator is that they are required to obtain a sufficient quantity of PEVs to be able to participate in the ISO/RTO markets.

Table 9. Integration Functional Requirements for Market Products

ISO/RTO PEV Products	Frequency of Communications		Latency (delays tolerated)			Energy Usage Reporting		Auditing Requirement	Notes
	Commands or instruction To Aggregator	Telemetry Reporting From Aggregator	Aggregator to ISO/RTO	PEV / ESVE to Aggregator	Aggregator to PEV / ESVE	Meter Data Reporting Interval	Meter Read Frequency		
Energy - real-time	As scheduled	Scan rate	Less than 1 scan rate	Less than 1 scan rate	Less than 2 seconds	1 hour	Daily		Scan Rate ≤ 6 seconds
Energy - day-ahead	As scheduled	Scan rate	Less than 1 scan rate	Less than 1 scan rate	Less than 2 seconds	1 hour	Daily		Scan Rate ≤ to 6 seconds
Enhanced Aggregation	As scheduled	Scan rate	Less than 1 scan rate	Less than 1 scan rate	Less than 2 seconds	N/A	N/A		
Capacity	As scheduled	Scan rate	Less than 1 scan rate	Less than 1 scan rate	Less than 2 seconds	1 hour	Daily	Yes	Scan Rate ≤ 6 seconds
Reserves	As scheduled	Scan rate	Less than 1 scan rate	Less than 1 scan rate	Less than 2 seconds	Sub-hourly	Sub-hourly	Yes	Scan Rate ≤ 6 seconds
DR as Regulation	Scan Rate	Scan rate	Less than 1 scan rate	Less than 1 scan rate	Less than 2 seconds	Sub-hourly	Sub-hourly		Scan Rate ≤ 6 seconds
Retail Dynamic Pricing Signal	As scheduled, sub hourly or hourly	Scan rate	Less than 1 scan rate	Less than 1 scan rate	Less than 2 seconds	N/A	N/A		
PEV Emergency Load Curtailment	on demand, as needed	Scan rate	Less than 1 scan rate	Less than 1 scan rate	1 scan rate				Scan Rate ≤ 6 seconds

4.2 Settlement and Scheduling Needs

Table 10 captures the issues associated with potentially new products if implemented in the aggregator-based model. Aggregator-based models assume the PEV can participate in the market by aggregating a number of PEVs. An exception might be EA that may be provided by the local utility through a time-of-use (TOU) or dynamic pricing (DP) product for states or areas that provide dynamic pricing rate models to the consumers.

In some ISO/RTOs, the primary interface for scheduling is through a type of market participant called Scheduling Coordinators (SC). These entities have a much broader responsibility than may have been described for an aggregator. For example, all business with CAISO markets, except for acquisition and holding of Congestion Revenue Rights, must be conducted through a CAISO-approved and -registered SC. The primary responsibilities of SCs generally include:

- Representing generators, load-serving entities, importers, and exporters;
- Providing NERC tagging data;
- Submitting bids and inter-SC trades;
- Settling all services and inter-SC trades related to the ISO/RTO markets;
- Ensuring compliance with the ISO/RTO tariff; and
- Submitting annual, weekly, and daily forecasts of demand.

In ISO/RTOs with a SC requirement, the aggregator would need to become a SC for the management of PEV assets, or schedule through an SC.

Table 10. Summary of Settlements and Scheduling Issues

New Potential Product	Aggregator-Based Model	
	Scheduling Issues	Settlements Issues
Enhanced Aggregation (EA)	• Aggregator identifies amount of energy that can be provided in a fixed window of time. o Delivery Location? o Validation of energy delivered? o Scheduling entity – utility or ISO/RTO? o Controls charging/not charging	• Aggregator pays Scheduler for energy o Special utility rate like TOU? o Required metering? o Location of the energy delivery o Aggregator to control the timed energy charging o Validation of energy taken in location and assigned time slot?

New Potential Product	Aggregator-Based Model	
	Scheduling Issues	Settlements Issues
Dynamic Pricing (DP)	• Aggregator provides forecast of demand reduction by price • ISO/RTO issues price signal o By utility or zone?	• Rate structure for DP o Validation of demand reduction o Required metering? o Location of the energy delivery o Separate meter?
Reserves	• Aggregator bids reserves/receives award for a period of time in the market. o Delivery location? o Validation of reserves available during award period?	• Validation of reserve supply capability • Separate meter? • Required metering • Location of the energy delivery
Regulation	• Aggregator bids regulation and receives award for a period of time in the market o Delivery location? o Validation of energy delivered? o Timely implementation of the control signal (within 6 seconds or less)	• Validation of regulation delivered • Required metering? • Location of the energy delivery • Timeliness of energy delivered
Emergency Load Curtailment (ELC)	• ISO/RTO detects emergency condition exists or will exist. o Issue signal to aggregators or utility to curtail PEV charging o Monitor system conditions and release PEVs to resume or start charging	• Paid service or product? • Validation of PEV participation?

4.3 Integration Capabilities with Proposed or Existing Standards

The project team reviewed the integration capabilities of existing standards for interaction between the ISO/RTO and aggregator. This focus was based on research that indicated the following encryption standards and standard communication interfaces with aggregators.

- Recommended standard communication interfaces:

- DNP3
    - ICCP or International Electrotechnical Commission (IEC) 60870-6/TASE.2
    - XML/HTTPS
- Recommended encryption standards
    - Secure ICCP
    - Secure DNP3; compliant with IEC 62351-5 for Secure Authentication
    - HTTPS with digital certificates

All of the above identified interfaces are based on international standards, either by a standards organization like IEC or widely held user group like DNP. Appendix F provides a summary of communication and IT standards by ISO/RTO. No gaps exist for the above list.

In addition to the identified communication interfaces and security requirements (including standards in development for smart grid and the NERC CIP 002-009 Standards), there are other integration requirements either not covered or partially covered by existing standards or developing standards. These include:

- **Scan rate and visibility—** frequency of communication between the ISO/RTO and aggregator and upon establishing communication, its continuously provide with the ISO/RTO;
- **Continuity of operation**—Aggregator is responsible for assuring 1) the functionality of its entire telemeter system, and 2) the integrity and accuracy of data telemetered to the ISO/RTO;
- **Telemetered data requirements—**type of data exchanged between the ISO/RTO and the aggregator;
- **Metering requirements—**metering requirements for the aggregate load and validation to the individual components of the load; and
- **Availability and reliability requirements**.

The *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0.*, has identified several areas where standards work is active. The IRC project team recommends that IRC participate in several areas such as:

- "Common Definition Price and Product Definition"
- "Common Scheduling Mechanism for Energy Transactions"
- "Standard Demand Response Signals"

- “Energy Storage Interconnection Guidelines”
- “Interoperability Standards to Support Plug-in Electric Vehicles”

The project team highly recommends continued and expanded participation by the IRC in ongoing and future standards development, which will define common interfaces for integrating PEVs into the electric system. The IRC currently has members who are participating or working on PEV or smart grid standards with NIST and SAE. In particular, the IRC has sent representatives to NIST initial working meetings to plan smart grid standards, some of which address the interface between the ISO/RTOs and aggregators.[8] A continued effort is needed to ensure the recommended standards are included in the smart grid interfaces. In addition, the IRC project team members joined the EPRI National Transportation Council PHEV Working Group, which is working with manufacturers and third parties to develop standards for the interface between the PEV and the utility or third parties. The evolving standards defining the interface between the aggregator and the ESVE/PEV are:

- SAE J1772 Standard for Electric Vehicles Supply Equipment (EVSE). (In parallel, the IEC is developing the IEC 61851 electric vehicle conductive charging system, and IEC 62196 plugs, socket-outlets, vehicle couplers and vehicle inlets - conductive charging of electric vehicles)
- SAE J2836 use cases and J2847 standards for electric supply to the PEV, which addresses communications between vehicles, EVSEs, and utilities, and secure communication to a billing entity.

In addition, the project team recommends that the IRC monitor the development of an IEEE P2030 Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System and End-Use Applications and Loads. This IEEE P2030 standard will focus on integrating energy technology with information and communications technologies to achieve seamless operation for electricity generation and delivery. It will define key elements of the modernized grid and tap into IEEE’s existing grid standards, such as IEEE 1547. IEEE Standards Coordinating Committee 21 is sponsoring the standard.

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[8] IRC participants were able to get the recommended standard interfaces included in the initial NIST list of 16 supported smart grid standards applicable to the ISO/RTO interface.

4.4 Commonality across ISO/RTO Markets

Generally, the rules and processes for non-demand response products are relatively consistent across products. For example, minimum capacity requirements tend to be 0.1 MW for capacity services and 1 MW for other products, though there is some variation across markets. (Capacity requirements can vary from none to 5 MW, depending on the market and product). Also, location appears to be monitored in most markets. However, several characteristics vary notably across markets and products. For example, non-response penalties and acknowledgement also vary across ISO/RTOs. Appendix G outlines some of the commonalities and differences across non-DR markets.

ISO/RTO DR products vary more widely, with differences occurring within a product type as well as across ISO/RTO markets. For example, minimum capacity requirements or ramp periods vary amongst products in some markets. While most markets have minimum capacity requirements, the minimum size requirements range considerably. DR products have limits that range from 100 kW to 1 MW, with the exception of one market which does not have minimum size requirements. Also, some emergency DR products do not have advanced notification, while other markets' emergency DR products do. Appendix G also outlines the main DR products and services provided by North American ISO/RTOs and highlights notable differences between markets. Overall, DR service/products rules/processes are similar to their non-DR product counterparts, but have some variation among the products offered.

Table 11 compares the PEV-related market products and services to the existing ISO/RTO market offerings and rules, noting variations and potential issues to resolve. Common concerns include addressing the locational aspects of PEVs as a mobile resource, product/service validation, and aggregation size limits. With regard to aggregation size, DR products and services using load as a resource appear to be a good starting template for new rules and processes for PEV-related services. Currently, DR products and services provide a variety of functions in the ISO/RTO markets including energy, reserves, capacity, and regulation. For a full list of DR and non-DR products and services considered, please see appendices H and I.

Table 11. PEV Products & Services Integration

PEV Product/Service	Market Variations	Issues to Resolve
Enhanced Aggregation (EA)	• Few to no rules or examples appear to exist today • Location: Not all markets monitor location nor have the capability to support monitoring of portable location • Validation: Non-response penalties and acknowledgement requirements vary by ISO/RTO	• Energy market is hourly in most ISO/RTOs, and does not plan energy services across multiple hours - Forecasting of PEV loads - Capacity aggregation necessary • Location requirements needed • Information required by aggregators • Validation: validation of timing and amount of energy received • Penalty: liability for price impacts resulting from schedule deviation
Dynamic Pricing (DP)	• Few to no rules exist today • Examples are available - Several utilities and retailers use DP - Demand response products in several ISO/RTOs use day-ahead and real-time pricing to trigger responses with limited to no advanced notification	• Price publication - Day- and hour-ahead? - Internet-based communication? • Translation from wholesale LMP to retail price • Notification: the frequency of price signals and whether to give advanced notice are important decisions to be determined • Forecast of load impact based on PEV owner response to price signals
Reserves	• Some markets currently allow demand response resources to provide regulation services • However, reserves products exist for the majority of markets • Demand response as a resource for reserves exists in multiple markets and could serve as a starting template for PEV products	• Aggregation - Minimum size requirements vary across products. PEV products might offer lower requirements to encourage participation. • Location - Geographic constraints are feasible if PEVs are the sole fast reserve source. Determining aggregation size by location will be important • Restoration of charging: given changes in time scales, this area should be considered further • Validation: the time horizons of the current markets vary; which is appropriate for PEVs?
Regulation	• Some markets currently allow demand response resources to provide regulation services • Current validation requirements vary across ISO/RTOs • Current minimum size requirements are generally 1 MW with the exception of one ISO/RTO that has no requirement	• Aggregation: what minimal aggregation size requirements are appropriate, if any? • Validation: what validation methods and time horizons are appropriate? • Location - Geographic information is important, especially if fast regulation resources are limited geographically
Emergency Load Curtailment	• Markets have emergency services • Examples of DR resources providing emergency services exist in multiple markets	• Questions about minimum PEV aggregation to be a reliable resource and sufficient notification times (in part to determine PEV aggregations by location) will need to be investigated, though examples to start from appear to exist

5. PEV First-Stage Products

5.1 Prioritization of Products and Services

The project team developed recommendations on first-stage products for PEVs, including a prioritization of existing product categories and identification of high-potential new products. To prioritize PEV products, researchers considered:

- the value of the services;
- the feasibility of provision by PEVs;
- the critical mass required; and
- the complexity and cost of necessary infrastructure investments.

The interaction of PEVs with the grid will likely evolve over time as technology infrastructure develops, penetration of PEVs increases, experience accumulates, and supporting regulatory policy is developed. As such, the analysis considered five interaction scenarios of varying complexity. These scenarios include:

- **Simple Management of PEVs as Charging-only or Reliability Assets**—This scenario assumes that simple charging management strategies such as TOU or critical peak pricing are available to incentivize PEV owners to limit PEV charging to off-peak hours. It also assumes the ability of aggregators to curtail PEV loads during emergency periods identified by the ISO/RTOs.
- **Complex Management of PEVs as Charging-only or Reliability Assets**— As PEV penetration increases and driving patterns become familiar, charging stations proliferate and aggregators begin to gather predictable blocks of PEV load. Aggregators interact more regularly with ISO/RTOs by providing data to help with regional forecasts.
- **PEVs as Charging and Discharging Reliability Assets**—With advancing electronic technologies and more experience, PEVs begin discharging back to the grid in addition to charging from the grid. Geographic information becomes more important.
- **PEVs as Price-Sensitive Demand**—Here, PEVs begin to participate in ISO/RTO markets with one-way managed charging. ISO/RTOs provide market signals and PEVs provide information to aggregators regarding willingness to pay. PEVs act as a price-sensitive demand, and aggregators and ISO/RTOs monitor geographic and temporal variations in price. Adjustments to market rules are required and high-quality metering is required.

- **PEVs as Ancillary Market Assets**—PEVs with two-way charging capabilities offer resources to the ISO/RTO markets. Two-way real time communications helps to manage interactions in this most complex scenario.

Several products or services are recommended for initial deployment based on a combination of their potential usefulness to the ISO/RTO and the likely response from aggregators and end consumers. In the phase implementation approach, the initial products and services are characterized by minimum infrastructure required and support of grid reliability. They include:

- Emergency Curtailment
- Dynamic Pricing
- Enhanced Aggregation

As the PEV penetration increases and additional infrastructure is installed, the market products providing value to the ISO/RTO and aggregators include regulation and reserves.

Other PEV products and services may evolve and eventually become part of the offerings available to the market. Such second-tier products and services include energy and capacity.

5.2 First-Stage Product Descriptions

This section provides a description of the first-stage products and services.

Emergency Curtailment

The ability of PEVs to stop charging and reduce load on a targeted basis and in very short time frames creates an opportunity for the ISO/RTO to take advantage of PEV characteristics. It is suggested that the PEVs' emergency curtailment be submitted by the IRC as a mandatory reliability service rather than as a market product.

Dynamic Pricing

The Markets Committee believes that establishment of a DP regime for PEV charging is also a very high priority. A DP product would require the ISO/RTO to publish the hourly prices on a day-ahead or hour-ahead basis to the PEV loads and then the PEVs or aggregators would autonomously determine when to charge. PEV DP is also seen as one way to introduce DP to consumer-level loads without raising some of the serious political sensitivities around DP for household application in some jurisdictions. DP for PEV will require that each load-serving entity or distribution utility provide a basis for adding transmission and distribution tariffs and uplifts to the wholesale price to achieve the retail-equivalent price. As the PEVs will normally be exposed to varying uplift tariffs based on where they are charging, some provision for communicating the locational pricing to the PEV is required, either via the charging station or through utilization of an in-vehicle global positioning system. The former seems more practical and reliable, and would be required in any case to support billing services. The Markets Committee also believes that extension of Dynamic Pricing to include real-time dispatch or balancing market energy price signals to PEV load is a distinct possibility, which would make use of the same infrastructure. One technical challenge the ISO/RTO community will face is the forecasting of load price elasticity for use in the SCUC market-clearing algorithms. However, an introduction of DP to a relatively small PEV load set initially will make it possible for development of methodologies and protocols well before the PEV load subject to DP is significant.

Enhanced Aggregation

The potential for PEV charging load to concentrate in the early evening as a result of normal commute patterns may affect market and system operations adversely. Therefore Enhanced Aggregation is seen as a very high priority. Aggregators are planning to be able to collect sufficient numbers of consumers with PEVs to provide enhanced aggregation. At least one investor-owned utility has issued a request for proposals for charge management software that contemplates this service, and several automotive manufacturers have announced that their PEVs will support managed charging. So it would seem that the PEV community expects to be able to offer this to consumers. EA could be a useful product for the aggregators as it could help them with managing retail load risk. In addition, being able to optimize energy over a multi-hour period gives the ISO/RTO additional flexibility. Providing this product will require the aggregators to optimize the delivery of power to the PEVs with information received from the ISO/RTOs. The aggregator’s algorithm would have to be able to manage total energy delivery over a window of hours so as to exploit the additional flexibility offered by the EA product. There is also the issue that in the later years when penetration of PEVs is higher, it may be necessary from the ISO/RTO perspective to have to have the aggregators support the managed charging of PEVs. Therefore, getting the PEV OEMs, EVSE developers, and aggregators to build out the software capabilities for managed charging early in the process is to the ISO/RTOs’ advantage. This product is complementary to the TOU functionality planned for some PEVs. It is also potentially linked to a DP regime.

Regulation

The amount of PEV load available for regulation in the next few years will not greatly increase the amount of total regulation to the ISO/RTO markets nor will it affect its price in general. However, the regulation market is one that has already attracted the attention of the PEV community as a result of PJM's pilot efforts with the Mid-Atlantic Grid Interactive Car Consortium (MAGICC). The regulation market is one that can generate revenues for participants fairly predictably, which is why the storage community has enthusiastically pursued it. Because regulation will require low latency communications from the aggregator to the PEV and a means for the aggregator to provide measurement and validation to the ISO/RTO, it will also serve to flush out the infrastructure issues associated with these requirements and lay the ground for subsequent PEV market participation in other products. Inquiries of several automotive manufacturers indicated that PEV designs today typically provide for a 2- to 30-second cycle of the charging system from full charge to full discharge; this is a parameter driven by normal driving conditions. In practice, ISO/RTO AGC systems normally issue regulation up and regulation down instructions in line with the normal PEV battery usage design. However, it may be necessary to ensure that regulation signals sent by PEV aggregators to the PEVs are in line with the battery usage design.

Reserves

The ability of PEVs to stop charging and reduce load on a targeted basis creates an opportunity for the ISO/RTO to include PEVs into its set of reserve product resources. It also sets the stage for parallel DR reserve products in which smart grid technologies allow aggregators to stop air conditioners, water heaters, and other loads rapidly as well. Expanding the use of demand response as a resource could enhance grid reliability in the presence of high renewables penetration and thus could be very useful to the ISO/RTO. Therefore, the recommendation is for PEV reserve provisions to fit within existing reserve product definitions. This includes the typical requirement that the resource be able to maintain output for up to one hour. Thus, the PEV aggregator offering reserves must be able to manage the charging load reduction for up to one hour, either by keeping PEVs off charging for that time period or by shifting PEVs from charging to not charging in a synchronized way so as to maintain the response. Validation in such a case will require special-purpose record keeping by the aggregator. As with any demand response providing reserves, before-the-fact validation so as to ensure that a critical reliability product will perform when called upon must also be addressed.

Recommended for Future Consideration

The following PEV products were considered but not recommended as initial PEV products. They can be included in the second tier of products.

Energy—Grid reliability, ancillary services, and DP products were seen as more beneficial initially than other types of energy resources.
Capacity—Existing or planned DR capacity markets are seen as adequate.

5.3 Infrastructure Required for First-Stage Products

5.3.1 Introduction

This section outlines a fundamental set of functional requirements necessary to enable PEV products and services. The interaction of PEVs with the grid will likely evolve over time as technology develops and experience accumulates, as presented in Section 5.1.

To develop the functional requirements, the project team made the following assumptions:

- ISO/RTO communications with PEVs are through PEV aggregators who manage blocks of PEV assets.
- Communications between the ISO/RTOs and PEV aggregators is secure and uses existing ICCP, DNP and Web Services standards.
- Communication between the PEV aggregator and individual assets is managed by the aggregator and include different methods.[9]
- Large-scale deployment of AMI Smart Meter technology and broadband intelligent metering becomes prevalent.

The following sections detail the scenarios considered, note critical information transactions, and discuss likely infrastructure needs. Appendix J provides a full description of the infrastructure scenarios.

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[9] Through NIST and other standards coordination efforts, the ISO/RTOs will explore opportunities to develop unified standards for this 'last mile' communications.

Simple Management of PEVs as Charging-Only or Reliability Assets

Little new ISO/RTO infrastructure is likely needed for this phase. Rather, the ISO/RTO might make some IT infrastructure investments if it chooses to forecast PEV load. Instead, investments center on local government, utility and homeowner investments in charging infrastructure and grid upgrades.

Complex Management of PEVs as Reliability Assets

Aggregators are likely to develop automated charging strategies in conjunction with other managed charging mechanisms such as dynamic pricing. This requires increased communication capabilities with PEVs. In addition, aggregator-ISO/RTO interactions are likely to increase with aggregators communicating detail on load assets, such as charging location, capacity, and voltages. This enables ISO/RTOs to monitor PEV loads and assess potential reductions available during peak demand or emergency periods. Reliable, secure communications between ISO/RTOs and aggregators is necessary in this phase. Increased metering is likely.

PEVs as Charging and Discharging Reliability Assets

Because net energy is being transferred between the grid and the PEV battery, tracking of battery state of charge and total capacity is necessary. In addition, aggregators must organize and communicate both charging and discharging signals. ISO/RTOs will likely receive information on cumulative charge and discharge, and the ability of PEVs to follow a signal. In addition, resource IDs for charging stations and PEVs are feasible, enabling PEVs to charge while roaming. Under this scenario, the expansion of IT infrastructure to handle more ICCP/DNP feeds is likely. Dispatch optimization and commitment and contingency analysis are necessary in this phase, and will require infrastructure.

PEVs as Price-Sensitive Demand

Demand from PEV charging is likely to be both interruptible and non-interruptible. Both cases require the ISO/RTO to send price signals to aggregators. Both cases also involve the communication of demand/price points for PEVs, coordinated by aggregators. Where demand is interruptible, market price may be impacted. In this case, real-time communication to the ISO/RTOs is critical. The ISO/RTOs will likely need additional IT infrastructure to integrate PEVs as price-sensitive demand assets within existing or new market-based optimizations.

PEVs as Ancillary Market Assets

Where PEVs offer charging and discharging as a resource into the ISO/RTO markets, aggregators must ensure a minimum capacity to participate. Two-way, real-time communication is required to provide verification of the response and participation of the aggregated PEVs to the ISO/RTO market signal. The ISO/RTOs will likely need additional IT infrastructure to integrate PEV assets as market assets within existing or new market-based optimizations.

5.4 High-Level Cost Estimates for Infrastructure Investments

5.4.1 Introduction

After identifying the type of investments necessary to integrate the initial PEV products and services, the project team estimated incremental investment costs. These costs include:

- ISO/RTO upgrades in market systems to support PEV-type aggregators;
- ISO/RTO infrastructure expenditures to support PEV aggregators and enhance system reliability; and
- Aggregator expenses to comply with ISO/RTO requirements for PEV resources.

The discussion below details the assumptions and estimates for each.

5.4.2 ISO/RTO Market-Related Investments

The project team estimated the investment required by the ISO/RTOs to incrementally upgrade their market systems to support PEV aggregators. This estimate includes incremental expenses for new hardware and software, as well as staff costs. Assuming that a PEV aggregator would likely support 800 to 1,000 end-point devices, the project team estimated hardware and software costs at up to $265,000. The actual cost per ISO/RTO may be slightly more or less, in part depending on whether it already has the capacity to support PEV-type aggregators or whether it would require new vendors to adapt the existing systems. The project team estimates that the cost of staff resources to help integrate PEV aggregators into the existing markets would be between $600 and $3,000 per aggregator. These staff costs include hours for such tasks as modeling, training, testing, and performance evaluation.

5.4.3 ISO/RTO Reliability-Related Investments

To estimate the cost of incremental upgrades necessary to improve ISO/RTO reliability, the project team considered how much additional infrastructure would be needed to support up to 250 aggregators. Each aggregator is assumed to have 15 data points for data exchange between it and the ISO/RTO. The total incremental cost to ISO/RTOs is estimated at approximately $80,000, broken down as follows:

- Two redundant servers: $20,000
- Network infrastructure: $5,000
- SCADA link engineering: $20,000
- Project management: $15,000
- Upstream impacts on EMS: $20,000

Communications would add additional costs. Redundant frame relay/ISDN for ICCP or DNP3 is expected to cost about $400 to $2,000 per month. ISP using DNP3 over Internet is estimated at $80 per month.

5.4.4 Aggregator Investments

In addition to ISO/RTO costs, the project team estimated the cost to aggregators for aggregating PEV loads. Again, the project team assumed roughly 800 to 1,000 PEVs per aggregator. The project team also assumed roughly ten data points per PEV. The total estimated incremental cost per aggregator is $70,000. This total cost breaks down as follows:

- Server: $10,000
- Network infrastructure: $5,000
- Engineering: $20,000
- SCADA software $15,000
- Project management: $20,000

6. Conclusions and Recommendations

Overall, the projected electrification of light-duty vehicles in North America poses a challenge to the electricity grid while also offering unique opportunities. The management of PEV charging, at a minimum, can limit the impact of new PEV loads on the grid and, at its best, provide new resource sources. To gauge the potential impacts, services, and needs of PEVs, the project team conducted an interdisciplinary analysis based on the best available information.

Comparisons of PHEV and PEV characteristics indicate that historical PHEV penetrations (such as those of the Prius) might be good predictors for PEV penetration. Based on these historical data and population estimates, the project team believes that high concentrations of PEVs are likely initially in cities and coastal regions. Furthermore, the assessment indicates that PEVs are likely to develop in concentrated pockets such that they may easily aggregate to form significant loads. An additional assessment of PEV capabilities confirms the hypothesis that, through managed charging, PEVs could potentially provide significant demand-response resources. This is true even when the total market penetration is under one million PEVs. In fact, an initial assessment of potential PEV price impacts indicates that without developing tools to manage charging, some regions could face wholesale price increases up to 10% in peak periods. Additional market penetration beyond one million PEVs would likely increase the regional PEV load and price impacts.

As a result of the assessment of PEV capabilities, several products or services are recommended for initial deployment based on a combination of their potential usefulness to the ISO/RTOs and the likely response from aggregators and end consumers. A phased implementation approach is recommended by selecting the initial products and services which are characterized by less infrastructure required and support of grid reliability. They include:

- **Emergency Load Curtailment (ELC)**—PEVs are able to provide a quick-response load-curtailment resource that may be aggregated for maximum effect for emergency events. Due to relatively simple mechanisms for engaging this resource, and the large benefit of doing so, emergency load curtailment of PEV charging is a likely near-term product.
- **Dynamic Pricing (DP)**—Dynamic pricing might be a way to accomplish the charging of PEV batteries in off-peak hours. However, further research on consumer behavior is necessary to understand how a PEV owner will respond to retail price differential. In addition, PEV-specific dynamic pricing may be one way to introduce dynamic pricing to

consumers while avoiding political sensitivities regarding dynamic pricing for existing retail loads.

- **Enhanced Aggregation (EA)**—The potential for high concentrations of PEV loads in the evening makes managing charging over the day a priority for the ISO/RTOs. Some aggregators, automakers, and information management groups appear to be proactive in developing scheduling capabilities. This product is complementary to time-of-use programs such as those typically offered by retail utilities. It could also be potentially linked to a dynamic-pricing product.

As the PEV penetration increases and additional infrastructure is installed, the following market products can provide value to the ISO/RTOs and aggregators:

- **Regulation—**Expected PEV load in the next few years is not likely to have a large impact on the amount of total regulation in the ISO/RTO markets or regulation-market prices. However, the regulation market is attractive to PEV stakeholders since it can generate fairly predictable revenues. In addition, the relatively simple but new communication requirements for this product make it a good trial for subsequent PEV products and services.
- **Reserves**—PEVs are able to provide reserve resources with relatively simple control of PEV charging. Furthermore, this product appears to complement upcoming developments in demand-response (DR) resources as a result of smart grid developments.

Other PEV products and services may evolve and eventually become part of PEV offerings, such as capacity and other energy products.

For several potential PEV products, aggregators will serve as liaisons between ISO/RTOs and individual PEVs. In particular, the ISO/RTO will communicate to a utility or aggregator that would in turn communicate to a PEV resource. This requires dedicated communications between the ISO/RTO and aggregator and communications capability between the aggregator and a PEV resource. In addition, the PEV resources would communicate directly with an aggregator. PEVs have local on-board intelligence so they can provide the requested information to the aggregator either in response to an aggregator request, as a planned service, or as part of some other agreed-upon communication scheme. The ISO/RTO would require the visibility of the aggregator-processed data and would not monitor the PEV resources directly. Prior to signaling, the ISO/RTO would likely want to rely on the aggregator to validate capacity to be provided. For post-instruction validation, the ISO/RTO would rely on a statistical analysis of take-out point capacity and aggregator-collected data from the PEV resources.

Because PEVs are mobile loads, and because aggregators will serve as liaisons between PEVs and ISO/RTOs, consistency across ISO/RTOs is a concern. As such, standard processes, including validation and settlement processes, and common communication protocols, including security requirements and communication interfaces, are desirable. Therefore, the project team recommends continued participation by the IRC in ongoing standards development, such as with SAE, NIST, NAESB, IEC and IEEE. The project team also recommends ISO/RTO investments in IT and communications infrastructure to meet the unique needs of PEV resources and aggregators and ultimately to enhance system reliability and enable participation of PEV resources in ISO/RTO markets.

As the market progresses and technologies develop, users of this study should check observed trends against analysis assumptions. Conducting near-term studies will help demonstrate concepts presented in this paper and gather new information before PEV numbers grow large. Testing might also assist in the ongoing development of relevant standards. Furthermore, better understanding of driver behavior is needed to help gauge which tools are appropriate for managing PEV loads and mitigating potentially negative impacts. For example, it is not clear to what extent electricity price signals can elicit sufficient driver responses, especially where transitions to PEVs result in significant fuel-cost savings. Experience with smart grid technologies and use of load as a resource in tandem with such testing and demonstrations will be an invaluable way to prepare for the unique changes predicted to arrive with PEVs.

7. Glossary

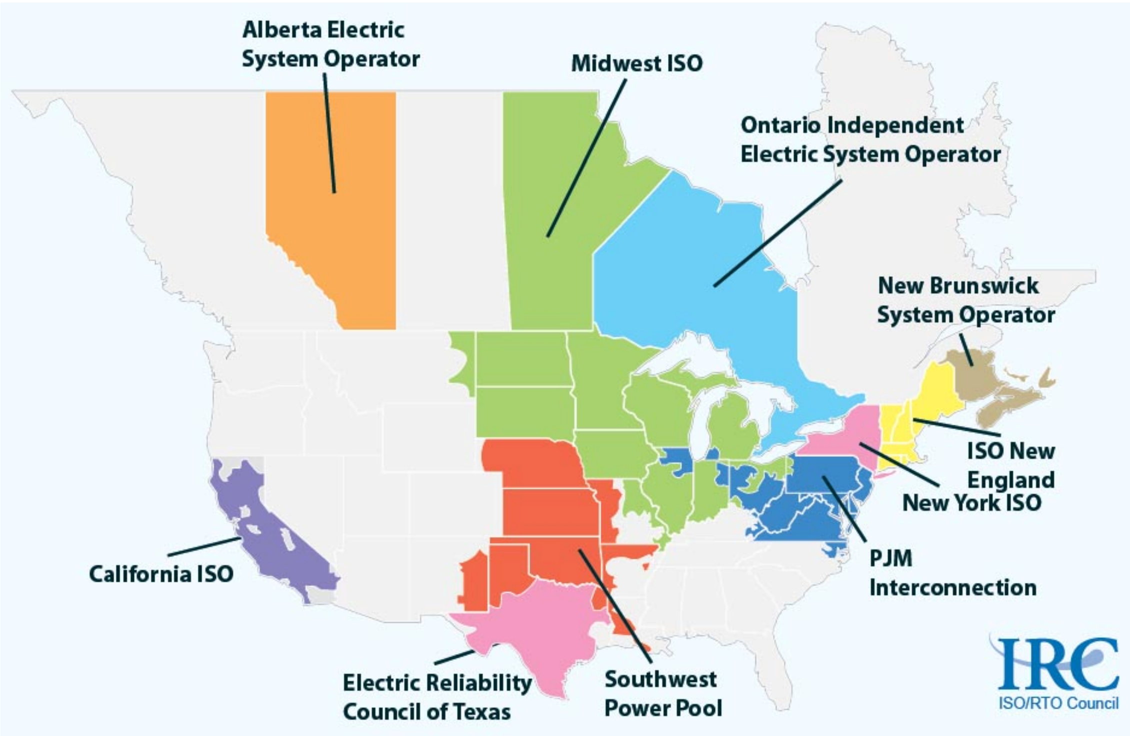
A/S	ancillary service
BEV	battery electric vehicle
CAISO	California Independent System Operator
CPP	critical peak pricing
DLC	direct load control
DNP	distributed network protocol
DP	dynamic pricing
ELC	emergency load curtailment
ERCOT	Electric Reliability Council of Texas
EREV	extended-range electric vehicle
EVSE	electric vehicle supply equipment
HTTPs	Hypertext Transfer Protocol Secure
ICCP	Inter-control center communications protocol
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IRC	ISO/RTO Council
ISO	independent system operator
ISO-NE	Independent System Operator of New England
kW	kilowatt
kWh	kilowatt-hour
MW	megawatt
MWh	megawatt-hour
NAESB	North American Energy Standards Board
NIST	National Institute of Standards and Technology
NYISO	New York Independent System Operator
OEM	original equipment manufacturer
PEV	plug-in electric vehicle
PF	power factor
PHEV	plug-in hybrid electric vehicle
RTO	regional transmission organization
SAE	Society of Automotive Engineers
SC	scheduling coordinator
SPP	Southwest Power Pool
SUV	sport utility vehicle
V	Volt
VAC	volts alternating current
V2G	vehicle to grid
Whr	watt-hour

8. About the ISO/RTO Council (IRC)

Created in April 2003, the ISO/RTO Council (IRC) is comprised of 10 independent system operators (ISOs) and regional transmission organizations (RTOs) in North America. These ISOs and RTOs serve two-thirds of electricity consumers in the United States and more than 50 percent of Canada's population. The IRC works collaboratively to develop effective processes, tools, and methods for improving competitive electricity markets across North America. The IRC's goal is to balance reliability considerations with market practices, resulting in efficient, robust markets that provide competitive and reliable service to electricity users.

The Council's member organizations include the Alberta Electric System Operator (AESO); California Independent System Operator (CAISO); Electric Reliability Council of Texas (ERCOT); Ontario's Independent Electricity System Operator (IESO); ISO New England, Inc. (ISO-NE); Midwest Independent Transmission System Operator, Inc. (Midwest ISO); the New York Independent System Operator (NYISO); New Brunswick System Operator (NBSO); PJM Interconnection, L.L.C. (PJM); and the Southwest Power Pool, Inc. (SPP).

For more information, please visit www.iso-rto.org.



Appendix A. OEM Announcements

Table A-1 summarizes recent PEV announcements by PEV manufacturers, by year.

Table A-1. PEV Announcements by OEM and Year

Year	OEM	Vehicle Type	Vehicle	Battery Manufacturer	Battery Size	All-Electric Range	Charger Type	Expected Volume
2009	Tesla	BEV	Roadster	Tesla		250 miles		Very limited production
	Fisker	PHEV	Karma (sedan)			50 miles		Planned to reach 15,000/yr Just secured DOE 136 money.
	Toyota	PHEV	Prius	Panasonic	?	10 miles	120 v 15 amp, 240 v 30 amp	Introduction, limited 2010 sales
2010	GM	EREV	Chevy Volt	LG/GM	16 kWh	40 miles	120 v 15 amp, 240 v 30 amp	Limited sales, expected to be initially 10,000/yr.
	GM	PHEV	*TBD*	LG/GM	8 kWh	TBD miles	120 v 15 amp	Limited sales, TBD
	Ford	PHEV	Escape	JCS		30 miles	120 v 15 amp, 240 v 30 amp	Electric utility PHEV demo
	Ford	BEV	Transit Connect (BEV Van)					Battery EV commercial van
	Chrysler	BEV	Dodge Circuit	A123 Systems	30 kWh	150-200 miles	120 v 15 amp, 240 v 30 amp	2-passenger, high performance
	BYD (China)	PHEV	F3DM	BYD	25-35 kWh	60 miles	Type 2 (?)	First release in China, U.S. in 2010
	BYD (China)	BEV	E6	BYD		180 miles		Release in China
	Think	BEV	Urban runabout (2-seater)			112 miles		First year in U.S.- 2,500 cars; eventual plan is 60,000/year
2011	Nissan	BEV	Leaf	Nissan/NEC JV	25-30 kWh	100 miles		40,000 vehicles for each of 1st 2 years
	Ford	BEV	Focus based.			~100 miles (TBD)		
	Tesla	BEV	Model S (sedan)	Tesla		150-300 miles		
2012	Ford	PHEV		JCS				

Notes:

1 Chrysler's ENVI division has announced that it is developing five different EV models; the Dodge Circuit will be released in 2010; no dates have been announced for the other vehicles

2 BYD has indicated that it intends to produce as many as 300,000 EV vehicles for the global market by the third year of production.

3 Ford's plans include the 2010 BEV Transit Connect van in conjunction with Smith Electric, and the 2011 BEV developed in conjunction with Magna (Canada), and demonstrated on a Ford Focus platform; Ford has not announced the platform for that vehicle; JCS has been announced for the PHEV demonstrations, but no announcements have been made for commercial vehicles; total production in the range of 10,000 vehicles has been discussed
4 For PHEVs, since the engine is generally running, "all electric range" may not be a valid measure of performance
5 Other than the numbers above, OEMs have not announced production targets

Appendix B. Cumulative PEV Projected Sales by ISO/RTO Region

The following figures depict projected PEV sales by ISO/RTO region and by scenario.

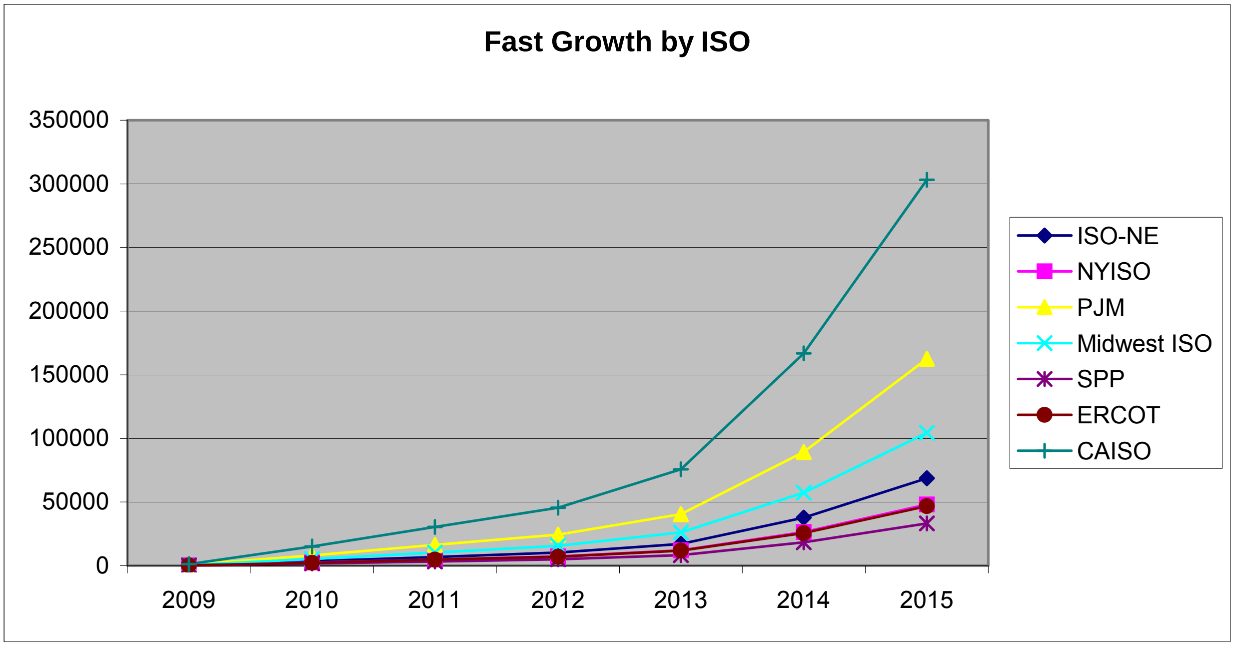


Figure C-1. PEV Penetration by ISO/RTO, Fast Growth Scenario

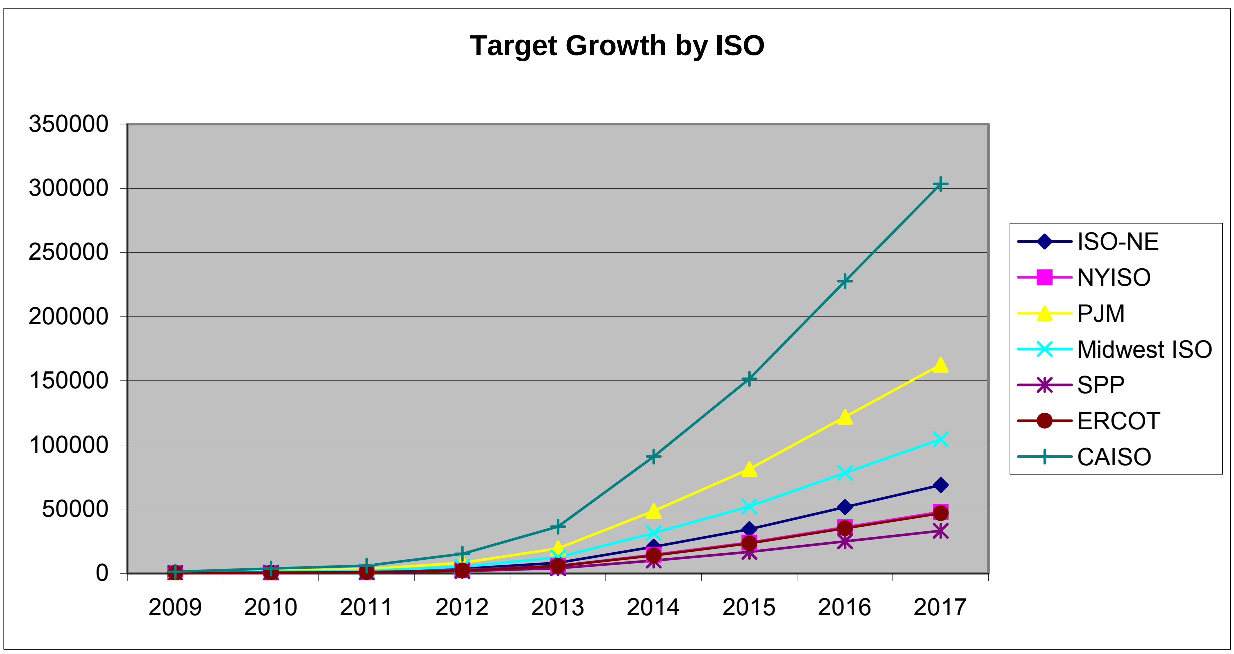


Figure C-2. PEV Penetration by ISO/RTO, Target Growth Scenario

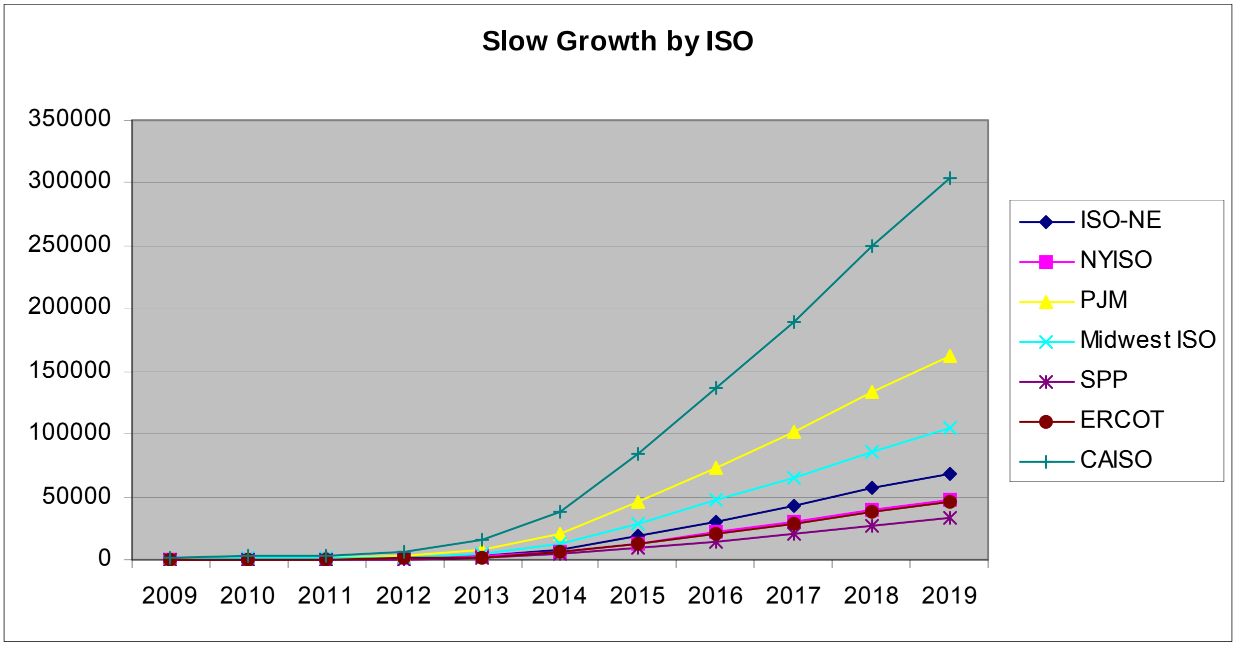
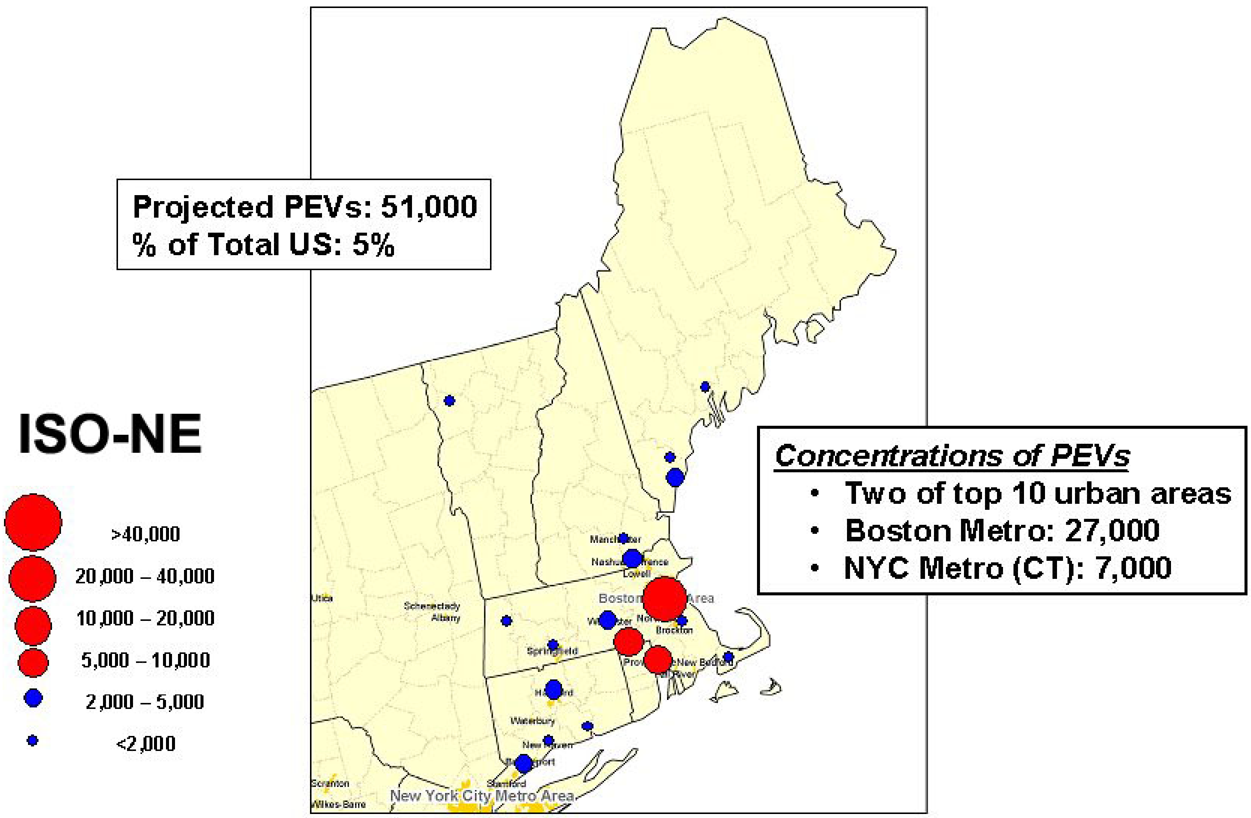
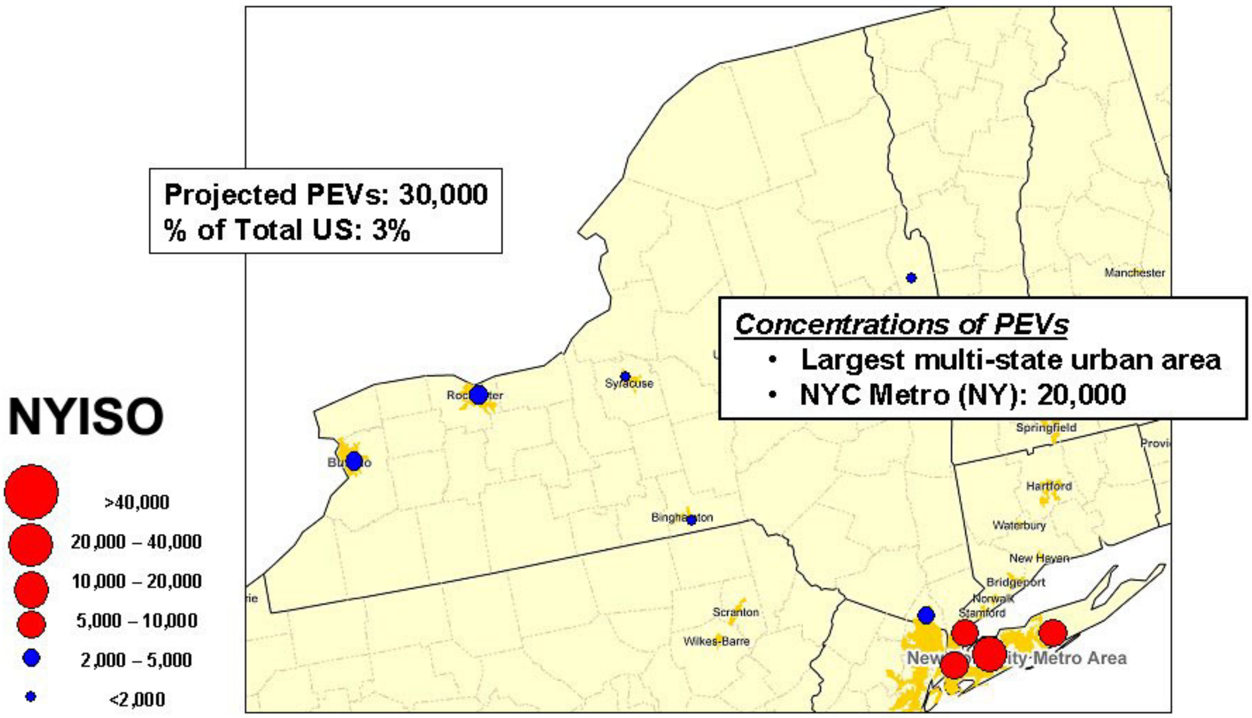


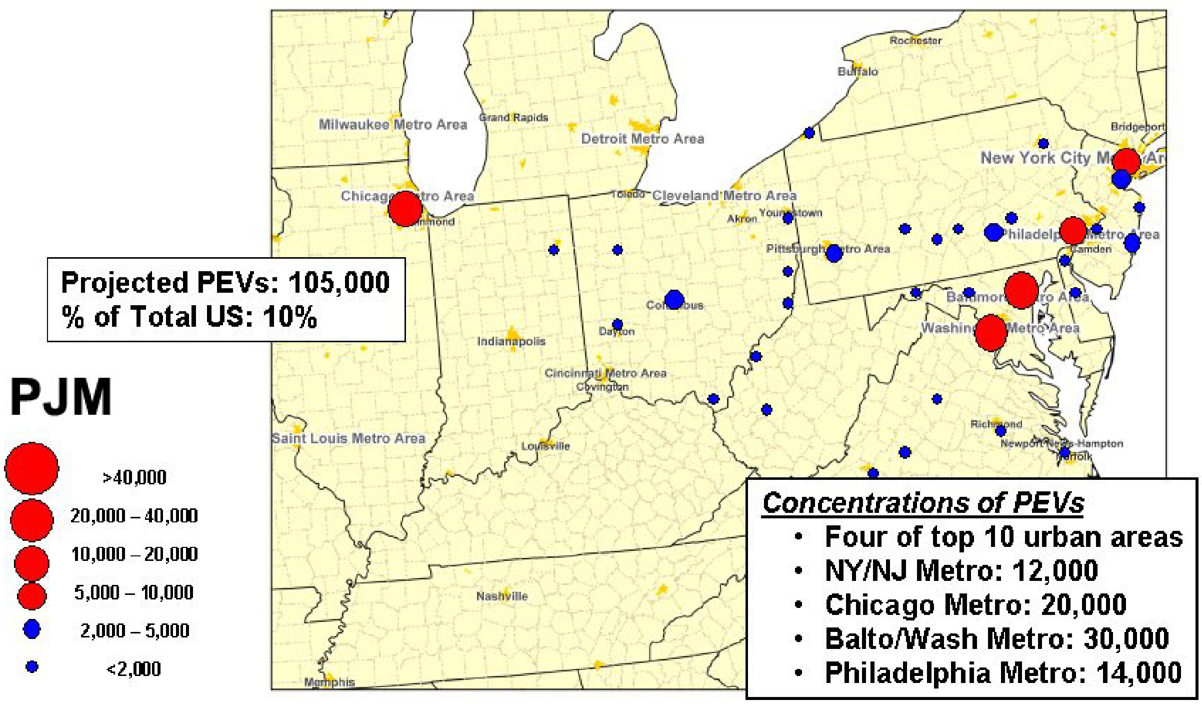
Figure C-3. PEV Penetration by ISO/RTO, Slow Growth Scenario

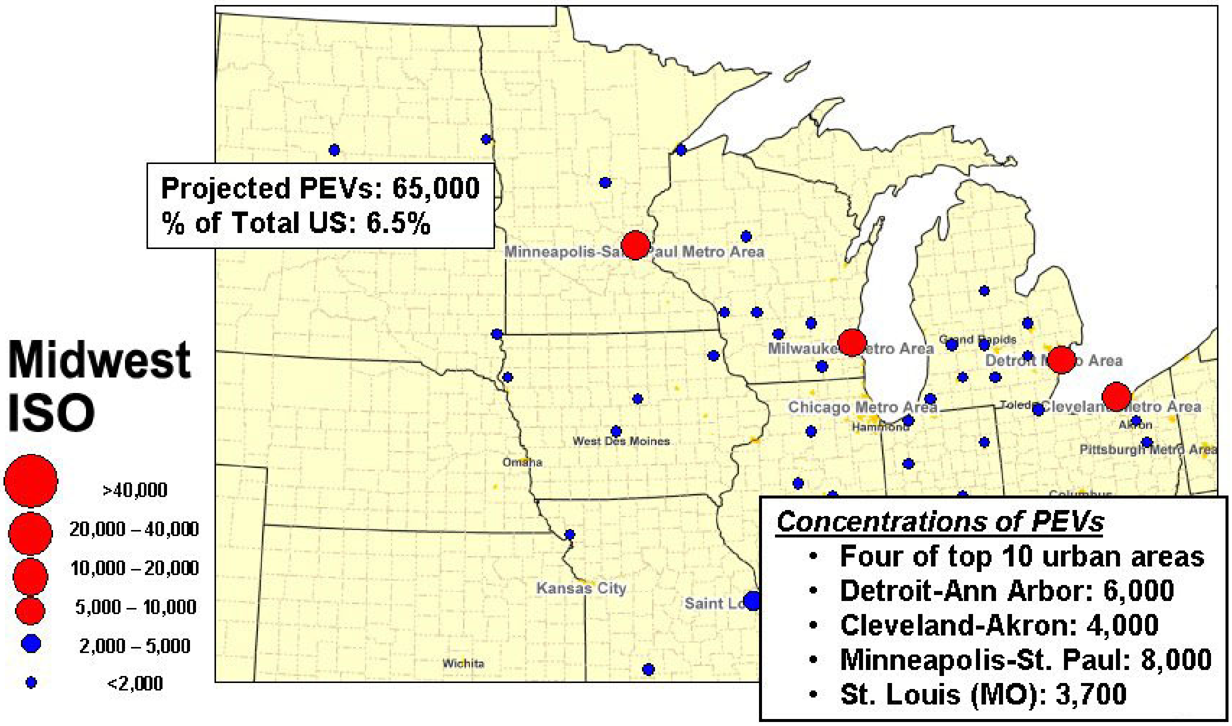
Appendix C. Distribution of Consumer PEVs Projected within ISO/RTO Regions

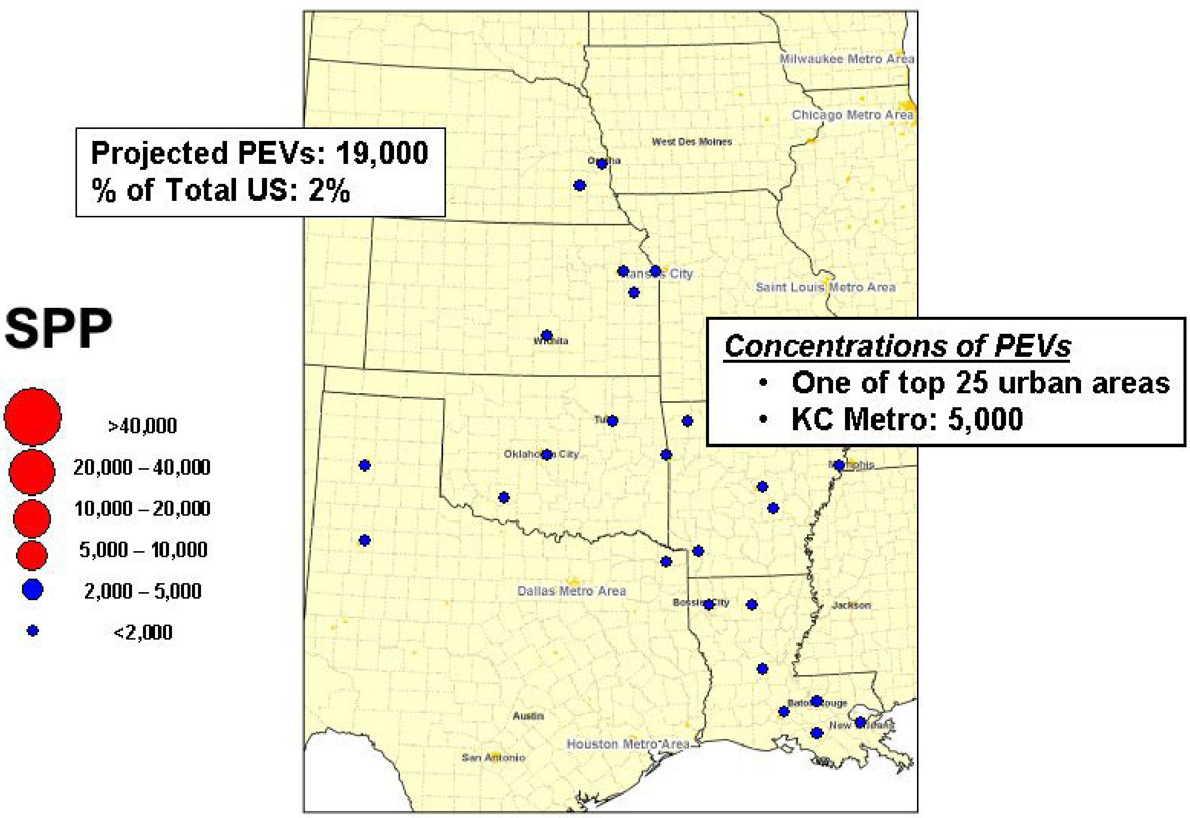
The following figures illustrate projected PEV market size by ISO/RTO region.

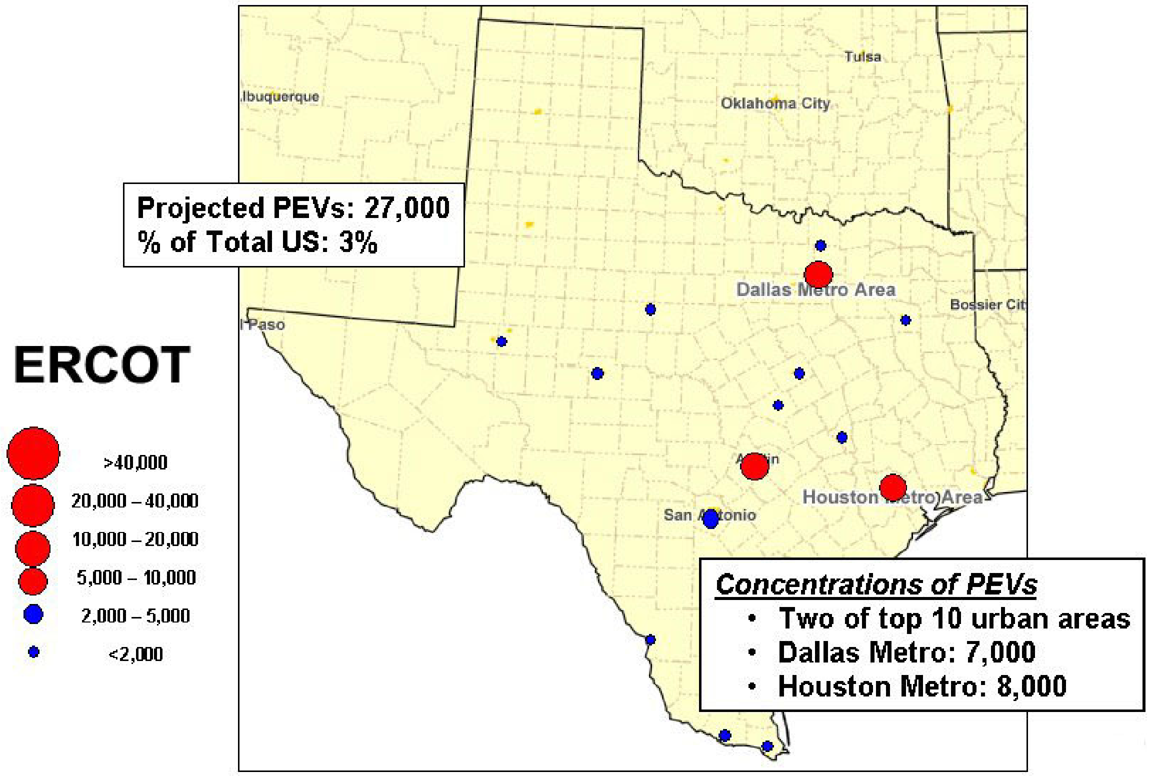


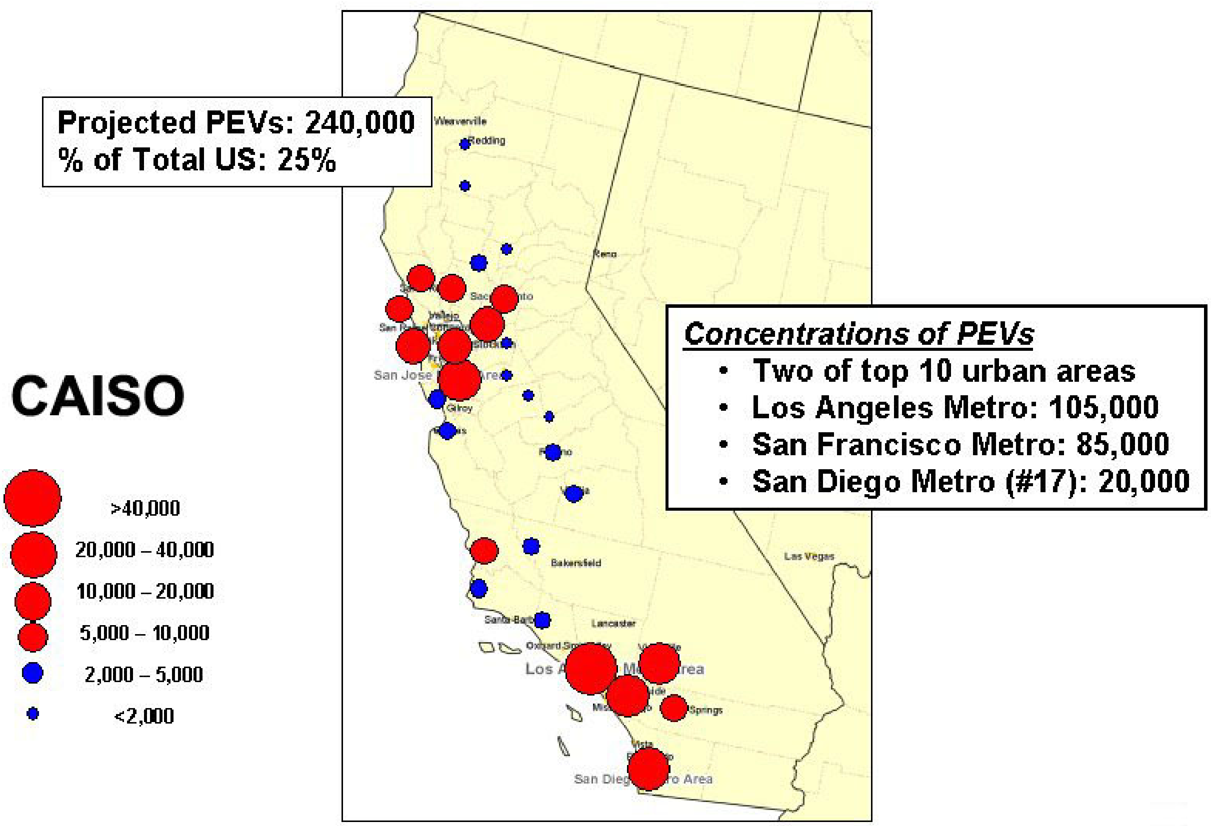

Projected PEVs: 30,000
% of Total US: 3%
Concentrations of PEVs
• Largest multi-state urban area
• NYC Metro (NY): 20,000
NYISO
>40,000
20,000 – 40,000
10,000 – 20,000
5,000 – 10,000
2,000 – 5,000
<2,000
Syracuse
Manchester
Springfield
Hartford
Waterbury
New Haven
Bridgeport
Norwalk
Stamford
Binghamton
Scranton
Wilkes-Barre


Projected PEVs: 105,000
% of Total US: 10%
PJM
>40,000
20,000 – 40,000
10,000 – 20,000
5,000 – 10,000
2,000 – 5,000
<2,000
Concentrations of PEVs
• Four of top 10 urban areas
• NY/NJ Metro: 12,000
• Chicago Metro: 20,000
• Balto/Wash Metro: 30,000
• Philadelphia Metro: 14,000
Rochester
Buffalo
Milwaukee Metro Area
Grand Rapids
Detroit Metro Area
Cleveland Metro Area
Akron
Indianapolis
Dayton
Cincinnati Metro Area
Covington
Saint Louis Metro Area
Louisville
Nashville
Memphis
Richmond
Bridgeport
Camden


Projected PEVs: 65,000
% of Total US: 6.5%
Midwest ISO
>40,000
20,000 – 40,000
10,000 – 20,000
5,000 – 10,000
2,000 – 5,000
<2,000
Minneapolis-Saint Paul Metro Area
Milwaukee Metro Area
Grand Rapids
Detroit Metro Area
Chicago Metro Area
Hammond
Toledo
Cleveland Metro Area
Akron
Pittsburgh Metro Area
West Des Moines
Omaha
Kansas City
Saint Louis
Wichita
Concentrations of PEVs
Four of top 10 urban areas
Detroit-Ann Arbor: 6,000
Cleveland-Akron: 4,000
Minneapolis-St. Paul: 8,000
St. Louis (MO): 3,700


Projected PEVs: 19,000
% of Total US: 2%
SPP
>40,000
20,000 – 40,000
10,000 – 20,000
5,000 – 10,000
2,000 – 5,000
<2,000
Milwaukee Metro Area
Chicago Metro Area
West Des Moines
Omaha
Kansas City
Saint Louis Metro Area
Wichita
Tulsa
Oklahoma City
Memphis
Dallas Metro Area
Bossier City
Jackson
Baton Rouge
New Orleans
Austin
San Antonio
Houston Metro Area
Concentrations of PEVs
One of top 25 urban areas
KC Metro: 5,000


Projected PEVs: 27,000
% of Total US: 3%
ERCOT
>40,000
20,000 – 40,000
10,000 – 20,000
5,000 – 10,000
2,000 – 5,000
<2,000
Tulsa
Oklahoma City
Dallas Metro Area
Concentrations of PEVs
• Two of top 10 urban areas
• Dallas Metro: 7,000
• Houston Metro: 8,000


Projected PEVs: 240,000
% of Total US: 25%
CAISO
>40,000
20,000 – 40,000
10,000 – 20,000
5,000 – 10,000
2,000 – 5,000
<2,000
Weaverville
Redding
Reno
Bakersfield
Lancaster
Las Vegas
Concentrations of PEVs
• Two of top 10 urban areas
• Los Angeles Metro: 105,000
• San Francisco Metro: 85,000
• San Diego Metro (#17): 20,000

IESO

15,700

AESO

3,700

Appendix D. PEV Price Impacts

The following tables detail the estimated percentage increase in wholesale prices due to PEV load by ISO/RTO for those ISO/RTOs which provided estimates. All three charging scenarios are shown where the PEV load is assumed to either occur within a time period of one hour, eight hours or twelve hours.

Table D-1. Price Impact due to Incremental Demand from PEVs Concurrently Connected over a 1-hour Period

ISO/RTO	Incremental Load (MWh)	Price Impact 6 PM
ISO-NE (yearly)	338	2.00%
NYISO (yearly)	242	1.34%
NYISO (peak days)	242	5.33%
PJM (yearly)	797	1.64%
Midwest ISO (yearly)	523	3.50%
ERCOT (yearly)	237	4.70%
CAISO (peak day)	1,480	10.00%

Table D-2. Price Impact due to Incremental Demand from PEVs Concurrently Connected over an 8-hour Period

ISO/RTO	Incremental Load (MWh)	Price Impact			
		6 PM	7 PM	8 PM	9 PM
ISO-NE (yearly)	75	insignificant	insignificant	insignificant	insignificant
NYISO (yearly)	27	0.17%	0.17%	0.17%	0.12%
PJM (yearly)	178	0.37%	0.24%	0.30%	0.21%
Midwest ISO (yearly)	117	0.80%	0.80%	0.80%	0.80%
ERCOT (yearly)	53	insignificant	insignificant	insignificant	insignificant
CAISO (peak)	331	insignificant	insignificant	insignificant	insignificant
PJM (yearly)	75	insignificant	insignificant	insignificant	insignificant

Table D-3. Price Impact due to Incremental Demand from PEVs Concurrently Connected over an 12-hour Period

ISO/RTO	Incremental Load (MWh)	Price Impact			
		6 PM	7 PM	8 PM	9 PM
ISO-NE (yearly)	50	insignificant	insignificant	insignificant	insignificant
NY ISO (yearly)	18	0.10%	0.09%	0.16%	0.00%
PJM (yearly)	119	0.24%	0.16%	0.20%	0.14%
Midwest ISO (yearly)	78	0.50%	0.50%	0.50%	0.50%
ERCOT (yearly)	35	insignificant	insignificant	insignificant	insignificant
CAISO (peak)	221	insignificant	insignificant	insignificant	insignificant

Appendix E: PEV Product Interaction Cases

To analyze and present the possible modes of PEV interaction with the ISO/RTO, the project team developed several value chains for PEV services. Before discussing potentially new PEV products and services for ISO/RTOs, this appendix begins with a high-level review of the business process and interactions as viewed by the PEV owner. The first figure shows the business process from the viewpoint of the physical delivery of the energy with an emphasis on the PEV. The participants in this process are:

- PEV Owners: Owners of PEV passenger and fleet vehicles
- Vehicle OEMs. In some visions of the mature PEV market, the PEV and the battery are sold by separate entities. For the purposes of this study, the team assumed that the PEV is sold with the battery.
- 3rd Party Financier: A city, mall, supermarket, or other independent party who finances charging infrastructure investments
- Charging Station Owner: An entity responsible for locating, purchasing and installing and operating charging equipment.
- Aggregator: Interface between the ISO/RTO and the PEVs; this could be a third party or the utility
- Utility: Investor-owned, public-owned and municipal entities that provide electrical services to customers
- ISO/RTO: The entity responsible for management of the transmission assets under it authority

Step 1: Battery Procurement. In this step, the PEV is purchased. (Here, the project team assumes the battery is bundled with the PEV purchase). The PEV owner needs to formulate the PEV purchase strategy with available infrastructure for charging while at home or at a commercial facility and how fast the PEV owner wants to re-charge the battery. Level 1 first generation chargers supply 120VAC and 30 Amps or less with a typical household plug. As such, coordination of vehicle purchase with charging infrastructure is necessary though relatively minimal. With Level 2, 3 or DC chargers coordination becomes more important. Level 2 chargers are specified as 240 VAC at up to 80 Amps while Level 3 AC and DC chargers are still being defined.

With communication to the charging stations and the PEV through smart grid or existing infrastructure, a number of entities can potentially interact with the PEV / PEV owners. The utility has a definite role as the supplier of power and provider for the power delivery infrastructure to the home or commercial operation (retail). Utilities are working with PEV OEM and third parties to develop the communications between the PEV to charger (EVSE) and from the charger to the utility or third party aggregator in the EPRI Infrastructure Working Council – Plug-in Hybrid and Electric Vehicle WG and the SAE standards working group (J2836 and J2847). SAE developed Use Cases for the interactions include:

- U1: Time of Use (TOU) pricing demand side management programs are when the customer has agreed to limit charges to the utility schedule for load balancing. (e.g., off-peak, mid-peak, on-peak, etc.).
- U2: Discrete Event demand side management program (Direct Load Control)
- U3: Periodic/Hourly Pricing Price Response program
- U4: Enrollment Process to Critical Peak Pricing (CPP) or Hourly/Periodic Pricing Program
- U5: Active Load Management program

Aggregators are developing packages to attract PEV owners for services not provided by the utilities today. Components of the package includes commercial charging stations, subscriptions or payment collections for public or commercial charging stations, web interfaces to locate charging stations, etc. Aggregation for Energy and/or Ancillary Services (A/S) to participate in the ISO/RTO market is viable if participation can appear valuable to the PEV owners. PEV owner will need to balance the desire for payments associated with participating in ISO/RTO-related products against concerns about battery life impacts or charging convenience. Future customer preferences, energy rates, social pressures, etc. will foster or disincentivize the growth of PEV as a participant in the ISO/RTO markets.

Step 2: Charging Station Financing, Installation and Maintenance. The charging infrastructure financing, installation and maintenance has to be in place for either the home garage and/or at a commercial or public charging facility. As discussed above, the type of charger depends on the infrastructure available and the time to re-charge the battery. The potential for dissatisfaction may arise as the PEV owners realize the cost involved in the infrastructure changes required to expand the power delivery circuit in the home which may extend beyond the home power distribution panel to the distribution transformer and up. There are several companies that specialize in home and commercial charging stations. Many of these companies will offer services as an aggregator. The utility will be involved in providing the service or updated service. The ISO/RTO is involved in signing up aggregators as registered Market Participants.

Step 3: Consumer Services Registration. Here, the PEV/battery owner registers for bundled services with an aggregator, commercial entity and/or the utility depending on products or services provided. For example, a PEV owner may set up an account with a commercial entity, such as Better Place, where the owner can either swap or re-charge their vehicle battery. They may use the company, commercial or public parking garage where they purchase a charge session using various payment card options or a subscription service. Finally, the utility may offer time-of-day charging discounts or related programs. Likewise the ISO/RTO may offer services for the PEV owner through an aggregator. For example, PEV owners may be environmentally conscience and choose to charge only with Green Power. An aggregator might offer services sensitive to PEV owners' preferences and could sign up a number of PEV owners to participate in related ISO/RTO products such as green charging (discussed in more detail below).

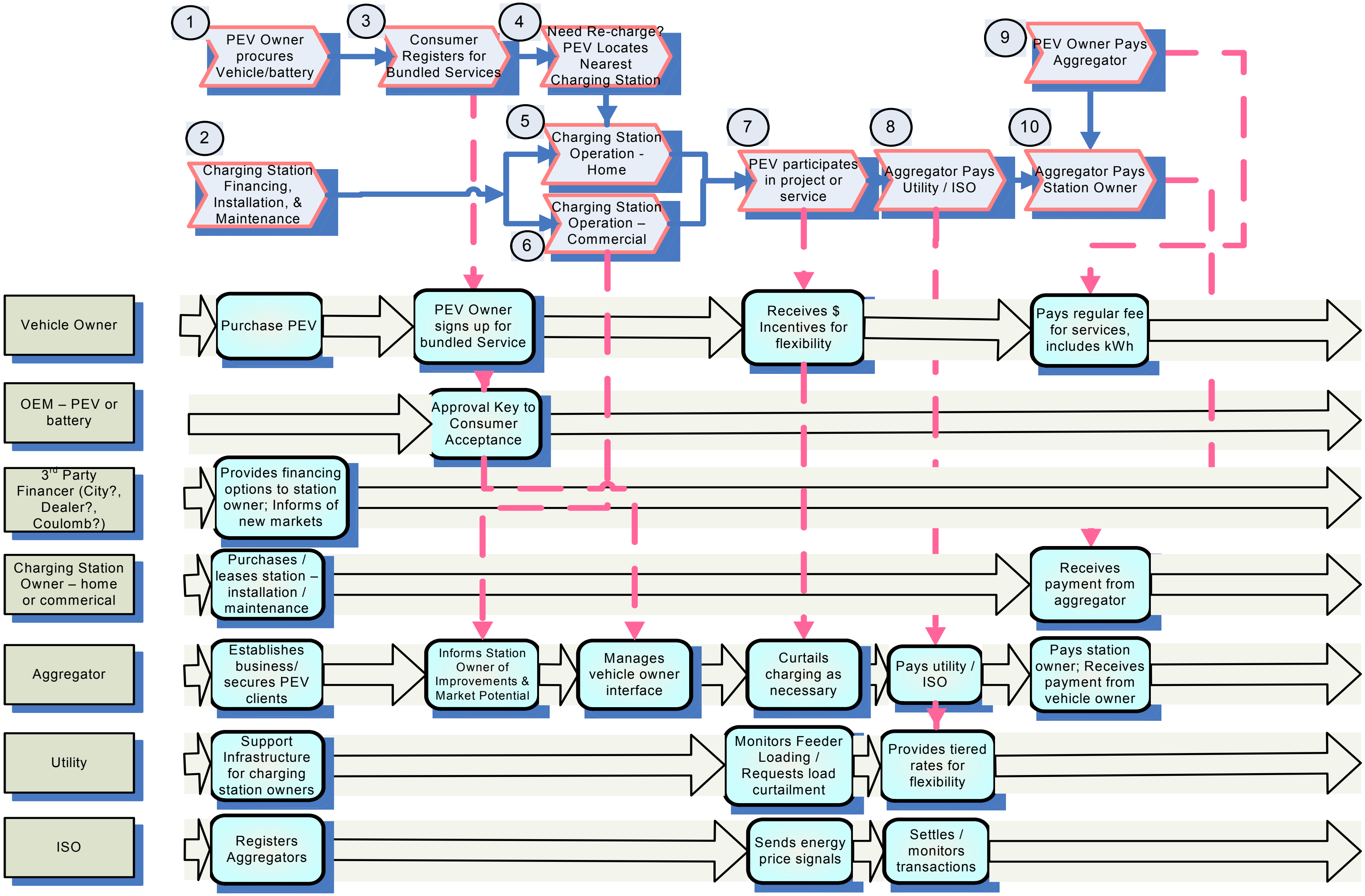
Step 4: PEV Re-Charge Notification. This stage in the value chain notes that the PEV needs a re-charge. The owner can use a familiar commercial facility or use the home facility depending on the level of charge. If the owner is unfamiliar with the area, a number of web based location services are available which also show unused charging stations.

Steps 5 and 6: Charging Station Operation. It is expected that most of the PEV charging will occur at the home. PEV owners will set their preferences on when to charge and the rate of energy recharge of the charger used to charge the PEV. When charging away from the home, the PEV owner may use a commercial charging station (where the owner must pay for recharging) or a facility where the can recharge for free (large store (e.g., Wal-Mart), shopping mall, company parking lot, etc.).

Step 7: PEV Participation. This step assumes the PEV owner agrees to participate in an ISO/RTO product offering via an aggregator or the utility. For participation, the PEV owner would receive a benefit in the form of a payment or lower overall cost of energy. An aggregator will need to sign up a sufficient number of PEVs to provide the product and meet the requirements specified by the ISO/RTO. Some products, like a regulation ancillary service, may require two-way communication with the ISO/RTO within the latency requirement defined in the NERC reliability standards.

Steps 8-10: Aggregator & PEV Owner Settlement. These steps represent the settlements portion of an ISO/RTO product delivery. Once the product has been successfully delivered and validated, the utility or aggregator is paid. Then, the aggregator or utility will pay or credit the account of the PEV owner or the commercial charging station (who will pay or credit the account of the PEV owner's).

Figure 1 Energy Commodity Process – Physical Delivery



For each of the potentially new products or services that a PEV may provide, the project team developed a business process to examine the interaction between the PEV and the ISO/RTO, and other intermediary parties. In the models discussed here, a retail entity would not directly interact with the ISO/RTO, but would interface via a registered market participant. This third-party could either be a utility or an aggregator who would provide the interface between the ISO/RTO and the end PEV owner. Though the business processes discussed here include new offerings, the models are grounded in the current market. As the markets evolve, new participants (such as information management experts) will likely enter the market and interactions may adjust. For example, the evolution of information systems and dynamic pricing could potentially limit the role of an intermediary and make consumer-ISO/RTO interaction more direct. Given the current emphasis and need for third parties, however, this paper assumes their participation when discussing the business processes.

For several of the potential ISO/RTO products listed below, the individual PEVs are the provider of the service. Since the PEV interface to the ISO/RTO is the aggregator, there needs to be a standard interface defined so the ISO/RTO can validate the aggregator and the PEV performance to the awarded product or service. The aggregator and the PEV instruction / charging data will need to be available in a standard model and format for validation and settlement purposes. Actually, this is an important standards concept for both PEV and DR on how the data will be collected / reported.

Below, the appendix outlines the following products and services and the likely stakeholder interactions to ensue:

- Enhanced Aggregation
- Ancillary service - Reserves
- Ancillary services – DR Regulation Resource (DRR)
- Dynamic Pricing (DP)
- PEV Emergency Load Curtailment (ELC)

Enhanced Aggregation

Figure 2, Energy – Enhanced Aggregation (EA)), describes the energy commodity process from the ISO/RTO business process perspective. In Figure 2, the first two steps in the process are collecting aggregate regional "installed" (i.e. sold/owned/registered) PEV capacity information so that total PEV demand potential can be known and forecast. This can happen via a number of possible paths:

- The PEV seller (OEM) can provide this information;

- The state Department of Transportation (DOT) can provide this information;
- The aggregator / utility / info-utility that enrolls the vehicle for energy sales can provide it; or
- The installer of the charging station could provide it.

There are difficulties with all these possibilities. For example, DOT will not know what addresses are in ISO/RTO territory or not, for instance.

Step 1: Registration. Here, the PEV/battery owner registers for bundled services with an aggregator, commercial entity and/or the utility depending on products or services provided. The aggregator or commercial entity, in turn, must be registered with the ISO/RTO.

Step 2: Energy Procurement. Step 2 involves acquiring or developing the energy production resource necessary to charge PEVs. A utility or commercial entity such as aggregators, battery manufacturers, etc. could all potentially sell energy to PEV owners. If the vehicle is contracting with the utility, the utility has the same obligation, either directly as in ERCOT or indirectly via capacity auctions and the like.

Step 3: Vehicle Schedule Updating. The following step is the daily update of vehicle-aggregated schedules. The information begins with the "default" for each vehicle but which can be overridden in real time by the owner; this could be via vehicle to aggregator, website entry, or via an information utility. The local charging station could also have a role to play here, and certainly would in the fleet operations or battery swap model. The updated information is used by the aggregator and the ISO/RTO for forecasting and dynamic pricing/market clearing. The ISO/RTO determines it operation plan considering the generation and loads and provide information to the aggregator as an input to schedule the battery charging of its PEVs

Steps 4 – 5: Bids & Awards. Under an "enhanced aggregation" paradigm the aggregate time deferral possibilities of the vehicle aggregate demand are communicated by the aggregator(s) to the ISO/RTO for planned aggregate PEV charging load. The aggregators are responsible for communications and control signals to the vehicles, the info-utility, and the charging stations. The generation schedules to provide the energy are cleared and established, and the ISO/RTO schedule transactions at the wholesale level finalized – these steps should be “as today" if the prior steps are robustly designed.

Steps 6 -7: Aggregator & PEV Owner Settlement. These steps address the payment for actual scheduled energy deferral provided by PEVs. Once the ISO/RTO validates the energy as scheduled has been provided, the settlement process is initiated. The ISO/RTO then pays the aggregator and aggregator, in turn, pays the PEV owner.

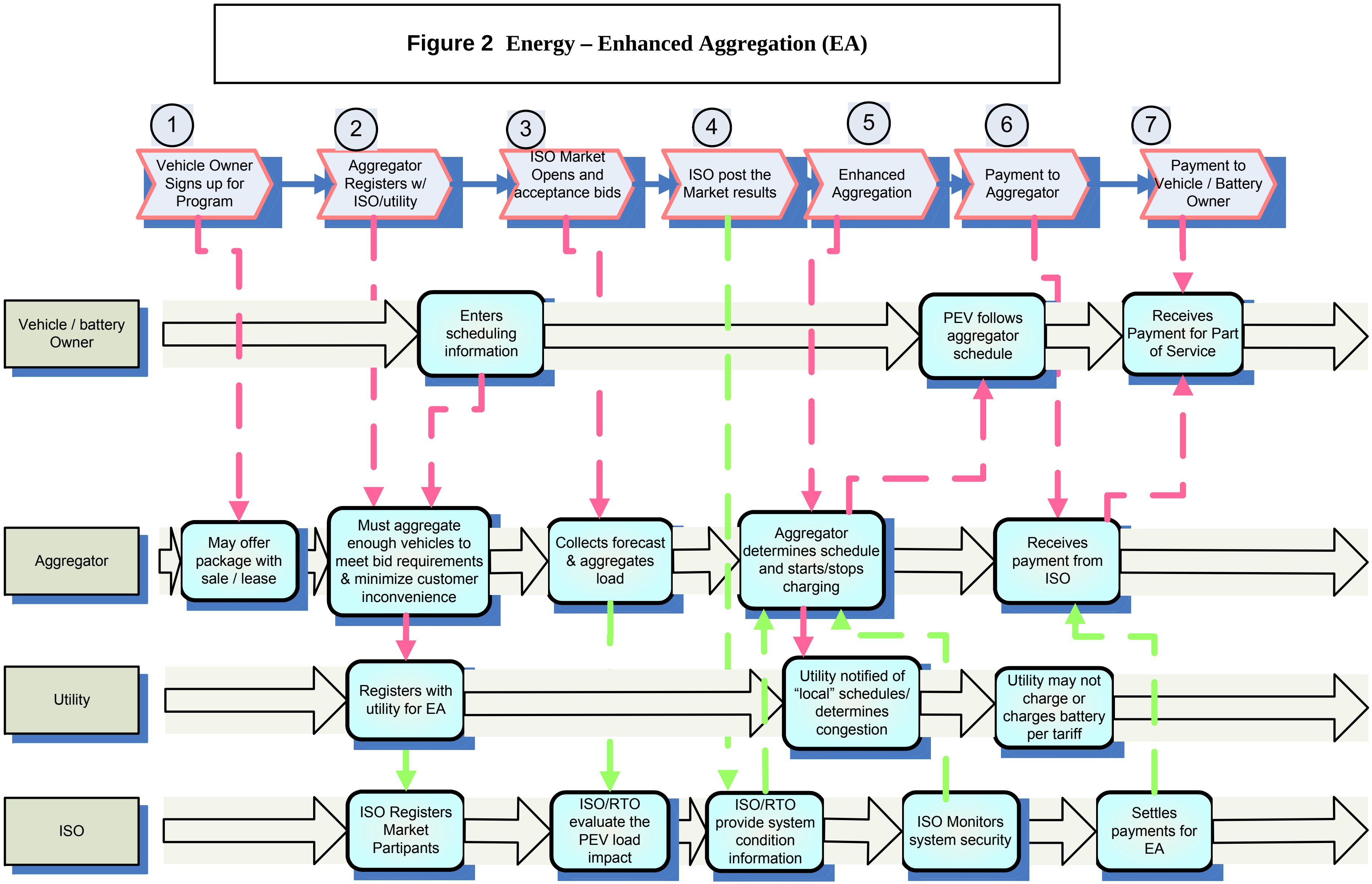


Figure 2 Energy – Enhanced Aggregation (EA)
1
Vehicle Owner Signs up for Program
2
Aggregator Registers w/ ISO/utility
3
ISO Market Opens and acceptance bids
4
ISO post the Market results
5
Enhanced Aggregation
6
Payment to Aggregator
7
Payment to Vehicle / Battery Owner
Vehicle / battery Owner
Enters scheduling information
PEV follows aggregator schedule
Receives Payment for Part of Service
Aggregator
May offer package with sale / lease
Must aggregate enough vehicles to meet bid requirements & minimize customer inconvenience
Collects forecast & aggregates load
Aggregator determines schedule and starts/stops charging
Receives payment from ISO
Utility
Registers with utility for EA
Utility notified of "local" schedules/ determines congestion
Utility may not charge or charges battery per tariff
ISO
ISO Registers Market Partipants
ISO/RTO evaluate the PEV load impact
ISO/RTO provide system condition information
ISO Monitors system security
Settles payments for EA

Ancillary Services –Reserves

The Ancillary Service (AS) for Reserves (business models is shown in Figure 3, Ancillary Services for Reserves. . The Reserve PEV product is a product offered to an aggregator in exchange for a payment or credit to ultimate PEV owner.

In the illustration, reserve is assumed to be a market bid product though it could potentially be part of the obligation for a market participant to participate in the market.

Reserve is designed to curtail PEV demand en masse either within a locational or within a control area, and provides a new kind of high response rate spinning reserves available for 30 minutes or an hour. This product could ease reserve costs in the face of renewable-induced increased demand, and could also provide enhanced system stabilization.

Steps 1:.PEV Owner Registration. This step starts the process, where the owner of the PEV signs up with an aggregator for reserve. It is expected the aggregators will offer a variety of value-based packages to get the PEV owners to be one of their clients. The PEV owner will sign up for this product only if reserve operation (quick stop/start charging) will fall under the warrant of the battery. It is conceivable that the aggregator will be required to provide assurances to the PEV owners that the process will meet some defined operation parameters.

Step 2: Aggregator Registration. The aggregators need to sign up for AS products with the ISO/RTOs and to participate in the market; the aggregator will have to meet the obligations to the PEV owner and to the ISO/RTO. For many markets, the ISO/RTO will require two-way communication with the aggregator and validation the AS award obligation is being met.

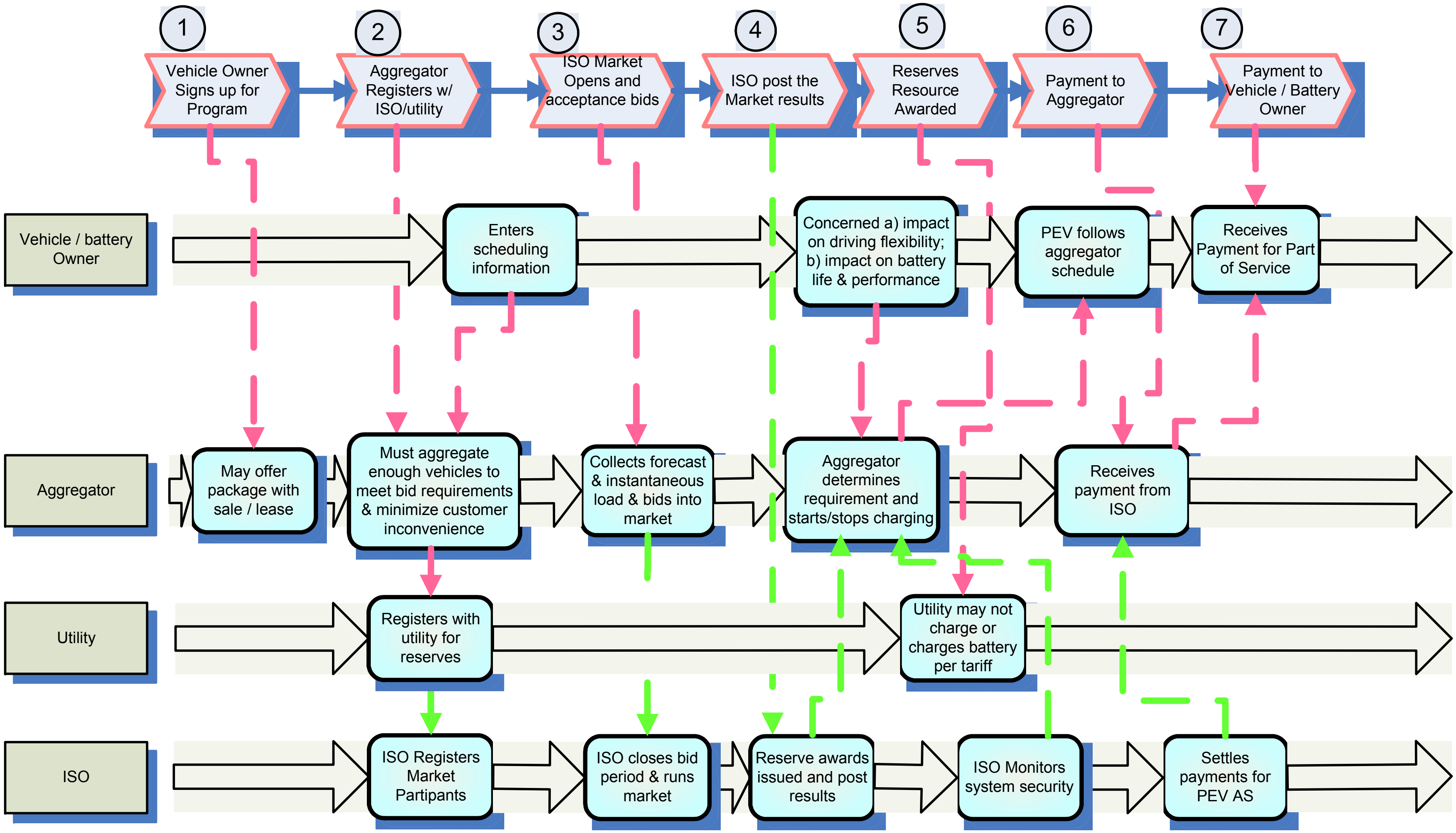
The aggregator is expected to have sufficient PEVs (capacity) to meet the bid requirements by understanding the PEV or battery owners' preferences and concern for driving flexibility and battery life. A business entity may be interested in participating in the market. To ease the PEV owner concern of not having a fully charged battery, an entity like Better Place may provide a valuable service to not only provide aggregation and battery charging but also provide battery swap services.

Steps 3-4: Bid & Award. In step 3, the ISO/RTO market opens for bids for AS products. The aggregator forecast based on PEV owner preferences and contract obligations, the PEV charging state and enters a bid into the A/S market. The market submittal period closes, market is run and the results are posted. In step 4 the market results are posted and the aggregator is informed of any A/S awards.

Step 5: Resource Award. In step 5 under reserve the aggregator builds a schedule for the reserve award and sends charge/ stop charging signals to the participating PEVs. It is expected the aggregator would continually monitor the obligation verse actual total stop charging/charging demand of the aggregate PEV and takes steps to meet the obligations.

Steps 6 -7 Aggregator & PEV Owner Settlement. Deal with the payment for actual A/S provided by PEVs. Once the ISO/RTO validates the A/S service has been provided, the settlement process is initiated. ISO/RTO pays aggregator and aggregator pays the PEV owner.

Figure 3 Ancillary Services for Reserves



Ancillary Services – DR Regulation Resource

The Ancillary Services (A/S) for Demand Response Regulation Resource (DRR) follows the business model shown in Figure 4, DR Regulation Resource, (DRR) Ancillary Services Business Model. There are some in the PEV community that believe that PEV can be aggregated to provide regulation services. This may be of interest for an aggregator since this ancillary service typically has the highest payment and they will need to sign-up a number of PEVs to adequately participate in the ISO/RTO market. However, the same advocates also acknowledge that once PEV penetration is significant, the price for regulation might well be driven to very low levels. Thus, the ISO/RTO community needs to evaluate the merits of this carefully. The entities on the left side of the figure are:

- Vehicle /battery owner – assumed to vehicle is purchased with the battery
- Aggregator
- Utility
- ISO/RTO

Step 1: PEV Owner Registration. The process starts in Step 1, where the owner of the PEV signs up with an aggregator for DRR. It is expected the aggregators will offer a variety of value-based packages to get the PEV owners to be one of their clients. The PEV owner will sign up for this product only if DRR operation of quickly charging /not charging operation will fall under the warrant of the battery. It is conceivable the aggregator will be required to provide assurances to the PEV owners that the on/off charging will meet some defined operation parameters.

Step 2: Aggregator Registration. In step 2, the aggregators need to sign up for AS products with the ISO/RTOs and to participate in the market, the aggregator will have to meet obligations to the PEV owner and to the ISO/RTO. For many markets, the ISO/RTO will require two-way communication with the aggregator and validation the AS award obligation is being met.

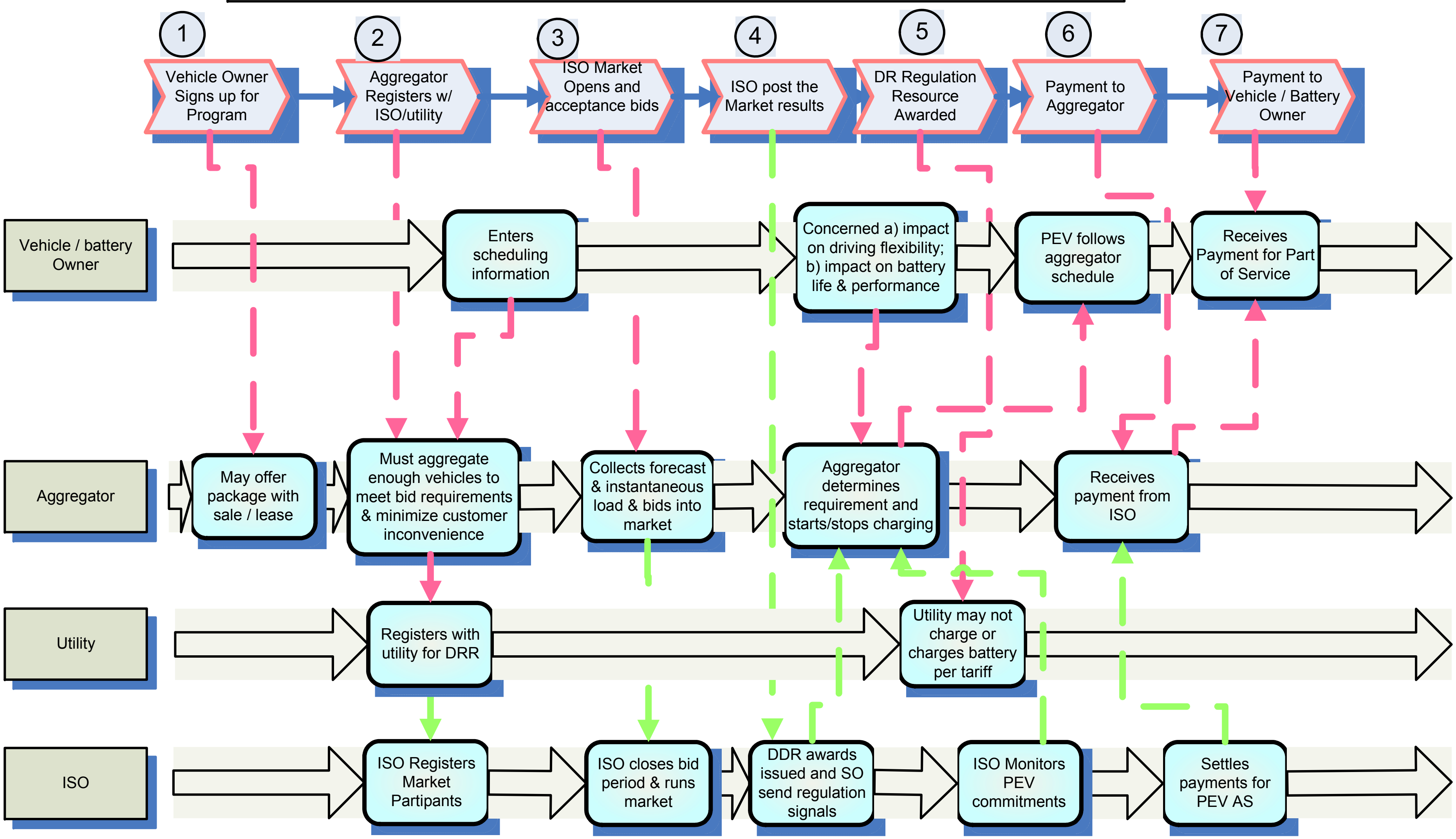
The aggregator is expected to have sufficient PEVs (capacity) to meet the bid requirements by understanding the PEV or battery owners' preferences and concern for driving flexibility and battery life. A business entity such as Better Place, GridPoint, etc may be interested in participating in the market. To ease the PEV owner concern of not having a fully charged battery, an entity like Better Place may provide a valuable service to not only provide aggregation and battery charging but to also provide a battery swap services.

Steps 3-4: Bid & Award. Here, the ISO/RTO market opens for bids for AS products. The aggregator forecasts based on PEV owner preferences, contract obligations and the PEV charging state and enters a bid into the AS market. The market submittal period then closes, the market is run and the results are then posted. In step 4, the market results are posted and the aggregator is informed of any AS awards.

Step 5: Resource Award. In this step, the aggregator receives signals from the ISO/RTO and sends charge / stop charging signals to the participating PEVs. It is expected that the aggregator would continually monitor the obligation versus the actual regulation up and regulation down (i.e., stop/start charging). Any penalties for non-commitment would be assessed in the next step.

Steps 6 -7: Aggregator & PEV Owner Settlement. Deal with the payment for actual A/S provided by PEVs. Once the ISO/RTO validates the A/S has been provided, the settlement process is initiated. ISO/RTO pays aggregator and aggregator pays the PEV owner.

Figure 4 Ancillary Services for DR Regulation Resource (DRR)



Dynamic Pricing

The Dynamic Pricing (DP) follows the business model shown in Figure 5, Interaction with Dynamic Pricing Model. In this model, the near real time price is published and if it meets the price sensitivity of the of the PEV owner, the owner participates by not charging the PEV. Stakeholders noted in the figure include:

- Vehicle / battery owner (assumes vehicle is purchased with the battery),
- Aggregator,
- Utility, and
- ISO/RTO.

This model shows the utility as the price provider (in dynamic pricing models) to the aggregator or PEV or the aggregator may get its prices directly from the ISO/RTO. The goal is to be broad enough to cover the majority of the future business models an ISO/RTO may provide for Dynamic Pricing

Step 1: PEV Owner Registration. This step starts the process where the owner of the PEV either signing up with an aggregator for price sensitive charging (PEV owner preference stored with the aggregator) or the PEV owner could interact directly with the price signal (assumes the owner preferences are located in the PEV or the EVSE (charging unit).

Step 2: Aggregator Registration. The PEV and/or aggregator will need to register with the utility (utility to interface with the aggregator or PEV) and the utility and/or aggregator needs to inform the ISO/RTO they want to participate in dynamic pricing.

Step 3: Bids. The ISO/RTO market opens for bids for energy products.

Steps 4-5: Award and Signal. The market is run and the results are posted. The dynamic prices (near real-time) are sent to the utility or aggregator to send to the price sensitive PEV.

Step 6: PEV Response. If the price is favorable; the PEV participates by not charging the PEV until the price drops or some other owner preference become more important.

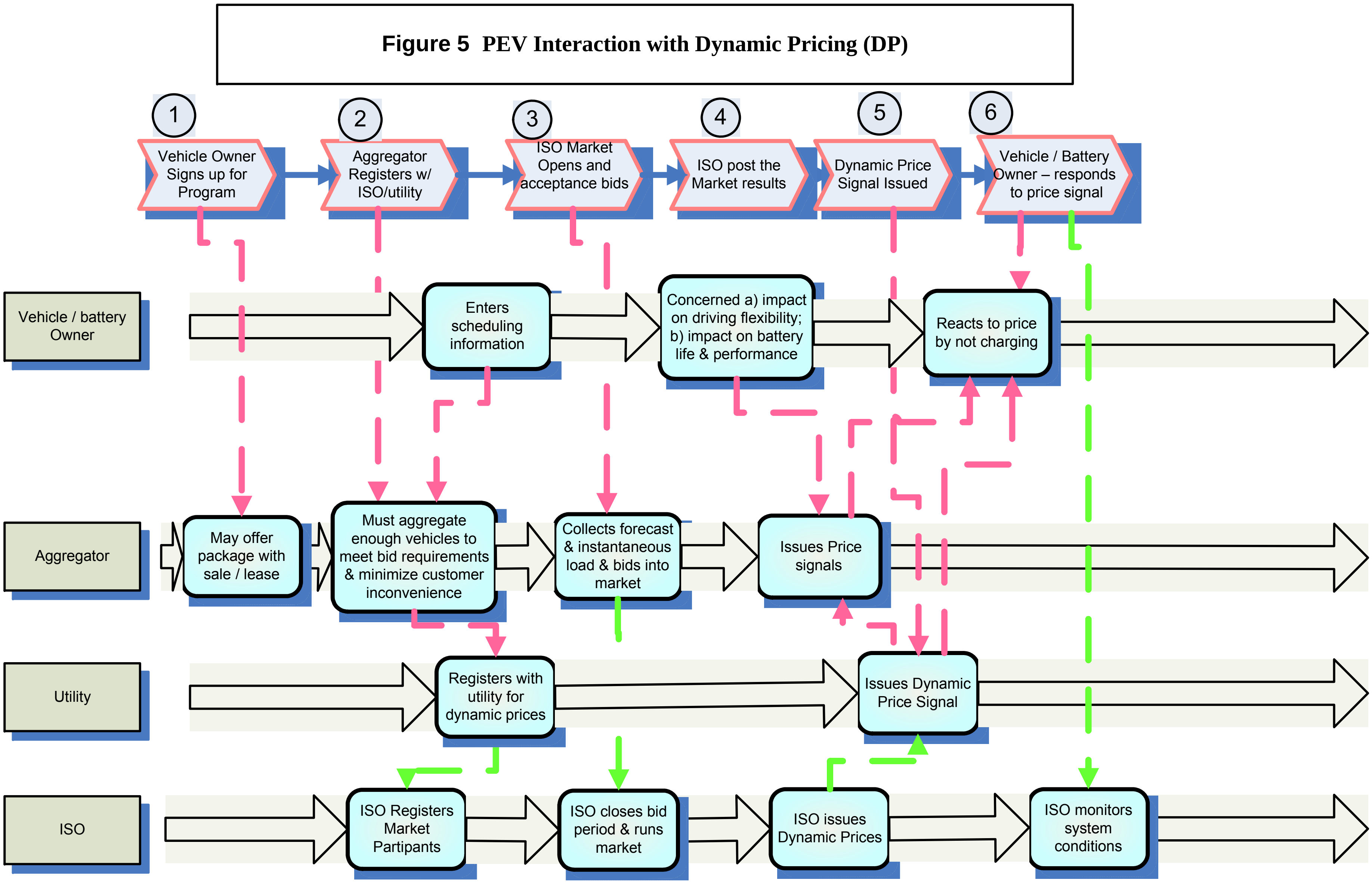


Figure 5 PEV Interaction with Dynamic Pricing (DP)
1
Vehicle Owner Signs up for Program
2
Aggregator Registers w/ ISO/utility
3
ISO Market Opens and acceptance bids
4
ISO post the Market results
5
Dynamic Price Signal Issued
6
Vehicle / Battery Owner – responds to price signal
Vehicle / battery Owner
Enters scheduling information
Concerned a) impact on driving flexibility; b) impact on battery life & performance
Reacts to price by not charging
Aggregator
May offer package with sale / lease
Must aggregate enough vehicles to meet bid requirements & minimize customer inconvenience
Collects forecast & instantaneous load & bids into market
Issues Price signals
Utility
Registers with utility for dynamic prices
Issues Dynamic Price Signal
ISO
ISO Registers Market Partipants
ISO closes bid period & runs market
ISO issues Dynamic Prices
ISO monitors system conditions

Emergency Load Curtailment

Figure 6 notes two potential market mechanisms for emergency load curtailment with PEVs. For this service, aggregators combine the quick-response of individual PEVs to offer larger-scale load curtailment resources for emergency events. Such resources might be contracted by utilities or by the market. Both models are depicted here, with the utility-based model noted in the last row of the figure. Both are represented as voluntary, where program participation by PEV owners and the aggregators is voluntary and where call response is either voluntary or mandatory. However, alternatively mandatory models are feasible. Nevertheless, it is clear that PEVs provide a quick-response load curtailment resource for emergency events that may be aggregated for maximum effect.

Step 1: Program Signup. The electric vehicle owner can sign up to participate in emergency curtailment plans with an aggregator or utility. As a result, the owner may receive a lower electricity rate or a lower price of a bundled package.

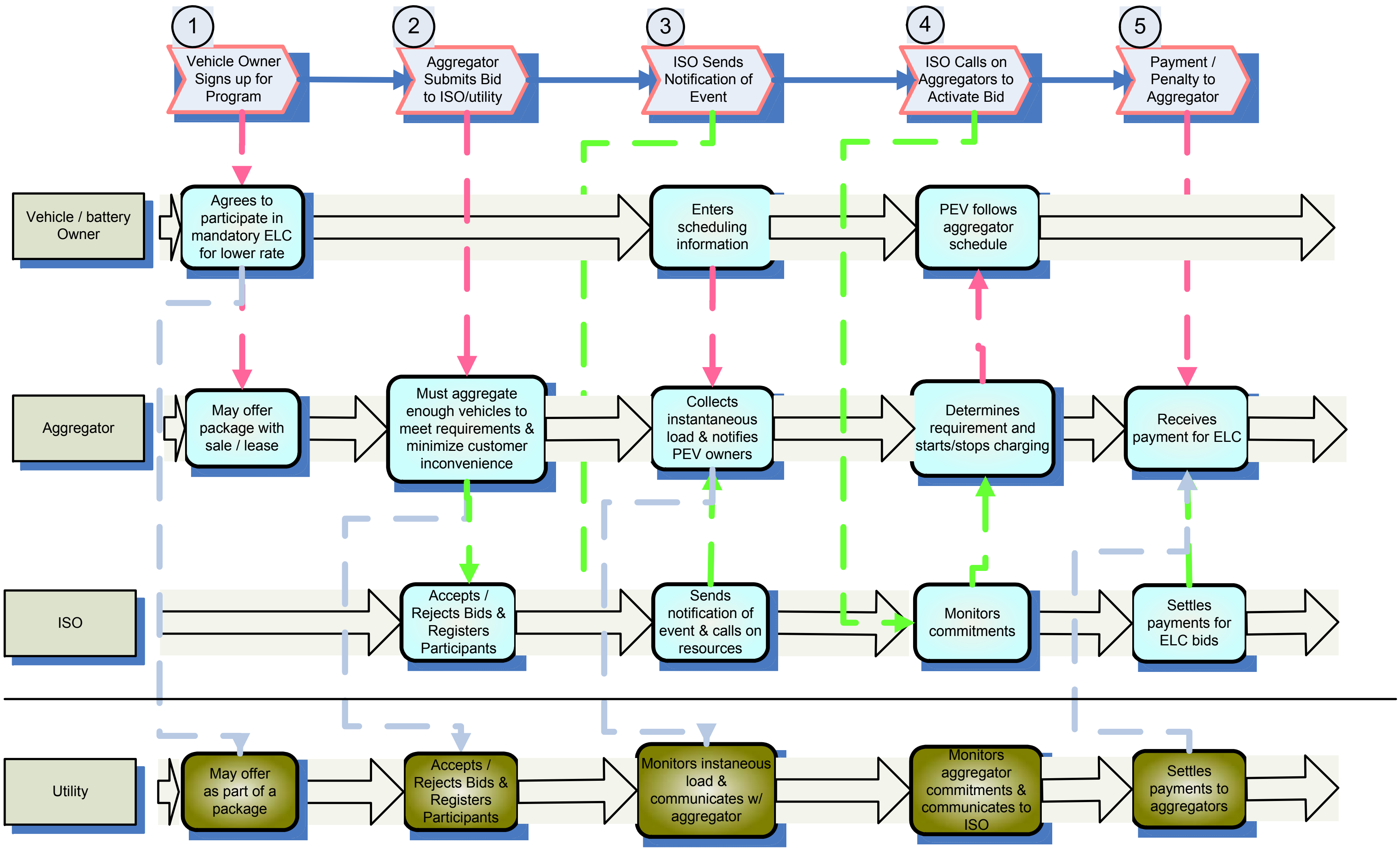
Step 2: Aggregator Registration. Aggregators must register with the ISO/RTO or utility to offer a bundled package of demand capacity available for emergency alerts. In turn, the ISO/RTO or utility would provide the ELC. If implemented by the ISO/RTO, a new product would be required that could be bid based. Before scheduling resources with the utility or ISO/RTO, the aggregator must have an initial estimate of driver usage patterns to forecast the availability of demand as a resource. Initial driver scheduling estimates would facilitate this forecast. Another approach would be for the utility to implement a PEV emergency load reduction program where the PEV owner get a break on their electric bill (since the car can move and be charging somewhere else) by signing up for this program. When the need arise for emergency load curtailment, the utility would shed PEV load by sending a signal for the PEV to not charge.

Step 3: Event Notification. Per usual, the ISO/RTO would monitor system reliability and notify market participants of impending emergency events. In this model, aggregators would then monitor which resources are available for curtailment, possibly notifying drivers. With voluntary programs, aggregators could confirm commitment from drivers. With mandatory programs, the aggregators could simply prepare for automatic curtailment.

Step 4: Resource Activation. Barring rectification through other means, the ISO/RTO would then call upon market participants (aggregators or utilities) to activate load curtailment resources. At this time, the aggregator would shut-off vehicle charging. As noted above, such curtailment could be voluntary or mandatory. (In the latter case, shut-off would be automatic. In the former, drivers could override attempts to limit charging).

Step 5: Aggregator Settlement. With aggregators as the primary interface between drivers and the ISO/RTO, or drivers and utilities, settlements could be arranged with a single load-resource entity. As such, ISO/RTOs or utilities would directly reward aggregators, who would pass on earnings to drivers through a variety of means (e.g., single up-front payment, subscription price reduction, follow-on payments). Such settlements could entail payments for service, or even a penalty for non-commitment.

Figure 6 Emergency Load Curtailment (ELC)



Appendix F. Communication and Information Technology Standards Summary

The following lists summarize communication and IT standards.

Standards

- DNP3 via Internet
- ISO WAN
- ICCP via private WAN
- DNP3
- eMail via Internet
- XML/HTTPS

Payload

From Aggregator

- Frequency
- MW
- MVAR
- Bus Voltage
- Line Voltage
- Line Amps
- Line Power Factor
- Load connectivity status
- Breaker Status
- Battery Charge State
- Charge Capacity
- Discharge Capacity
- Heartbeat
- Last message ID received
- Resource ID
- Backend communications status
-

To Aggregator

- Dispatch Instructions
- Dispatch Forecast
- Wholesale Price
- Regulation Signal
- AGC

- Neighboring System reliability data (line flows, breaker status, etc.) –
- Message ID
- Resource ID
- Dispatch Time
- Effective Time
- Audit Flag
- Failure to follow
- Generation deviation
- Self schedule
- AGC price
- Hour ahead DDP
- Regulation price
- Spinning Reserve price
- Regulation range
- Economic, Emergency and Regulation high and low limits

Encryption

- X.509v3 Digital Certificates and SSL
- PGP (optional)
- Secure DCP3
- https with digital certificate
- Triple DES

Appendix G. ISO/RTO Market Comparison

The following tables summarize the demand response and non-demand response markets in the ISO/RTOs. The first two tables summarize differences while the latter two provide additional detail.

Table G-1. ISO/RTO Non-DR Markets Comparison Summary

Energy: Real-Time	
Non-Response Penalty	- Prevalent but not universal across the ISO/RTOs
Minimum Capacity Requirements	- Prevalent but not universal; 1 MW is typical though some are as low as 100 kW
Participation	- Generally voluntary though some have conditional requirements
Aggregation allowed?	- Aggregation is typically allowed, though not universally
Dispatch Duration Limits	- Vary. Some markets having a min or max requirement and others having none
Ramp Requirements	- About as varied as dispatch duration limits
Acknowledgement	- Generally required, though not in all markets
Location Monitoring	- Most markets, but not all
Energy: Day-Ahead	
Non-Response Penalty	- Do not exist for any market
Minimum Capacity Requirements	- Varies from 0.1 to 1 MW
Participation	- Generally voluntary, though mandatory for certain cases in some markets
Aggregation allowed?	- Generally allowed, though not in all markets
Capacity	
Non-Response Penalty	- Generally exists
Minimum Capacity Requirements	- Generally 100 kW though can be as high as 1 MW
Participation	- Voluntary (though in one market, may have repercussions)
Aggregation allowed?	- Allowed in some markets and not in others
Reserves	
Non-Response Penalty	- Exist in some markets though not universal
Minimum Capacity Requirements	- Generally 1 MW though can be as high as 5 MW
Participation	- Generally voluntary though some markets have requirements for certain cases
Aggregation allowed?	- Typically allowed, though not in all cases
Dispatch Duration Limits	- Duration limits vary widely, from 60 min to 2 hr maximum, to what is scheduled
Ramp Requirements	- Typically 10 or 30 minutes
Acknowledgement	- Typical though not existent for all markets
Location Monitoring	- Typical, though not existent for all markets
Regulation	
Non-Response Penalty	- Prevalent but not universal across the ISO/RTOs
Minimum Capacity Requirements	- Generally 1 MW though some markets have smaller or no requirements
Participation	- Generally voluntary though there are a few limited cases where it is not
Aggregation allowed?	- Typically allowed, though not in all cases
Dispatch Duration Limits	- Varies (5 min to no minimum and 60 to 30 min maximum, or based on schedule)
Ramp Requirements	- Response times are generally quick or even “instantaneous”, though varies
Acknowledgement	- Prevalent but not universal across the ISO/RTOs
Location Monitoring	- Typical, though not existent for all markets

Table G-2. ISO/RTO DR Markets Comparison Summary

Energy	
Minimum Capacity Requirement	- Ranges from 0.1 to 1 MW, depending on market and program
Participation	- Voluntary in all markets
Aggregation Allowed?	- Typically allowed, though not for all programs
Duration Limits?	- Generally vary by program and typically depend on the schedule
Response Period	- Varies across markets and programs (5 min, 2 hrs, instant)
Capacity	
Minimum Capacity Requirement	- 0.1 MW in most markets, 1 MW in some
Participation	- Voluntary in all markets
Aggregation Allowed?	- Allowed across all programs and markets
Reserves	
Minimum Capacity Requirement	- 1 MW in most markets, 0.1 MW in others
Participation	- Voluntary in all markets
Aggregation Allowed?	- Varies by program and market; mostly yes but not always
Duration Limits?	- Typically based on schedule though sometimes 1 to 2 hour minimum
Response Period	- Varies among markets and programs, from instant to 30 minutes
Regulation	
Minimum Capacity Requirement	- Typically 1 MW, though not all markets have a requirement
Participation	- Voluntary in all markets
Aggregation Allowed?	- Varies across markets, sometimes yes and sometimes no
Duration Limits?	- Typically based on schedule, but not always
Response Period	- Typically instantaneous

Table G-3. ISO/RTO Non-DR Markets Comparison Detail

	AESO	IESO	MISO	PJM	SPP	ERCOT	NBSO	NYISO	ISO-NE	CAISO
Energy: Real-Time										
a. Penalty?	Y	Y	Y	?	Y	Y	N	Y	Y	N[1]
b. Minimum Capacity (MW)	None	1	1	0.1	1	1	1	1	1	1
c. Participation Voluntary?	Y	Depends[2]	Y	Y	Y	Y	Y	Y	Depends[3]	Y
d. Aggregation Allowed?	Y	Depends[4]	Y	Y	Y	Y[5]	Y	N	Y	Y
e. Duration (minutes)	?	5 dispatch	60	Depends[6]	60	60	60	5 – 60	None	None
f. Ramp Requirement	?	5 dispatch	5 min	Depends[6]	5 min	Bid MW/4	None	>1%/min	None	None
g. Acknowledgement	?	Y	N	Y	Y	Y	Y	N	Y	Y[7]
h. Location Monitored?	?	Y	N	?	Y	Zonal	Y	Y	Y	Y
Energy: Day-Ahead										
a. Penalty?	?	?	N	?	n/a	n/a	n/a	N	?	?
b. Minimum Capacity (MW)	?	?	1	0.1	n/a	n/a	n/a	1	1	1
c. Participation Voluntary?	?	?	Y	Y	n/a	n/a	n/a	Depends[3]	Depends[3]	Depends[8]
d. Aggregation	?	?	Y	Y	n/a	n/a	n/a	N	Y	Y
Capacity										
a. Penalty?	?	n/a	Y	?	n/a	n/a	n/a	Y	Y[9]	n/a

	AESO	IESO	MISO	PJM	SPP	ERCOT	NBSO	NYISO	ISO-NE	CAISO
b. Minimum Capacity (MW)	?	n/a	0.1	0.1	n/a	n/a	n/a	0.1	0.1	n/a
c. Participation Voluntary?	?	n/a	Y	Y	n/a	n/a	n/a	Y	Y[10]	n/a
d. Aggregation	?	n/a	Y	N	n/a	n/a	n/a	N	Y	n/a
Reserves										
a. Penalty?	Y	Y	Y	?	n/a	Y	Y	N	Y	N[1]
b. Minimum Capacity (MW)	5	1	1	Depends[11]	n/a	1	1	1	1	1
c. Participation Voluntary?	Y	Y	Y	Y	n/a	Y	Y	Y	Y	Depends[8]
d. Aggregation	Y	Depends[4]	Y	Y, N	n/a	Y[5]	Y	N	Y	Y
e. Duration	?	1 hr	1 hr	?	n/a	1 hr	1 hr	Scheduled	1 hr	2 hr
f. Ramp Requirement (min)	10	10, 30	10	?	n/a	10,30	10,30	10,30	10,30	Depends[6]
g. Acknowledgement	?	Y	N	Y	n/a	Y	Y	N	Y	Y[7]
h. Location Monitored?	?	Y	N	?	n/a	Zonal	Y	Y	Y	Y
Regulation										
a. Penalty?	Y	Y	Y	N	n/a	Y	Y	Y	N	N
b. Minimum Capacity (MW)	None	1	1	1	n/a	1	1	1	0.1	1
c. Participation Voluntary?	Y	Depends[12]	Y	Y	n/a	Y	Y	Y	Y	Depends[8]
d. Aggregation	Y	Y	N	Y	n/a	Y[5]	Y	N	Y	Y
e. Duration (min)	?	?	5 min	5-60	n/a	1 hour	60 min	scheduled	None	10-30

	AESO	IESO	MISO	PJM	SPP	ERCOT	NBSO	NYISO	ISO-NE	CAISO
f. Response Time	Instant	Instant	Depends[6]	Depends[6]	n/a	Instant	Instant	30 sec	Depends[6]	Depends[6]
g. Acknowledgement	?	N	?	Y	n/a	Y	Y	N	Sometimes	Y
h. Location	?	Y	N	Y	n/a	Zonal	Y	Y	N	Y

Source: IRC. North American Wholesale Electricity PHEV Impact Analysis. 2009

Notes:

[1] May be ineligible for certain payments.

[2] Mandatory to inject to IESO-controlled grid

[3] Mandatory only if participating in the Capacity market

[4] So long as connected as the same electrical location

[5] Portfolio obligation & bidding

[6] Resource specific

[7] Uni-direction communication from plant system to ISO/RTO

[8] Mandatory for RA resources

[9] Loss of revenue if non performance during shortage hours

[10] May delist

[11] 1 MW for spinning reserves; 100 kW for day-ahead scheduled

[12] Contracted, must be registered in Energy Market

Table G-4. ISO/RTO DR Markets Comparison Detail

	AESO	IESO	MISO	PJM	SPP	ERCOT[1]	NBSO	NYISO	ISO-NE	CAISO
Energy										
a. Minimum Capacity (MW)	None	1	0.1, 1	0.1	1	1	1	0.1,1	0.1	0.1
b. Participation Voluntary?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
c. Aggregation Allowed?	Y	Y,N	Y.N	Y	Depends[2]	Y	Y	Y	Y	Y
d. Duration (minutes)	Program	Scheduled	Program	Scheduled	5	15	1 hr	Program	Scheduled	Depends
e. Ramp Period	Program	Instant	Program	Program	5 min	n/a	Program	2 hr	Program	1 hr
Capacity										
a. Minimum Capacity (MW)	n/a	n/a	0.1	0.1	n/a	1	n/a	0.1	0.1	n/a
b. Participation Voluntary?	n/a	n/a	Y	Y	n/a	Y	n/a	Y	Y	n/a
c. Aggregation	n/a	n/a	Y	Y	n/a	Y	n/a	Y	Y	n/a
Reserves										
a. Minimum Capacity (MW)	None	1	1	1	n/a	1	1	1	0.1	0.1
b. Participation Voluntary?	Y	Y	Y	Y	n/a	Y	Y	Y	Y	Y
c. Aggregation	Y	N	Program	Y	n/a	Y	Y	N	Y	Y
d. Duration	1 hr	Scheduled	Scheduled	Scheduled	n/a	Scheduled	1 hr	Scheduled	Scheduled	2 hr
e. Ramp Period (min)	10	Instant	10	10,30	n/a	Program	Program	Program	30	10
Regulation										
a. Minimum Capacity (MW)	None	n/a	1	1	n/a	1	1	1	0.1	n/a
b. Participation Voluntary?	Y	n/a	Y	Y	n/a	Y	Y	Y	Y	n/a
c. Aggregation	Y	n/a	N	N	n/a	Y	Y	N	Y	n/a
d. Duration	Scheduled	n/a	Scheduled	Scheduled	n/a	Scheduled	1 hr	Scheduled	Scheduled	n/a
e. Ramp Period (min)	Instant	n/a	Instant	Instant	n/a	Instant	Instant	Instant	Instant	n/a

Source: IRC. North American Wholesale Electricity Demand Response Program Comparison. 2009.

Notes:

[1] In this document, ERCOT real-time energy participation is considered as voluntary load reductions, and does not reference the Balancing Up-Load program

which has no qualified participants to date and which expires upon launch of the Nodal market.

[2] Aggregation to a single withdrawal point from the transmission grid (and single retail provider) is permitted

[3] 1 hr metering report interval is used for settlement. Real-time metering is required of all resources to determine responsiveness.

Appendix H. Core Market Programs across North American ISO/RTO

The following tables summarize core market programs by ISO/RTO.

Table H-1. AESO

Service Type	Program Name
Energy	Demand Opportunity Service
	Voluntary Load Curtailment Program
Reserve	Supplemental Operating Reserves
Regulation	Frequency Load Shed Service

Table H-2. CAISO

Service Type	Program Name
Energy	Participating Load Program
Reserve	Participating Load Program

Table H-3. ERCOT

Service Type	Program Name
Reserve	Loads Acting as a Resource providing Responsive Reserve Service -- Under Frequency Relay Type
	Loads Acting as a Resource providing Responsive Reserve Service -- Controllable Load Resource Type
	Loads Acting as a Resource providing Non-Spinning Reserve Service
Regulation	Controllable Load Resources providing Regulation Service
Capacity	Emergency Interruptible Load Service

Table H-4. IESO

Service Type	Program Name
Energy	Emergency Load Reduction Program
	Emergency Demand Response Program
	Dispatchable Load
Reserve	Dispatchable Load (30 minute reserve)
	Dispatchable Load (10 Spinning / 10 Non-Spinning Component)

Table H-5. ISO-NE

Service Type	Program Name
Energy	Real Time Demand Response Program [Energy Component]
	Day-Ahead Load Response Program for RTDRP
	Day-Ahead Load Response Program for RTPR
	Real Time Price Response Program
Reserve	Demand Response Reserves Pilot Dispatchable Asset Related Demand
Capacity	Real Time Demand Response Program [Capacity Component]
	Real Time Demand Response Resource
	FCM: On-Peak, Seasonal Peak Resources
	Real Time Emergency Generation Resource

Table H-6. MISO

Service Type	Program Name
Energy	Emergency Demand Response
	Demand Response Resource Type I
	Demand Response Resource Type II
Reserve	Demand Response Resource Type-I
	Demand Response Resource Type-II
Regulation	Demand Response Resource Type-II
Capacity	Load Modifying Resource

Table H-7. NYISO

Service Type	Program Name
Energy	Day-Ahead Demand Response Program
	Emergency Demand Response Program
	Installed Capacity Special Case Resources (Energy Component)
Reserve	Demand Side Ancillary Services Program
	Demand Side Ancillary Services Program
Regulation	Demand Side Ancillary Services Program
Capacity	Installed Capacity Special Case Resources (Capacity Component)

Table H-8. PJM

Service Type	Program Name
Energy	Economic Load Response
	Emergency Load Response - Energy Only
	Full Emergency Load Response (Energy Component)
Reserve	Economic Load Response
	Economic Load Response
Regulation	Economic Load Response
Capacity	Full Emergency Load Response (Capacity Component)

Table H-9. SPP

Service Type	Program Name
Energy	Variable Dispatch Demand Response

Table H-10. NBSO

Service Type	Program Name
Energy	Bid-Based Demand Response
Reserve	10 Minute Spinning Reserve
	10 Minute Non-Spinning Reserves
	30 Minute Non-Spinning Reserves
Regulation	Regulation and Load Following
Capacity	Interruptible Load

Appendix I. Demand Response Programs across North American ISO/RTOs

The following tables summarize demand response programs by ISO/RTO.

Table I-1. Energy Services

Region	Program Name
AESO	Demand Opportunity Service
AESO	Voluntary Load Curtailment Program
CAISO	Participating Load Program
IESO	Emergency Load Reduction Program
IESO	Emergency Demand Response Program
IESO	Dispatchable Load
ISO-NE	Real Time Demand Response Program [Energy Component]
ISO-NE	Day-Ahead Load Response Program for RTDRP
ISO-NE	Day-Ahead Load Response Program for RTPR
ISO-NE	Real Time Price Response Program
MISO	Emergency Demand Response
MISO	Demand Response Resource Type I
MISO	Demand Response Resource Type II
NBSO	Bid-Based Demand Response
NYISO	Day-Ahead Demand Response Program
NYISO	Emergency Demand Response Program
NYISO	Installed Capacity Special Case Resources (Energy Component)
PJM	Economic Load Response
PJM	Emergency Load Response - Energy Only
PJM	Full Emergency Load Response (Energy Component)
SPP	Variable Dispatch Demand Response

Table I-2. Reserves Services

Region	Program Name
AESO	Supplemental Operating Reserves
CAISO	Participating Load Program
ERCOT	Loads Acting as a Resource providing Responsive Reserve Service -- Under Frequency Relay Type
ERCOT	Loads Acting as a Resource providing Responsive Reserve Service -- Controllable Load Resource Type
ERCOT	Loads Acting as a Resource providing Non-Spinning Reserve Service
IESO	Dispatchable Load (30 minute reserve)
IESO	Dispatchable Load (10 Spinning / 10 Non-Spinning Component)
ISO-NE	Demand Response Reserves Pilot Dispatchable Asset Related Demand
MISO	Demand Response Resource Type-I
MISO	Demand Response Resource Type-II
NBSO	10 Minute Spinning Reserve
NBSO	10 Minute Non-Spinning Reserves
NBSO	30 Minute Non-Spinning Reserves
NYISO	Demand Side Ancillary Services Program
NYISO	Demand Side Ancillary Services Program
PJM	Economic Load Response
PJM	Economic Load Response

Table I-3. Capacity Services

Region	Program Name
ERCOT	Emergency Interruptible Load Service
ISO-NE	Real Time Demand Response Program [Capacity Component]
ISO-NE	Real Time Demand Response Resource
ISO-NE	FCM: On-Peak, Seasonal Peak Resources
ISO-NE	Real Time Emergency Generation Resource
MISO	Load Modifying Resource
NBSO	Interruptible Load
NYISO	Installed Capacity Special Case Resources (Capacity Component)
PJM	Full Emergency Load Response (Capacity Component)

Table I-4. Regulation Services

Region	Program Name
AESO	Frequency Load Shed Service
ERCOT	Controllable Load Resources providing Regulation Service
MISO	Demand Response Resource Type-II
NBSO	Regulation and Load Following
NYISO	Demand Side Ancillary Services Program
PJM	Economic Load Response

Appendix J. Infrastructure Scenarios

The IT Working Group developed a set of fundamental set of functional requirements for the first stage of PEV products. The requirements are laid out in a progression of five evolutionary "Phases". These requirements will likely be further enhanced with the upcoming standards definitions developed by the Society of Automotive Engineers (SAE) and the National Institute of Standards and Technology (NIST)

1. **Simple Management of PEV as Charging-only or Reliability Assets**

   "Depending on the power level, timing, and duration of the PEV connection to the grid, there could be a wide variety of impacts on grid constraints, capacity needs, fuel types used, and emissions generated." [Note: The above sentence and much of the information included in this section is taken from the ORNL paper 'Impact of Plug-in Hybrid Vehicle on the Electric Grid', October 2006] A key question is when will consumers recharge their vehicles? The optimum time for the electric utilities is typically at night when demand is low and low-cost plants are the marginal producers. However, for consumers the preferred time (absent any incentives to change their preference) is likely to be as soon as they are within easy access to a plug. This is most convenient since they are at the vehicle already, and also improves their options since they may need the vehicle soon and would prefer a more fully charged battery.

   i. To manage this PEV charging demand, electric rate structures are needed that incent PEV owners to charge during off-peak hours.
      i. Simple asset management strategies such as Time of Use (TOU) or Critical Peak Pricing (CPP) would initially be considered to incentivize owners for home-based off-peak charging of PEVs.
         1. TOU or CPP metering at home would be the responsibility of the local utility as well as TOU or CPP rate structures designed to encourage PEV off-peak charging.
      ii. Price sensitive demand is likely the longer range inventive for smart grid homes and PEV owners. Wholesale prices reflected in time sensitive retail price structures will provide economic incentives for PEV charging times. Software will enable PEV owners to set maximum cost of electricity for charging; and allow overriding of the cost maximum when selected by the owner.
   ii. Aggregators could use curtailment of PEV charging to qualify as a load relief step in ISO/RTO Emergency Procedures or in existing capacity markets to reduce demand to maintain grid reliability.
      i. Curtailment could be applied to residential and public charging.

iii. Little ISO/RTO infrastructure is needed for this phase
    i. If successfully implemented, no additional grid facilities will be required
    ii. Some IT infrastructure will be required to forecast PEV load
iv. Local utility and homeowner infrastructure changes may be required.
    i. Potential homeowner infrastructure changes may be required for Level II, 220V charging.
    ii. Upgrades to some distribution feeders could be required for neighborhoods with multiple PEV residences.

2. **Complex Management of PEV as Reliability Assets**

As the novelty of owning and running a PEV morphs into public acceptance and greater value, increased numbers means increased load demand. Loading patterns become more recognizable and will start having an impact on regional load forecasts for both utilities and ISO/RTOs. New strategies and enhanced facilities must be in place to handle the increased loading and complexity of both public and private distribution infrastructures.

a. The business of aggregation of municipal and commercial blocks of PEV load becomes more mature with enhanced interfacing and communications with both utilities and ISO/RTOs.
    i. More automated strategies such as mobile charging-only stations would be employed for on-peak and off-peak charging including TOU or CPP rates
    ii. Charging stations would include PEV Smart Meters (facility level metering rather than individual PEV meters) for billing and communication of key PEV operating parameters (control and indication) with Aggregator(s) and ISO/RTOs.
    iii. At minimum, data sent to the ISO/RTO from the Aggregator would include at least the following for each aggregation point:
        - Aggregated MW Load
        - Aggregated MVAR Load

        Additional information may also be required based on the needs of the ISO/RTO, such as integrated MWH and load asset details. The amount, type, and frequency of data will drastically change for phase 3.
    iv. Aggregator may have systems to “sub-meter” (recognize) which individual PEV is charging and how much energy is consumed for accounting purposes. While accounting focuses on the aggregator, requirements from the ISO/RTOs may require some of the same data.

v. Aggregator may have to identify the geographic aggregation locations (i.e. substation or feeder level) of the PEVs and/or charging stations

b. ISO/RTOs may want to monitor the Aggregator's charging assets at the aggregation points to assess total PEV charging load and potential reduction/restoration during peak demand and/or emergency procedures.

   i. Similar to current strategies, ISO/RTO Demand Response functions will be applicable to commercial and municipal PEV load assets through the aggregator.
   ii. It is anticipated that the ISO/RTO would not have direct control of individual PEV charging assets for load reduction/restoration during peak demand and/or implementation of emergency procedures to maintain Bulk Power System (BPS) reliability. This control would be the responsibility of the Aggregator (or utility) on an aggregation point basis.

c. In phase 1, commercial and municipal PEV deployment drove the use of facility level charging stations. Very few areas were equipped with public access to charging stations, including PEV Smart Meter. In phase 2 the use of public charging stations will expand and become more common. An adaptation of the PEV Smart Meter could be extended for home use.

   i. Most private homes will require either two meters, one for PEV and the other for home energy consumption, or a single meter designed to separate load usage.
   ii. Apartments and similar complexes would provide parking areas with individual PEV smart meters and will require a concentrated infrastructure enhancement for the complex. Combining the charging infrastructure within these parking areas with clean alternate energy sources, such as solar or even wind, would become feasible.
   iii. PEV Smart Meters will become more common in public parking areas around concentrated business complexes or places of employment as part of services for employees. Public areas, such as amusement parks, shopping malls, and stadiums may be the last areas to have installed PEV Smart Meters.
   iv. No matter what the urban setting is, local utility infrastructure enhancements will likely be required for substations and feeders to handle the additional load demand.
   v. Both utilities and ISO/RTOs (through a third party aggregator) could offer to the private PEV owners incentives to participate

in demand response and emergency load shed activities. As an alternative, third party aggregators could offer lower charging costs in order to participate in the same ISO/RTO and utility programs.

3. PEV as Charging and Discharging Reliability Assets

Same as Phase 2, Complex Management of PEV as Reliability Assets, except requires changes to PEV asset power electronics enhancements to both charge/discharge to the grid.

Requirements for PEV as Charging and Discharging Reliability Asset

i. Cumulative charge (load) MW and MVAR values to be provided by aggregator by subzone or other ISO/RTO required electrically specific areas.

ii. Cumulative discharge (generation) MW and MVAR values to be provided by the aggregator by subzone or other ISO/RTO required electrically specific areas.

iii. Other required data points to be sent to ISO/RTO through Aggregator:
- Status (Available to follow signal)
- Frequency
- MW
- Voltage
- Amps
- Battery Charge State
- Charge/Discharge Capacity

Infrastructure charging station requirements for reverse current scenarios when PEVs are called to discharge to the grid via the PEV Aggregator and ISO/RTO

iv. A resource ID is required for all charging stations and all PEVs. [The analogy is the EZPass highway toll system that identifies the vehicle via its EZPass ID and the ID of the toll station reader.]

v. Aggregator shall be responsible for discharging into the grid with the same rules and requirements of any generator.

vi. Aggregators are responsible for tracking the electricity exchange of all its PEVs and allocating those exchanges to the associated charging stations.

vii. Discharge metering values from the aggregator must align with subzone or bus points for adequate reliability control.

ii. Probable infrastructure changes to PEV to handle charge/discharge control signals as well as remaining charge capacity to the PEV Aggregator and ISO/RTO

i. All PEVs will have a unique Resource ID (most likely the VIN number).
ii. All charging stations will have a unique Resource ID that identifies its location (distribution circuit) and charge/discharge capacity.
iii. Roaming PEVs that are charging at public charging stations or residences of another PEV will be identified by their Resource ID, the charging station ID and the PEVs associated aggregator if it has one.
iv. Aggregators are responsible for providing the ISO/RTO the charge/discharge rate of their PEV by location or load balancing area. [Location will be determined by GPS and/or charging station location by distribution circuit.]
v. Complete and partial load shedding response to an ISO/RTO signal must be acknowledged and performed by the charging station, the vehicle or both.

iii. Probable ISO/RTO additional IT infrastructure needed to integrate PEV as generating reliability assets
  i. Added data elements will be required for PEVs
  ii. Possible expansion of IT infrastructure to handle more ICCP/DNP feeds and the requisite optimization of dispatch, commitment and contingency analyses for this larger set of variables.
  iii. PEVs will be handled like any other resource for Regulation/etc markets – aggregator is the communication entity to ISO/RTO not PEV itself.
  iv. ISO/RTOs may need to evaluate how 'roving' generators with variable aggregated capacities will be monitored. PEVs can now easily cross zone boundaries. The aggregator will have to reflect that in their metering.

With IT and PEV infrastructure in place for Phases One-Three, additional phases including Market Integration will become probable.

4. PEV as Price Sensitive Demand (Charging-only Market Assets)

In this scenario, PEV aggregated blocks operate in *charge-only mode* and are incentivized through ISO market signals to charge at times other than peak demand or during periods of congestion at their location. In general, there are at least two types of price sensitive demand.

Interruptible Demand allows the PEV charging agent to specify a set of demand/price pairs that state the amount the load is willing to pay as well as inter-temporal constraints. This information is part of the ISO/RTO market optimization solution. Since this type of demand can be dispatched by the ISO/RTO depending on the overall system demand and/or locational constraints, the price this demand pays can vary at its location *and* the demand is eligible to set the uniform clearing price. This approach requires control signals by the ISO/RTO to the demand to interrupt/restore depending on system conditions. This technique allows the demand to influence the market clearing price through its bidding behavior and therefore can result in overall lower pricing for the demand. The downside is that demand is a function of current system conditions and prices since the ISO/RTO controls the dispatch level of the demand based on submitted parameters. The decision of which PEVs remain connected and charging is left to the aggregator to decide during periods when the ISO/RTO calls for an interruption/restoration of demand.

Non-interruptible Demand is simply a price taker and pays the current market clearing price at its particular location. If the price becomes too high, the load can choose to interrupt at its own discretion. The ISO/RTO cannot control this demand and therefore this demand is ineligible to directly set the uniform clearing price.

Non-interruptible Demand could be considered a higher quality, more valuable service, to the consumer since the PEV is guaranteed to charge regardless of the price. This could be considered analogous to the premium price paid for higher octane gasoline. Although the quality of the electrons provided by the charging station are no different, they are guaranteed to flow regardless of prevailing locational price and the PEV will more likely be able to travel to its destination with less risk on a fully charged battery. The consumer bears the risk that the price paid could vary greatly during the charging period. An informed consumer would plan to charge their PEV during off-peak hours with a higher level of certainty that the charge will complete in the shortest time possible and at the lowest price.

If consumers were provided with the ability to change their price levels daily, hourly, or at any time, or to set in place a schedule of prices specifying willingness to pay , the consumer would be able to manage the price paid versus battery charge risk quite effectively. This technique of Price Sensitive Demand for PEVs theoretically offers the greatest amount of flexibility for the aggregator and ISO/RTO. It would likely spur competition between and innovation by aggregators to provide a choice in price and quality of service to the consumer.

In terms of complexity to the ISO/RTO and auto manufacturer, this scheme is ranked *medium* since it requires no changes to the vehicles power electronics since the vehicle operates in a charge-only mode with metering and charge control provided on the outlet side of the connection to the PEV. The ISO/RTO would send dispatch and price signals to the aggregator and the aggregator would provide instantaneous and billing quality metering to the ISO/RTO for Settlement purposes.

Requirements, Interruptible Demand:

i. Charging agent to specify a set of demand/price pairs that state the amount the load is willing to pay.
ii. The price this demand pays can vary at its location *and* the demand is eligible to set the uniform clearing price.
iii. Requires control signals by the ISO/RTO to the demand to interrupt/restore depending on system conditions.

Requirements, Non-Interruptible Demand:

a. Non-interruptible Demand is simply a price taker and pays the current market clearing price at its particular location.
b. The ISO/RTO would send dispatch and price signals to the aggregator and the aggregator would provide instantaneous and billing quality metering to the ISO/RTO for Settlement purposes.

Potential impact of PEVs treated as Price Sensitive Demand

- Probable ISO/RTO additional IT infrastructure needed to integrate PEV as price sensitive demand assets within existing or new Market-based optimizations
- Probable ISO/RTO Market Rule changes
- Probable PEV Charging Station and Smart Meter enhancements will be needed to accommodate bidding
- Bidding rules will be dependent upon local ISO/RTO Market Rules
- Probable Host Meter Readers (think of them as the Local Distribution Company) for handling these locations in Settlement and reporting model

5. PEV as Ancillary Market Assets

Automotive OEMs are unlikely to produce vehicle-to-grid (V2G) capable vehicles in the next 2-3 years, and the long-term effects of continuous V2G activity on lithium ion battery life are still in question. The exception for OEMs could be V2G capable vehicles build for fleet purchases. In addition, many aftermarket PEV vehicle conversions are V2G capable. One such example are the recently 500 Mini-Es produced AC Propulsion; while initial piloting will be charge only, all 500 vehicles are capable of V2G participation. V2G participation in the ancillary services markets is attractive from the market's point of view because of the fast, accurate signal following; and it is attractive from the aggregator/vehicle's point of view because of the potential contribution to vehicle economics. PEV regulation market pilots are already in place and/or planned within PJM and ISO-NE.

Requirements:

i. PEVs must be equipped with inverters to provide enable bidirectional transfer of power into and out of the grid; making the PEV charge and discharge capable.
ii. In at least some markets, regulation service providers are required to be equipped with the equivalent of generator governor response. For PEVs, this would require the vehicles effectively to be able to charge and discharge continuously based on change in grid frequency.
iii. PEVs must be equipped with anti-islanding equipment to prevent back feed by isolating generation from the electric grid in the event of an outage, thereby protecting workers servicing the lines.
iv. The aggregator of must have a minimum of 1MW, 500KW or 250KW (depending on the current ISO/RTO tariff) to participate in the ancillary services market.
v. Two-way, real-time communications is required that provides verification of the response and participation of the aggregated PEVs to the ancillary market signal.

PEVs with V2G capability are ideal for providing regulation service for the following reasons:

- PEVs response to the regulation signal is extremely fast (less than a second).
- Response to regulation signals has little or no effect on the life of the battery.
- PEVs are capable of participating with the regulation signal while increasing their charge.
- PEVs are typically parked 22-23 hours of the day, and are available to participate in the regulation market whenever parked and plugged in.

Value proposition for PEVs participation in the Ancillary Services markets:

- CAISO, ERCOT, ISO-NE, NY-ISO and PJM all offer a regulation market and over the past 3 years have an average of $35-$40 per megawatt-hour annual market clearing price.
- Gross annual revenue for a 15 kW output PEV participating in the regulation market 80% of the time (7000 hours annually) at an average payment of $40 per megawatt-hour is $4200.

- These prices would likely fall with significant market participation by PEVs.

Potential impact of PEVs participating in the ancillary services market

- Possible use of PEV assets for Spinning and/or Operating Reserve Assets
- Probable ISO/RTO additional IT infrastructure needed to integrate PEV assets as Ancillary Market assets within existing or new Market-based optimizations
- Probable ISO/RTO Market Rule changes