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Electricity Pricing Strategies to Reduce Grid Impacts from Plug-in Electric Vehicle Charging in New York State

Final Report

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Final Report

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Abstract

Increased penetration of plug in electric vehicles (PEVs) in New York will inevitably increase electric load. It is unlikely that modest PEV penetration rates would create a near-term need for new generating capacity, but the added load could stress the electric grid in other ways. If PEV charging coincides with peak demand from other sources of peak load, the results may include the need for upgrades to the distribution system, the need for new transmission to relieve congestion, higher wholesale market prices, and greater reliance on less efficient peaking units. Peak demand is growing four times faster than overall electricity demand. A growing amount of empirical data has shown that the grid impacts of PEV charging are best managed when utilities have the ability to create incentives for PEV owners to charge their vehicles during off-peak hours. Controlled charging, which describes the practice of managing charging load to minimize PEV integration costs, also has numerous potential economic and environmental benefits and can facilitate the integration of variable renewable resources.

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Summary

Greater penetration of plug-in electric vehicles (PEV) in New York has the potential to provide multiple benefits for customers, including reduced emissions of greenhouse gases (GHG) and conventional air pollutants, as well as lower total energy costs. However, absent pricing strategies to incentivize customers to charge during off-peak periods, the added load from PEV charging could increase peak electricity demand, especially in the summer, and increase costs for New York utilities and customers. Conversely, the managed integration of PEV load could improve system asset utilization and facilitate the integration of variable renewable generation. This report explores the economic and environmental benefits of electricity pricing strategies for PEV charging in New York State.

To evaluate the effect of electricity rate policies on daily PEV charging load profiles, a PEV charging model was developed. The model is used to project PEV penetration rates from 2015 through 2030 and the effect on daily charging load of three different options for PEV charging pricing strategies: 1) a business as usual base case assuming current flat-rate consumer tariffs, 2) time-of-use rates or other incentives for off-peak charging, and 3) fully controlled charging to lower average charge rates and spread charging demand more evenly across the day. Specifically:

- The base case assumes that current consumer flat-rate electric rate tariffs will be maintained throughout the analysis period, with no changes intended to modify or influence consumer charging behavior.
- A time of use (TOU) rate or other incentive would vary the cost of electricity (dollars per kilowatt-hour) depending on the time of day, with higher rates for electricity used during a peak time period and lower rates for off-peak periods. The TOU rate or incentive would incentivize a significant portion of PEV owners who charge their vehicles at home to delay the start of charging to the start of the lowest TOU rate period.
- For fully controlled charging, the charge rate is assumed to be constant throughout the charge period for each vehicle, but is assumed to be just high enough to ensure completion of charging after 8 hours, for both at-home and at-work charging. The controlled charging scenario modeled is fairly simplistic and is one of many potential controlled charging scenarios that could be implemented by utilities to control PEV charging load.

Based on the research and analysis conducted for this project the recommendations are that New York utilities and the New York Public Service Commission (PSC) pursue a series of pilot offerings to incentivize off-peak PEV charging using both whole-house TOU rates and off-peak charging rebate programs (each PEV owner should be able to choose which program to participate in).

Voluntary Whole-House TOU Rates. From the utility perspective, the simplest mechanism to incentivize off-peak PEV charging is to offer PEV owners whole-house TOU rates. However, current voluntary whole-house TOU rates in New York are not popular with PEV owners; therefore, absent some reforms, existing voluntary whole-house residential TOU rates are unlikely to be effective in mitigating negative grid effects resulting from PEV charging because they are unlikely to be adopted by many PEV owners. New York utilities should gather more information on patterns of household electricity use by PEV owners, and consider modifying existing TOU rate structures to: 1) make them simpler for customers to understand, and 2) provide consistent net benefits to PEV owners. Utilities should also develop outreach programs to educate customers as to the benefits of whole-house TOU rates for PEV owners.

PEV-only TOU rates face significant regulatory and financial barriers in New York, primarily related to the need to install a second utility-grade meter or submeter to measure the PEV charging load, separate from other household loads. According to regulatory requirements, the second meter or the submeter must be under the control of the utility in order to insure the accuracy of the meter for billing purposes. In addition, a second meter or submeter present an additional cost burden for the PEV customer. Based on these barriers this analysis concludes that PEV-only TOU rates would be no more effective at incentivizing off-peak charging than PEV-optimized whole-house TOU rates and should therefore not be prioritized in New York.

Rebate Program for Off-Peak Charging. As an alternative to whole-house TOU rates, utilities should also offer PEV owners the option of a rebate program that would provide a monthly credit or rebate in exchange for consistent off-peak PEV charging, while maintaining standard rates for all household electricity use. A rebate program to incentivize off-peak PEV charging would be analogous to existing load control programs; there is significant experience and familiarity with these programs in New York by both utilities and the PSC. This type of rebate requires the ability to continuously monitor current in the charging circuit and one-way communication to collect and centrally record the monitored signal. However, it would not require the utility to measure PEV charging electricity use for billing purposes – so it would avoid the costs of a second utility-grade meter. Implementation costs for an off-peak charging rebate program would therefore likely be significantly lower than implementation costs for PEV-only TOU rates, and could be similar or lower than implementation costs for whole-house TOU rates.

Rebate Program for Controlled Charging. Although a rebate program focused on off-peak charging will likely provide the greatest net benefits for most customers, a rebate program for allowing utility controlled charging may be warranted in certain locations, particularly those with high potential for PEV clustering. Under such a program the customer would get a monthly rebate for allowing the utility to control PEV charging within set parameters, but would be allowed a maximum number of “overrides” of utility control per month. Depending on the technology chosen for implementation of each program, net costs for full utility control of charging could be higher than for a rebate program to incentivize off-peak charging, but the benefits could also be greater because it would potentially allow the utility to better manage negative effects of PEV clustering.

The potential benefits from implementing these recommendations include benefits to the grid and to the environment. The analysis conducted for this project found that if approximately 50 percent of all PEV owners delay the majority of their PEV charging to off-peak hours, as incentivized by the recommended adoption of a whole-house TOU rate or rebate program, the benefits to the grid in New York State in a high PEV penetration scenario could include, by 2030, up to \$46 million annually in reduced generating costs and reduced monthly generating capacity costs. In addition, reduced infrastructure upgrade costs resulting from mitigation of PEV clustering could total \$103 million statewide over the next 15 years.

The recommendations from this analysis would also result in environmental benefits. Based on the current New York Independent System Operator (NYISO) marginal CO₂ and NO_x emissions curve the off-peak PEV charging incentivized by the recommendations would reduce CO₂ emissions by one kilogram of CO₂ per PEV per year and would reduce NO_x emissions by 0.26 kilograms of NO_x per PEV per year. In a high penetration scenario, this reduction would amass an annual savings in 2030 of 755 metric tons of CO₂, equivalent to the CO₂ emissions from the annual energy use of nearly 70 homes in New York State, and 196 metric tons of NO_x, equivalent to fleet average annual NO_x emissions from almost 300,000 gasoline vehicles.

The recommendations in this report are well aligned with several of the objectives articulated in the Reforming the Energy Vision (REV) initiative initiated by the PSC in order to make New York’s electric system cleaner, more resilient, and affordable including: enhanced customer knowledge and tools that will support effective management of the total energy bill, market animation and leverage of customer contributions, system wide efficiency, system reliability and resiliency, and reduction of carbon emissions.

1 Introduction

The transportation sector accounts for approximately 40 percent of New York State's combustion-based greenhouse gas (GHG) emissions. The gasoline-fueled light-duty vehicle sector is responsible for the vast majority of those emissions [1]. Greater penetration of plug-in-electric vehicles (PEV) in New York has the potential to provide multiple benefits for customers including reduced emissions of GHGs and conventional air pollutants, as well as lower total energy costs. However, absent PEV charging pricing strategies to incent customers to charge vehicles during off-peak periods, added load from PEV charging could increase peak electricity demand, especially in the summer, and increase costs for New York utilities and customers.

This report explores the economic and environmental benefits of managed PEV charging relative to baseline uncontrolled charging, and explains the implications for a PEV charging pricing strategy in New York State. This report begins by providing background information on current electricity pricing regulations in New York State and PEV charging experiences and lessons learned that should inform New York's PEV charging pricing strategy. Next, the report presents an analysis of PEV charging scenarios including PEV vehicle penetration, baseline charging load profiles, peak load impacts, and the benefits of alternative charging load profiles based on time-of-use rates and controlled charging. Finally, the report details a recommended PEV charging pricing strategy, including technology implications and costs associated with implementation of such a strategy.

According to the New York State Department of Public Service, 47 electric utilities provide electric delivery service to residential and commercial customers in New York. Forty are small, local utilities that primarily serve customers within a single city, town, or village. The remaining seven large utilities distribute approximately 98 percent of the total electrical power annually in New York and serve almost 99 percent of residential and commercial customers [2]. These utilities are listed in Table 1 along with the number of customers and annual total electricity sales of each. The geographic service territories of these utilities are shown in Figure 1.

Table 1. Seven Largest Electric Distribution Utilities in New York

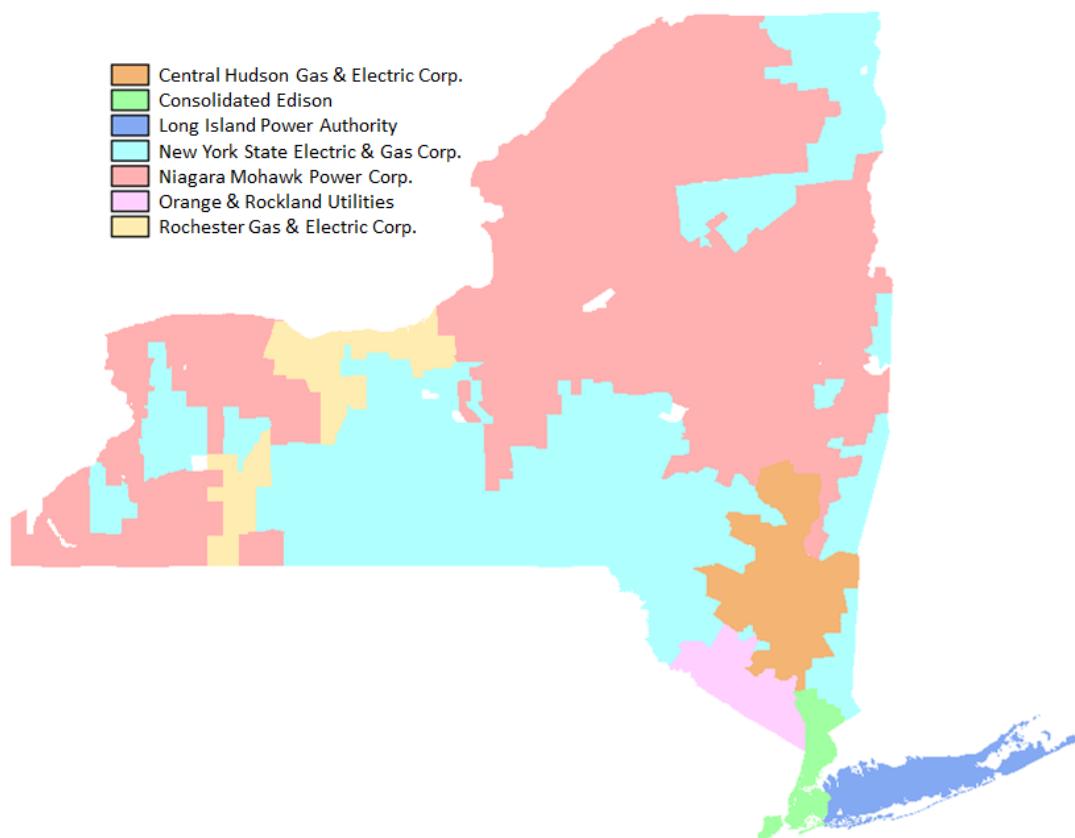
Source: Energy Information Administration

Distribution Utility	Residential Customers	Total Customers	Total Sales (megawatt-hours)
Consolidated Edison	2,859,548	3,354,612	56,917,897
Niagara Mohawk Power Corp. ^a	1,466,580	1,637,911	33,957,382
Long Island Power Authority ^b	996,432	1,116,576	19,931,093
New York State Electric & Gas Corp.	761,664	881,659	15,496,680
Rochester Gas & Electric Corp.	330,180	370,703	7,154,965
Central Hudson Gas & Electric Corp.	253,893	300,225	5,108,653
Orange & Rockland Utilities	195,267	226,446	4,003,207
All Other	97,982	111,476	3,673,999
TOTAL	6,961,546	7,999,608	146,243,876

^a Niagara Mohawk is a subsidiary of National Grid
^b Service is managed for Long Island Power Authority by PSEG Long Island

Figure 1. Service Territories for Seven Largest Utilities in New York

Source: Ventyx Velocity Suite™ database, MJB&A analysis



In April 2014, Governor Cuomo announced plans for a modernization of the way New York State distributes and uses electricity. To meet the challenge, the PSC commenced its Reforming the Energy Vision (REV) initiative to make New York's electric system cleaner, more resilient, and more affordable. In a customer-oriented regulatory reform, REV seeks to promote the coordination of a wide range of distributed energy resources for load management, system operator optimization, and enabling of clean distributed power generation. The initiative aims to empower customers to optimize their energy usage and reduce electric bills, while stimulating innovation and new products to further enhance customer opportunities through reformed markets and tariffs.

The REV initiative has six objectives, as stated by the PSC:

- Enhanced customer knowledge and tools that will support effective management of the total energy bill.
- Market animation and leverage of ratepayer contributions.
- System wide efficiency.
- Fuel and resource diversity.
- System reliability and resiliency.
- Reduction of carbon emissions.

The PSC has separated REV into two tracks. In Track One, the PSC examined the role of distribution utilities in enabling market-based deployment of distributed energy resources to promote load management and greater system efficiency, including peak load reductions. Based on input from stakeholders, the Department of Public Service staff developed a comprehensive proposal released on August 22, 2014. In Track Two, which is currently underway, the PSC is examining changes in current regulatory, tariff, and market designs and incentive structures to better align utility interests with achieving the policy objectives.

The recommendations in this report align with several of the objectives articulated in the REV initiative including, enhanced customer knowledge and tools that will support effective management of the total energy bill, market animation and leverage of customer contributions, system wide efficiency, system reliability and resiliency, and reduction of carbon emissions.

2 Current NYS Electricity Pricing Regulations

This section summarizes existing electricity pricing regulations in New York State and existing residential electricity tariffs for four of the largest electric distribution utilities operating in the State.

2.1 New York State Electricity Pricing Laws

The New York Code of Rules and Regulations 16 (NYCRR 16) contains the rules that apply to the PSC. The rates and terms of service under which utilities provide electric service are set forth in tariffs filed with the PSC, which regulates the State's utilities and reviews and approves rates and terms of service. The primary mission of the PSC is to ensure affordable, safe, secure, and reliable access to electric, gas, steam, telecommunications, and water services for New York State's residential and business consumers, while protecting the natural environment [3].

In New York, as in other states, most residential customers pay a fixed monthly fee for electric service, plus a flat rate for the energy they consume (\$/kWh), regardless of the time of day the electricity is used. The flat rate for energy use is composed of a delivery charge (\$/kWh) intended to account for the utility's cost of installing and maintaining electrical distribution infrastructure, and an energy charge (\$/kWh) which covers the utility's actual cost to purchase the delivered electricity on the open market. Delivery charges change only infrequently, in response to approved rate cases filed with the PSC. Energy charges typically change monthly, in response to competitive market forces.

In contrast, many commercial and industrial customers pay for the electricity they consume based on time-of-use (TOU) or time-of-day (TOD) rates, or based on rates that include both usage and demand charges. These rates can take one of two forms. Typically, for smaller customers the day is divided into off-peak and peak periods, with higher delivery and energy charges (\$/kWh) for electricity used during peak periods than for energy used during off-peak periods¹. The timing of peak and off-peak periods may be different during the summer than during other times of the year, and both delivery and energy charges during peak periods may be higher in the summer than during other times of the year.

¹ Some utilities also designate super-off-peak periods with even lower rates than off-peak periods. Conversely, some utilities also designate super-peak periods with even higher rates than peak periods.

For larger customers with expected peak demand greater than 10 kilowatts, the form of the electricity rates are different; the delivery and energy usage charges (\$/kWh) are constant throughout the day, but the customer must also pay a monthly demand charge (\$/kW) based on their peak demand during the month. The demand charge is usually set based on the highest demand over any 15-minute or 30-minute period during the past 18 months; demand charges may be higher in the summer than during other times of the year.

Although all of the largest New York utilities have voluntary TOU rates for residential customers that are similar to those for small commercial customers, the NY Public Service Law was amended in 1997 so that the PSC could not mandate residential time-of-use (TOU) rates.

As measured by opt-in rates, voluntary residential TOU rates are not popular in New York. For customers that can switch the majority of their household electrical load to off-peak hours, TOU rates would result in significant monthly energy cost savings compared to standard rates. However, most customers believe that they cannot control the timing of the majority of their electrical loads, and any savings from electricity use during off-peak hours would be outweighed by higher on-peak prices, negating the benefits of TOU pricing.

Specifically, PEV owners could move the majority of home PEV charging to off-peak hours, reducing the cost of PEV charging with a TOU rate compared to standard rates. However, if the remainder of household electricity use (other than PEV charging) remained unchanged, and a significant portion was during day-time (peak) hours, it is not clear whether “whole house” TOU rates would actually produce a net savings for PEV owners.

Another alternative would be to charge a PEV using a TOU rate, but leave the rest of the house on standard rates. Although this option could be very attractive to PEV owners, there are currently several significant financial and regulatory barriers to this approach in New York.

First, the use of a TOU rate requires different meter programming than use of a standard rate. Because a single meter cannot measure two different loads, a PEV-only TOU rate would require a second meter to be installed at the PEV owner's residence to measure the load on the PEV charging circuit, separate from other household loads. All utilities surveyed for this report will supply and install TOU meters to customers at no up-front cost², if they switch the entire house to a TOU rate, but none will supply a second meter for a single service at a single location, due to regulatory restrictions.³

Section 139.1 of NYCRR 16 states that “[e]xcept when multiple meters are provided at the request of a customer, or when provided under the conditions or circumstances set forth in sections 139.3, 139.4, and 139.6 of this Part, all service to a customer at a single location shall be rendered through a single meter.” The exceptions allowing two meters at a single location only apply in specific situations that do not affect the majority of customers. This regulation effectively prohibits utilities from providing customers with a second meter for a single residential account in order to implement a PEV-only TOU rate, while all other electricity use is metered under a standard rate. The rationale for limiting meters to one per customer is that the high cost of buying and installing meters makes providing multiple meters to individual customers prohibitively expensive.

Given this regulation, a customer who wanted to use a TOU rate only for their PEV while keeping other household loads on standard rates would need to request a second meter. Although the utility would be obligated to provide the second meter itself at no cost, the customer would need to hire an electrician to install a second meter pan to accommodate it; the cost of this work could be \$1,000 or more. In addition the utility would be obligated to treat the second meter as a second account, subject to a separate monthly service charge. As discussed in the following sections, these monthly service charges range from \$14 to \$30 per month in New York (\$168 - \$360 per year). These additional up-front and ongoing customer costs related to a second meter create an additional barrier to customer adoption of TOU pricing strategies for PEV charging.

² In some cases an existing standard meter may be able to be re-programmed for TOU rates; in others it may need to be replaced with a new meter. While the utility owns all meters, and does not charge the customer for their installation, these costs are recovered, for both standard and TOU meters, through the monthly account service charge.

³ National Grid has submitted a request to the PSC to establish a new TOU rate which will include a monthly fee for meter purchase and installation.

2.2 NY Utility Retail Tariffs

This section summarizes the retail tariffs, both standard and TOU, for Con Edison, Long Island Power Authority (PSEG Long Island), Niagara Mohawk (National Grid), and Central Hudson Gas & Electric. These four utilities, which all participated actively in this project, provide electric delivery services to approximately 80 percent of all New York customers. All of these utilities offer TOU rates, but they are neither popular with customers (measured by customer opt-ins), nor optimized for PEV owners.

2.2.1 Con Edison

For residential customers, Con Edison offers a standard non-TOU rate and a voluntary whole-house TOU rate. Although standard non-TOU electricity rates do not vary by time of day, the supply portion of rates does vary slightly across Con Edison's service zones, and from month to month. For example, the supply rate in Zone J (New York City) and in Zone H (northwest Westchester County) will be slightly different in a given month. During summer months (June-September), delivery charges per kilowatt-hour increase after the first 250 kWh of electricity use; the delivery charge is flat during all other months regardless of electricity use. There is also a customer charge, in addition to the energy charges, billed every month; this customer charge is currently \$15.76 per month.

Customers who sign up for TOU pricing will have a new meter installed by Con Edison at no additional cost but will pay a higher monthly customer charge primarily to account for the cost of the TOU meter. Once a customer has switched to TOU rates, they must remain on TOU pricing for at least one year (except for Retail Choice customers). TOU supply rates are divided into three periods: off-peak, on-peak, and super-peak. Super-peak periods are a subset of peak hours during the summer (June -September), but apply on weekdays only. TOU delivery rates have a peak and off-peak time period. These time periods apply to both weekdays and weekends. Both supply and delivery charges are tied to time of use, with higher prices during peak and super-peak hours. For both supply and delivery charges, the difference between standard and TOU rates can be significant. As with standard rates, TOU supply rates vary across service zones. Table 2 provides a summary of Con Edison's TOU rate including delivery and supply charges and how it compares to the standard rate, based on a TOU rate calculator on Con Edison's website [4]. In Table 2, the off-peak and on-peak periods apply to both delivery and supply while the super-peak period applies to supply only.

Unlike the standard rate, delivery charges under the TOU rates do not increase after a certain amount of electricity is used. The monthly customer charge for the TOU rate is higher than that of the standard rate, currently at \$19.87/month. Customers with PEVs who sign up for the SC1 Rate III TOU rates can qualify for a price guarantee for their first year of service by registering their PEV. Under the price guarantee, the customer will receive a credit following the one-year period for the difference, if any, between what the customer paid under the TOU rate and what the customer would have paid under the non-TOU rate over that one-year period.

In its 2015 rate case, Con Edison proposed to allow customers who wanted to separately meter their PEV usage to take service under the SC1 Rate III whole-house TOU rate rather than requiring the separate meter to be billed under the nonresidential rate.

Table 2. Con Edison Standard and Voluntary Residential Time of Use Rate

Source: Consolidated Edison

Rate Type	Time Period	Rate (\$/kWh) ^a	Monthly Service Charge
Standard	All day year round	\$0.3090	\$15.76
Time-of-Use	Off-peak 12 a.m. – 8 a.m. All Days	\$0.1397	\$19.87
	On-peak 8 a.m. – 12 a.m. All Days	\$0.4165 (June-Sept) \$0.2968 (Oct-May)	
	Super-peak 2 p.m. – 6 p.m. Weekdays, Jun – Sept	\$1.1963	

^a Includes delivery charges and an estimate for supply

2.2.2 Niagara Mohawk (National Grid)

National Grid's residential customers can choose either a standard rate or a voluntary whole-house TOU rate. The standard rate (\$/kWh) is constant throughout the day and is set monthly for each billing period; the monthly rates vary across National Grid's six service zones. The delivery charge under the standard rate is constant year-round and monthly variances in the total \$/kWh charge are based on differences in supply charges. In addition to the charges for energy use customers pay a \$17 monthly service charge.

National Grid's voluntary TOU rate requires customers to sign up for a minimum of one year. TOU requires a new meter, which is installed at no cost to the customer. Although available to residential customers, the rate is designed primarily to benefit larger-use customers with substantial off-peak electricity consumption.

Under the TOU rate, days are divided into three periods: peak, shoulder peak, and off-peak. As with the standard rate, TOU rates vary across service territories and by time of year. The TOU delivery charge is a constant regardless of time of day, but the supply charge is lower during off-peak than during shoulder peak and peak periods. The service charge for the TOU rate is \$30/month.

Generally speaking, National Grid's on-peak prices and shoulder peak prices are higher than the standard rate while off-peak prices are lower than the standard rate. A comparison of National Grid's standard and TOU rates can be found in Table 3 [5]. As previously noted, the delivery portion of both rates are flat, with the monthly delivery charge for the standard rate roughly 1.5 cents higher than that for the TOU rate. The rates shown in Table 3 are as of April 2015; note that the actual \$/kWh charge for both standard and TOU rates could be slightly different than that shown in any given month, due to monthly adjustments to the supply portion of the rate.

On December 20, 2013, National Grid submitted a proposed TOU tariff, filed as Case 12-E-0201, to the New York PSC. The proposed rate is designed specifically for residential customers and intended to support New York's PEV initiatives and encourage off-peak charging. Under the rate, both supply and delivery charges will be based on three rate periods: on-peak, off-peak, and super-peak. The proposed rate includes an incremental charge to recover the costs of the enhanced metering required to bill the rate. The rate also offers a price guarantee for PEV full service customers for the first 12 months they are on the rate; during this period monthly charges would be no higher than they would be under the standard rate regardless of actual billed amount under the TOU rate.

The proposed rate divides the day into three TOU periods: super-peak from 2 p.m. to 6 p.m. June through August, on-peak 7 a.m. to 11 p.m. year round (with super-peak as a subset), and off-peak 11 p.m. to 7 a.m. year round. Both super- and on-peak periods apply to weekdays and weekends. Supply charges under the proposed rate are based on the actual hourly NYISO day ahead prices. During most of the year, capacity costs are applied to the supply rate on weekdays from 12 p.m. to 8 p.m. During the summer, capacity costs are only applied during the super-peak period (2 p.m. to 6 p.m.), significantly increasing the supply charge for that period. Unlike the standard rate, the proposed TOU supply rates do not factor in a New Hedge Adjustment, which hedges exposure to volatile market prices and softens price signals.

Table 3. National Grid Standard and Voluntary Residential Time of Use Rate

Source: National Grid

Rate Type		Time Period	Rate (\$/kWh)	Monthly Service Charge
Standard		All day year round	\$0.1031	\$17.00
Time-of-Use	Peak	5 p.m.-8 p.m. Weekdays, Dec-Feb 11 a.m.-5 p.m. Weekdays, Jun-Aug	\$0.13047	\$30.00
	Shoulder Peak	9 a.m.-5 p.m. Weekdays, Dec-Feb 8 a.m.-11 a.m. & 5 p.m.-8 p.m. Weekdays, Jun - Aug	\$0.10347	
	Off-peak	8 p.m. -9 a.m. Weekdays, Dec-Feb 8 p.m. -8 a.m. Weekdays, Jun-Aug All hours Sep-Nov & Mar-Apr All weekends	\$0.08247	

Delivery charges under the proposed TOU rate are 5.906 cents/kWh during on-peak and 0.904 cents/kWh during off-peak. Super-peak rates are the same as on-peak. The proposed rate's monthly service charge is \$20.36, which includes the standard rate charge of \$17 plus \$3.36 to cover the cost of purchasing and installing a TOU-capable meter. After one year on the TOU rate, National Grid will offer to provide PEV owners with a comparison of their bill under TOU and what it would have been under the standard residential rate. If the bill would have been lower under the standard rate, National Grid will provide a one-time refund of the difference. Customers have the option to switch rates every 12 months.

2.2.3 Central Hudson

Central Hudson Gas and Electric (Central Hudson) offers residential customers a standard rate and voluntary whole-house TOU rate. Central Hudson does not have multiple service zones, so both the supply and delivery charges under the standard rate are constant across the utility's entire service territory. The standard rate includes a monthly service charge of \$24.

To sign up for Central Hudson's TOU rate, customers must commit to a one year contract. Central Hudson's TOU option differs from other utilities in that it allows customers to choose from three different 12 hour on/off-peak time periods. The choices for peak period are 8 a.m. – 8 p.m., 9 a.m. – 9 p.m., or 10 a.m. – 10 p.m.. Supply charges under Central Hudson's TOU rate are unique in that they are based on a percentage of the standard rate pursuant to the relationship of on-peak and off-peak supply cost to the system average supply cost for a representative period, all as priced at market rates. The on-peak price is 118 percent of the standard rate while off-peak is 89 percent of the standard rate. The delivery charge also varies between on and off-peak usage, and TOU customers pay a \$27 monthly service charge. A summary

of Central Hudson's standard and TOU rates is provided in Table 4 [6]. The rates shown in Table 4 are as of April 2015; note that the actual \$/kWh charge for both standard and TOU rates could be slightly different than that shown in any given month due to changes in the supply portion of the rate on a monthly basis.

In a proposed rate case, certain charges under the TOU rate are modified. The monthly service fee increases to \$34, while the on-peak delivery charge increases slightly and the off-peak charge decreases slightly. There are no changes to the methodology for calculating supply costs.

Table 4. Central Hudson Voluntary Residential Time of Use Rate

Source: Central Hudson

Rate Type		Time Period	Rate (\$/kWh)	Monthly Service Charge
Standard		All day year round	\$0.1382	\$24.00
Time-of-Use	Peak	Weekdays Choice of 8 a.m. – 8 p.m., 9 a.m. - 9 p.m., or 10 a.m. – 10 p.m.	\$0.1659	\$27.00
	Off-peak	All other hours, all weekends	\$0.1190	

2.2.4 Long Island Power Authority (PSEG Long Island)

The Long Island Power Authority (LIPA), now managed by PSEG Long Island (PSEG-LI), offers a standard residential rate (Rate Code 180), which consists of a monthly Fuel & Purchase Power Charge (FPPCA) for all kWh and delivery charges. PSEG-LI offers a voluntary TOU rate (Rate Code 188), which consists of a monthly FPPCA for all kWh and delivery charges that vary by time period. The standard rate varies monthly due to the FPPCA and seasonally (summer/winter) due to delivery charges. TOU rates also vary monthly due to the FPPCA and seasonally (summer/winter) due to delivery charges, and also vary based on time periods. The standard delivery energy charges increase after the first 250 kWh of use, however TOU delivery energy charges only vary by time period. The standard rate is subject to a service charge of 36 cents/day. The TOU rate is subject to a service charge of 36 cents/day, plus a meter charge of 10 cents/day.

Customers signing up for the TOU rate must commit to the rate for one year. PSEG-LI rates are unique in that the power supply charge is included in both the standard rate and the TOU rates. Table 5 provides detailed information on PSEG-LI's standard and TOU rates [7].

Table 5. PSEG Long Island Voluntary Residential Time of Use Rate

Source: PSEG Long Island

Rate Type		Time Period	Rate (\$/kWh)		Monthly Service Charge
			Jun - Sep	Oct - May	
Standard		All day year round	\$0.1666 (first 250 kWh) \$0.1784 (over 250 kWh)	\$0.1813 (first 250 kWh) \$0.1743 (over 250 kWh)	\$0.36/day
Time-of-Use	Peak	10 a.m. – 8 p.m. weekdays	\$0.3544	\$0.1844	\$0.36/day plus \$0.10/day meter charge
	Off-peak	8 p.m. – 10 a.m. weekdays All weekends	\$0.1387	\$0.1393	

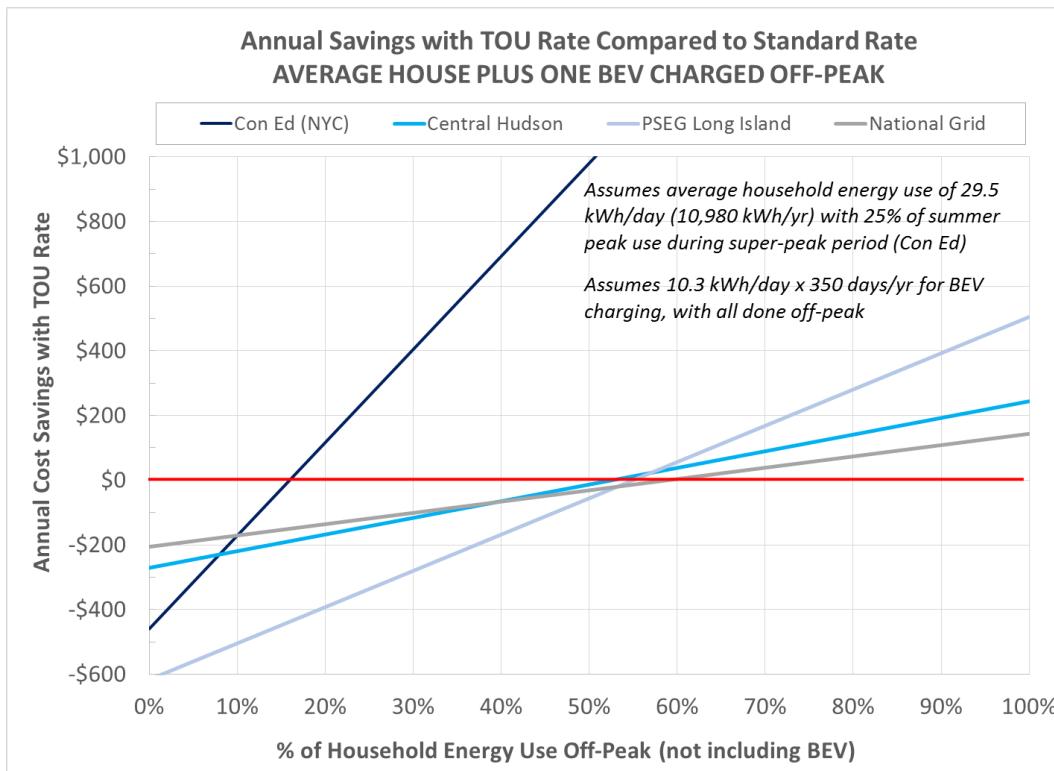
The rates shown in Table 5 are as of April 2015; note that the actual \$/kWh charge for both standard and TOU rates could be slightly different than that shown in any given month due to changes in the supply portion of the rate on a monthly basis.

2.3 Potential PEV Owner Savings with TOU Rate

Based on the New York voluntary TOU rates described in Section 2.2, the authors evaluated the potential savings to a PEV owner who switched from a standard electricity rate to a whole-house TOU rate. This analysis is summarized in Figure 2. In this figure, the annual savings under TOU rates compared to standard rates are plotted against the percentage of total (non-BEV [battery electric vehicle]) household electricity use during off-peak hours. The analysis assumes that each household would have one BEV which would, on average, use 10.3 kWh per day and would be charged 350 days per year. These assumptions are consistent with the modeling described in Section 4. The analysis also assumes that 100 percent of BEV charging would be conducted during off-peak hours in accordance with the time period definitions of the TOU rate. The analysis assumes that other household energy use (other than BEV charging) would average 29.5 kWh/day (10,980 kWh/year) which was the US average in 2013 according to the U.S. Energy Information Administration.

Figure 2. Potential Annual Savings with New York Whole-house TOU Rates, for Average Household with one BEV Charging Off-peak

Source: Utility TOU rates; MJB&A Analysis



As shown in Figure 2, for a household using this much energy, plus charging one BEV 100 percent off-peak, the breakeven point for savings under the Con Edison TOU rate would be 85 percent of household energy use (other than BEV charging) on-peak and 15 percent off-peak; if more than 15 percent of household energy use was off-peak the Con Ed TOU rate would result in a net annual savings for a BEV owner compared to the standard rate. For example, if 30 percent of household energy use (other than BEV charging) was off-peak, net annual savings could be as high as \$400. These figures assume that 25 percent of peak-period energy use would be during the super-peak period defined under the Con Edison TOU rate (2 p.m. – 6 p.m. weekdays, June through September). If a higher percentage of total peak-period electricity use was during the super-peak period the savings would be lower.

The household breakeven point for savings under the Central Hudson, PSEG Long Island, and National Grid TOU rates would be much higher than the breakeven point under the Con Edison TOU rate. For customers of these utilities 50 – 60 percent of household energy use (other than BEV charging) would have to be off-peak in order to break even with a TOU rate; if a lower percentage of household electricity use was off-peak TOU rates would increase net annual electricity costs, but if a greater percentage of

household electricity use was off-peak TOU rates would produce a net savings. For example, if only 30 percent of household energy use (other than BEV charging) was off-peak a Central Hudson or National Grid customer would pay about \$100 per year more with TOU rates than with standard rates, while a PSEG Long Island customer would pay about \$280 per year more.

The analysis summarized in Figure 2 assumes that 100 percent of BEV charging would be off-peak. If some of the BEV charging was done during on-peak periods the break-even point would be higher for all of these TOU rates. For example, if only 50 percent of BEV charging was done off-peak the break-even point for net savings under the Con Edison TOU rate would increase to 29 percent of other electricity use off-peak – below 29 percent the TOU rate would increase total annual electricity costs compared to the standard rate. With only 50 percent of BEV charging off-peak the break-even point for the Central Hudson, PSEG Long Island, and National Grid TOU rates would increase to between 60 and 65 percent of other household electricity use off-peak.

The analysis summarized in Figure 2 is also based on standard and TOU rates for a specific point in time. For all rates the supply portion of the rate can and does change on a monthly basis, which could affect the break-even point for all utilities. However, assuming that any change to supply rates would likely affect both standard and TOU rates similarly, the effect of supply rate changes on the breakeven point would be small.

2.4 NY Utility Load Control Programs

This section summarizes the direct load control programs operated by Con Edison and PSEG Long Island, to reduce forecast system peak loads. On December 15, 2014, the PSC ordered Upstate utilities, which do not currently have load control programs, to develop programs similar to those implemented by Con Edison and PSEG Long Island. These new programs are scheduled to begin this summer.

2.4.1 Con Edison

Con Edison has several peak load shaving program offerings to reduce the forecasted system peak demand. These programs were designed to support electric system reliability and reduce operational costs in Con Edison's service territory. These programs were designed to reduce load on call at the discretion of Con Edison (i.e., when actual demand reaches 96 percent or greater of the forecasted summer system peak). Two of these programs offered to residential customers are the Direct Load Control (DLC)

program and CoolNYC, both targeted toward facility air conditioning loads. Both programs are voluntary, target load reductions during peak system demand, require the installation of devices at the customer site for the utility to control the load, and include a financial incentive for customers in exchange for allowing Con Edison to cycle air conditioning equipment.

The DLC Program consists of two components: the Residential DLC and the Business DLC. The program allows Con Edison to remotely curtail system demand utilizing radio communication enabled thermostats, provided by Con Edison, that control participants' central air conditioning units. The thermostats also enable customers to remotely control their central air conditioning units. Customers have the ability at all times to over-ride any control.

Customers apply to participate in the DLC Program. Residential participants receive a \$25 incentive, and businesses receive \$50, after thermostats are installed. DLC participants are able to program their thermostats via the Internet or a smart phone. The thermostats are equipped with two-way communicating technology and can store seven days of compressor run-time data and temperatures, which is used to estimate hourly load reductions during curtailment events.

The CoolNYC program allows Con Edison to reduce demand from residential window air conditioning units. According to Con Edison estimates, there are over six million room air conditioners in its service territory representing approximately 2,500 MW of peak load. If just 5 percent of six million window air conditioners participated in CoolNYC, the company could conservatively expect 40 MW of demand reduction per event.

Con Edison contracted ThinkEco to provide the technology solution and implementation support for the CoolNYC program. Customers that enroll in CoolNYC are provided with a free or reduced-cost smart AC kit which enables them to monitor and control their window air conditioner(s) from a smartphone or Internet-enabled computer. As part of the program, participants receive a \$25 thank you gift at the end of the summer in the form of an e-gift card. The smart AC technology platform allows Con Edison to control load at the room AC level, and execute load control programs. During an event either the target temperature is increased by a number of degrees or the thermostat is set to a specific temperature.

2.4.2 PSEG Long Island

PSEG Long Island's Programmable Thermostat Program provides participants with a controllable thermostat and uses a one-way pager signal to remotely cycle (i.e., switch off) central air conditioning units and pool pumps. Customers who enroll in the program agree to allow PSEG LI to remotely adjust their air conditioning between the hours of 2 p.m. and 6 p.m. for a maximum 7 days throughout the summer (June-Sept.).

PSEG LI pays for the programmable thermostat and installation. A DLC device is also attached to the furnace or in the attic by the air handler that allows for customer and PSEG communication with the central AC system. Customers can adjust their air conditioner through the Web or a mobile app. The DLC program started in 2001 and achieved 35 MW peak demand reduction in 2013.

In PSEG LI's October 2014 update to its Utility 2.0⁴ filing, it proposed to modernize and expand the Programmable Thermostat Program to provide up to 125 MW of peak demand reduction, including replacing the existing 35 MW demonstrated in 2013 and adding an incremental 90 MW to the program. PSEG LI is targeting activating the program for approximately 27 to 45 hours annually (i.e., 6 to 11 days, for an average of 4 hours a day). PSEG LI also proposed a pilot to test "smart plugs" capable of monitoring and controlling plug-in appliances, with a focus on capability to cycle room AC units for peak reduction and overall energy savings.

⁴ The Utility 2.0 plan focuses on improving energy efficiency and reducing peak load to address infrastructure needs across Long Island and in targeted load pockets.

3 PEV Charging Experiences and Literature Review

This section summarizes information gathered during the literature review, including information on PEV tariff programs in other states, and data on consumer charging behavior and grid interactions developed by the EV Project.

3.1 PEV Tariff Programs in Other States

This section provides background on several voluntary residential PEV charging tariff programs in other jurisdictions, and provides insights into their effectiveness and lessons learned from the perspectives of the utilities and administrators from the Public Utility Commissions with jurisdiction. The PEV charging tariff programs reviewed include: California (SDG&E), Michigan (DTE Electric), and Virginia (Dominion). An overview of each program is provided in the following subsections.

3.1.1 California – San Diego Gas & Electric

San Diego Gas & Electric (SDG&E) is a regulated public utility that serves 3.5 million customers. Its service area covers 4,100 square miles in San Diego and southern Orange counties in California.

SDG&E designed a study with California Public Utilities Commission (CPUC) approval to examine PEV customer time-of-use charging behavior. SDG&E completed the pilot program in 2013. A February 2014 report details the findings of the pilot program [8]. The primary goal of the study was to understand the potential impact of PEV charging on electric utility infrastructure as well as identify methods to mitigate any negative impacts from integrating these loads into the grid.

SDG&E customers were randomly assigned to one of three PEV tariffs, each with different price ratios between on-peak, off-peak, and super off-peak rates. The three rates were designed to test low, medium, and high price ratios between the on-peak and super off-peak TOU periods. The low rate (EPEV-L) has an on-peak to super off-peak price ratio of roughly 2:1, the medium rate (EPEV-M) has a ratio of roughly 4:1 and the high rate (EPEV-H) ratio is roughly 6:1. The rates apply only to load or usage from the electric vehicle supply equipment (EVSE) and not to the customer's entire house load, which was separately metered and billed. The study only examines charging behavior at home; it does not look at public or workplace charging facilities. The pricing is shown in Table 6.

Approximately 430 customers are part of the experimental program. Each one had a Level 2 (240 volt) home charging unit; had technology that allowed programming of charging time (either through the PEV or EVSE); and were separately metered (and billed) on a dedicated 40 amp home circuit for PEV charging loads.

Table 6. SDG&E PEV Pricing Schedule

Source: SDG&E

Period	SDG&E Study Rates						
	EPEV-L		EPEV-M		EPEV-H		
	\$/kWh	Ratio to Super-Off-Peak	\$/kWh	Ratio to Super-Off-Peak	\$/kWh	Ratio to Super-Off-Peak	
Summer	Peak	\$0.25	2.02	\$0.28	3.83	\$0.036	5.71
	Off-Peak	\$0.16	1.23	\$0.17	2.41	\$0.14	2.28
	Super Off-Peak	\$0.13		\$0.07		\$0.06	
Winter	Peak	\$0.17	1.24	\$0.23	3.03	\$0.32	4.83
	Off-Peak	\$0.16	1.19	\$0.16	2.02	\$0.13	1.93
	Super Off-Peak	\$0.13		\$0.08		\$0.07	

After the two and a half year study, the researchers had several findings:

- PEV charging takes place mostly during the super off-peak period using charging timers.
- Charging frequency is greater on weekdays than on weekends and the typical charging event lasts an average of about three hours.
- The majority of participants do not charge their PEVs every day and those who do generally do it once per day.
- Timers were used heavily by the majority of PEV customers. Timer data signify that customers facing stronger price signals are more likely to adhere to a fixed PEV charging schedule.
- Participants began the vast majority of their PEV charging events during the super off-peak period, specifically between 12 a.m. and 2 a.m.
- Experimental Plug-In Electric Vehicle Service – High and Medium Ratio EPEV-H and EPEV-M customers had the highest percent of total charging done during the super off-peak period (85 percent and 83 percent, respectively).
- Experimental Plug-In Electric Vehicle Service - Low Ratio EPEV-L customers had 78 percent of all charging done during the super off-peak period.
- The super off-peak charging pattern was facilitated by use of programmable charging technology available on Nissan Leafs and charging units.

The influence of customer-owned solar electric (also known as photovoltaic or PV) systems emerged as an important customer characteristic that may have a material impact on PEV charging. The study found that customers with solar electric are less price responsive than non-PV participants. Solar electric systems were present in 25 percent of the PEV households in the study population. These customers face significantly different incentives regarding their charging behavior due to the onsite generation from their systems. In many cases, customers sized their solar electric systems accounting for the added load from PEV charging.

SDG&E currently offers two voluntary EV TOU rates: EV-TOU-2 and EV-TOU. The EV-TOU-2 rate uses the existing household smart meter (and therefore results in a whole house TOU rate) while the EV-TOU rate requires a separate meter for the PEV paid for by the customer. The TOU rates are differentiated by the summer and winter seasons and the only difference between the two rates is the definition of on-peak. However, customers with solar electric installed on their homes that want to utilize the solar electricity to charge their PEV must stay on the standard rate or chose the EV-TOU-2 rate. The TOU rates are provided in Table 7.

Table 7. SDG&E's Current PEV TOU Rates

Source: SDG&E

Rate	On-Peak	Super Off-Peak	Off-Peak
Summer (\$/kWh) EV-TOU EV-TOU-2	\$0.49	\$0.16	\$0.22
	Noon-8:00 p.m.	Midnight-5:00 a.m.	All other hours
	Noon-6:00 p.m.		
Winter (\$/kWh) EV-TOU EV-TOU-2	\$0.20	\$0.17	\$0.19
	Noon-8:00 p.m.	Midnight-5:00 a.m.	All other hours
	Noon-6:00 p.m.		
Standard	\$0.17224		

SDG&E submitted a proposal for a Vehicle-Grid Integration (VGI) Program in April 2014. The proposal is aimed at testing market response to a variable electric rate for vehicle charging. The proposed pilot program will explore how consumers respond to an hourly variant rate and day-ahead pricing for EV charging, and examine the benefits of efficiently integrating EV charging loads with the grid.

Under the VGI Pilot Program, SDG&E will contract with third parties to build, install, operate, and maintain EV charging facilities targeted at workplace and multi-unit dwelling host facilities. SDG&E demonstrates in their proposal that prospective EV customers who could benefit from multi-unit dwellings and workplace charging sites may be currently underserved.

The proposal includes the following timeline for installations and number of charging stations:

- Year 1 (2015) – 50 site installations of 10 charging stations.
- Year 2 (2016) – 100 site installations of 10 charging stations.
- Year 3 (2017) – 200 site installations of 10 charging stations.
- Year 4 (2018) – 200 site installations of 10 charging stations.

If approved, the utility will develop a mobile app and website allowing customers to set their vehicle charging preferences and respond to signals from the pilot rate. The resulting data would be an opportunity to examine the rates' effects on charging behavior and grid utilization.

The VGI Pilot Program will allow an EV customer on a VGI rate to enter preferences for energy price and quantity into a mobile phone application or a website. Hourly pricing for each day will be made available on the VGI mobile and web application on a day-ahead basis. The charging rate incorporates three components: (1) a variable commodity component based on the California Independent System Operator (CAISO) day-ahead hourly price; (2) a dynamic pricing signal via a tariff mechanism for the recovery of commodity capacity costs; and (3) a dynamic pricing signal designed to recover distribution circuit peak costs and address local capacity concerns. The end result is a VGI Rate that reflects the hourly differences in the CAISO Day-ahead price.

The pilot program also proposes a model for examining VGI's cost-effectiveness from three different perspectives: 1) the utility ratepayer, 2) the EV driver, and 3) society at large.

The timeline for the new pilot project includes five years for site installations and a ten year period from 2015 to 2025 for data collection, analysis and reporting. The expected costs of the program include \$59 million in capital costs and \$44 million in operations and maintenance over the life of the project.

3.1.2 Virginia – Dominion Virginia Power

Dominion Virginia Power operates regulated electric transmission and distribution utilities in Virginia and northeastern North Carolina, providing electric service to about 2.5 million customer accounts in the two-state area.

In October 2011, Dominion Virginia Power, with agreement from Virginia State Corporation Commission (SCC), began to study whether rate options affect charging patterns for PEV program participants. The ultimate goal of the program is to encourage behavioral changes such as load shifting, peak-shaving, or conservation during high electricity demand periods by customers, therefore reducing the company's future capacity needs and energy costs.

In 2011, Dominion anticipated a far greater number of PEVs on the road by 2020 than what is now likely. Dominion indicated that there could be 86,000 electric vehicles in the state – equal to 5 percent of all vehicle sales – by 2020. If charged on-peak, these vehicles could increase peak demand that year by about 270 megawatts. According to the Virginia Department of Motor Vehicles, as of October 2014 there are approximately 3,531 registered PEVs in Virginia, 2,827 of which are in Dominion Virginia's service territory.

Dominion has two pilot rate schedules. The first is EV+ Home rate. This TOU plan is for PEV users for energy consumed across the entire household. This program does not distinguish from loads generated throughout the house or the charging station. The rate schedule for the EV+ Home is in Table 8.

Dominion's second pricing schedule for PEV vehicles is their EV Rate. It requires a second meter at the residence, as it provides a TOU pricing for energy consumed by the EVSE only. The household load continues to be billed at the existing rate on the original meter. The rate does not provide for seasonal differentiation in pricing. The rate schedule for the EV Rate is shown below in Table 9. The additional meter required is provided at no charge to the customer. However, there may be installation costs incurred from the installation itself.

Table 8. Dominion EV+ Home Rate Schedule

Rate Type	Time Period	Rate (\$/kWh)
April 16 through October 15		
On-Peak	1 p.m.-7 p.m.	\$0.12
Intermediate	10 a.m.-1 p.m. & 7 p.m.-10 p.m.	\$0.07
Off-Peak	10 p.m.-1 a.m.	\$0.04
Super Off-Peak	1 a.m.-5 a.m.	\$0.01
October 16 through April 15		
On-Peak	6 a.m.-11 a.m. & 5 p.m.-10 p.m.	\$0.07
Intermediate	Not applicable	Not applicable
Off-Peak	5 a.m.-6 a.m., 11 a.m.-5 p.m., & 10 p.m.-1 a.m.	\$0.04
Super Off-Peak	1 a.m.-5 a.m.	\$0.02
June-September		
Standard	Not applicable	\$0.06053 (first 800 kWh) \$0.07058 (over 800 kWh)
October-May		
Standard	Not applicable	\$0.06053 (first 800 kWh) \$0.04212 (over 800 kWh)

Table 9. Dominion EV Rate Schedule

Rate Type	Time Period	Rate (\$/kWh)
On-Peak	6 a.m.-10 p.m.	\$0.13
Off-Peak	10 p.m.-1 a.m. & 5-6 a.m.	\$0.04
Super Off-Peak	1-5 a.m.	\$0.007

The current pilot provides important data on charging behavior and the value of a whole house TOU rate versus an EV only TOU rate. There is an \$825,000 cap on the cost of the EV pilot. The cost is recovered in the rate rider established for all Dominion's demand side management (DSM) programs, as Dominion has categorized this pilot as a peak shaving program. To date, the cost of the program has been less than one half the approved amount, with most of the costs incurred for monitoring and evaluation.

Dominion submits annual reports to the Virginia SCC and submitted its most recent report in October 2014. Between 2013 and 2014, 445 customers participated in the EV+Home program while 145 customers participated in the EV program. According to the 2014 annual report, the pilot program has thus far had positive results. Enrollment has increased steadily and feedback from participating EV owners has been positive. The current data show that participants from both rate options are more likely to charge their EVs during the super off-peak period. Over 90 percent of participants stated that they were satisfied with their rate plan, and 75 percent of those indicated they were very satisfied. Dominion plans to continue the pilot program through November 30, 2016.

3.1.3 DTE Electric

DTE Electric generates, transmits and distributes electricity to 2.1 million customers in southeastern Michigan. DTE Electric offers a limited incentive program for home charging stations to help customers in Michigan make the transition to a PEV. Customers who enroll in the program may receive a reimbursement of up to \$2,500 to help cover the purchase, installation, and required home wiring of a Level 2 charging station. Any costs that go beyond \$2,500 are the responsibility of the customer.

DTE Electric also has two rate options for EV customers: a TOU rate plan and a monthly flat rate (FR) plan. The TOU plan requires the installation of a separate meter and a Level 2 charger. TOU rates are seen in Table 10 below. The FR plan is \$40 per month per vehicle and is limited to 250 DTE customers. There are currently 2,150 customers enrolled in the TOU plan and 182 customers enrolled in the flat rate plan. While the program was originally limited to the first 2,500 participants, in May 2014 the Michigan Public Service Commission (MPSC) approved a request by DTE to increase program participation to 5,000 customers.

Table 10. DTE EV Pricing Schedule

Source: DTE

Time of Use Plan	Time	Cost per kWh
On-Peak	9 -11 p.m. Monday-Friday	\$0.18195
Off-Peak	11 p.m. -9 a.m. Monday-Friday and all day Saturday and Sunday	\$0.07695
Standard	Not applicable	\$0.11915 (first 17 kWh/day) \$0.1326 (over 17 kWh/day)

Key takeaways and lessons learned:

- Approximately 75 percent of TOU customer charging is during off-peak while approximately 40 percent of the flat rate FR customer charging is during off-peak.
- Without delayed charging capabilities within the EVs, most customers would prefer a FR.
- The flat rate offering must mirror increasing battery capacity trends (a \$40 monthly charge may result in too much of a loss for DTE).
- Customers want to flip flop back and forth from TOU and FR.
- Many EV drivers charge at their workplace during the day, making home charging more of a “top off” than a full charge.
- Range anxiety still exists with new customers who are in the preliminary stages of acquiring an EV.
- The DTE incentive program (\$2,500 for the first 5,000 customers) held significant weight in the EV purchase decision.

The PEV TOU and FR will remain the same throughout 2015.

3.2 Controlled PEV Charging Pilot Projects

Four voluntary PEV charging pilot programs are currently underway which focus on off-peak and/or managed charging: one being conducted by Con Edison, one being conducted by Eversource, one by the Potomac Electric Power Company (Pepco), and one by Pacific Gas & Electric (PG&E). Con Edison is the largest electric distribution utility in New York, serving 3.4 million customers in New York City and Westchester County. Eversource serves 1.4 million customers in Massachusetts. Pepco serves more than 788,000 electric customers, 531,000 in Maryland and 257,000 in the District of Columbia. PG&E serves 5.4 million electric customers in northern and central California.

The Con Edison pilot is testing the ability of a Branch Circuit Energy Management Device (BCEMD) to measure, and to a limited extent control, PEV charging in five-minute intervals. The Eversource and Pepco pilots are using the same third-party electric vehicle supply equipment (EVSE) technology for each enrolled PEV – a 240-volt charging station made by Clipper Creek which includes an Itron revenue-grade meter and command and control communication capability. The EVSE allows for flexible and automatic control of charging, receiving inputs such as charging schedules, and control signals for demand response. In addition, the EVSE allows a utility to remotely measure the energy delivered to the vehicle as interval metering data. The PG&E pilot is a joint program conducted with BMW that provides incentives to PEV owners participating in demand response.

3.2.1 Con Edison BCEMD Pilot Project

Con Edison is currently conducting a pilot program for 50 customers with PEVs. The pilot is testing the ability of a Branch Circuit Energy Management Device (BCEMD) to measure, and to a limited extent control, PEV charging in five-minute intervals. For some customers, Con Edison is using the BCEMD to measure solar energy consumption as well. In the pilot, Con Edison is also evaluating customer responsiveness to pricing and other information to evaluate its effect on charging behavior.

Of the 50 customers enrolled in the study, 29 are in Westchester County and the rest are in Brooklyn, Queens, the Bronx, and Staten Island. These customers own a total of 54 PEVs: 32 BEVs and 22 plug-in hybrid electric vehicles (PHEVs). Thirty-four of the customers are on standard electricity rates and 16 are signed up for one of three different TOU rates. Fifteen customers also have solar arrays installed on their house, and 12 of these are in Westchester County; Con Edison notes a strong correlation between PEV ownership and solar installation, especially in Westchester.

Con Edison has been collecting data from the pilot participants since September 2014. To date, for customers on the standard electricity rate, more than 60 percent of PEV charging took place during peak, or super-peak hours. By comparison, customers on TOU rates did virtually all of their PEV charging during non-peak hours.

Using data from September 2014 to February 2015, Con Edison analyzed potential savings with a TOU rate for those pilot customers for which both PEV charging and total household electricity use was measured. Over this time period more than half of these customers would have saved money if using the whole-house TOU rate, described in Section 2.2.1, rather than standard rates. Note, however, that this preliminary analysis includes limited summer data during which the much higher super-peak rates are applicable.

Using command signals run through the communications portal developed for this pilot project, Con Edison is able to open and close contactors in the BCEMD to interrupt the load on the PEV charging circuit in each pilot participant's house. As such, they can implement limited control of PEV charging – i.e., they can remotely turn charging on and off, but cannot vary the rate of charging. Con Edison has conducted 27 utility control test events, with the participation of 21 pilot program customers. Each event lasted two minutes and removed between 0.1 and 9.6 kW of load.

Con Edison has also conducted a test of voluntary load reduction by the pilot program participants. An email was sent to all 50 participants asking them to refrain from charging between 12 a.m. and 1 a.m. on March 18, 2015; the email was sent 36 hours prior to this requested load reduction period. During the previous 30 days, average PEV charging load from 12 p.m. to 1 a.m. was 37.7 kW for all 50 households. Actual load from 12 p.m. to 1 a.m. on March 18 was less than one kilowatt (at two houses), demonstrating almost universal participation, and the ability to voluntarily shed about 37 kW of load.

This pilot program is ongoing and is expected to continue into 2016. Con Edison has identified the following next steps:

- Provide each EV Pilot participant with reports beginning in June 2015, including a summary of the customer's total household energy consumption and EV energy consumption in off-peak, on-peak, and super-peak periods, and a billing comparison demonstrating what the customer would pay on various rate alternatives.
- Using a full year of EV load data, prepare a report by November 15, 2015 analyzing customer charging behavior and the cost savings under different current and proposed voluntary time of use rate VTOU rate options.
- Run utility-controlled and participant-controlled demand response events to coincide with Con Edison heat emergencies during the summer of 2015.
- Consider using a BCEMD for incentive programs: a monthly payment for off-peak EV charging and/or a monthly payment for utility-controlled EV charging.
- Monitor and evaluate other BCEMD technologies.
- Continue evaluating the accuracy of the BCEMD.

3.2.2 Eversource Smart Charging Pilot

The Eversource Smart Charging Pilot is a research project for residential PEV charging designed to collect detailed charging profile data, and for Eversource to test communication with the EVSE to manage the charge rate. The pilot is available to 105 Eversource customers in Massachusetts, and is scheduled to run for one year once the program is fully subscribed.

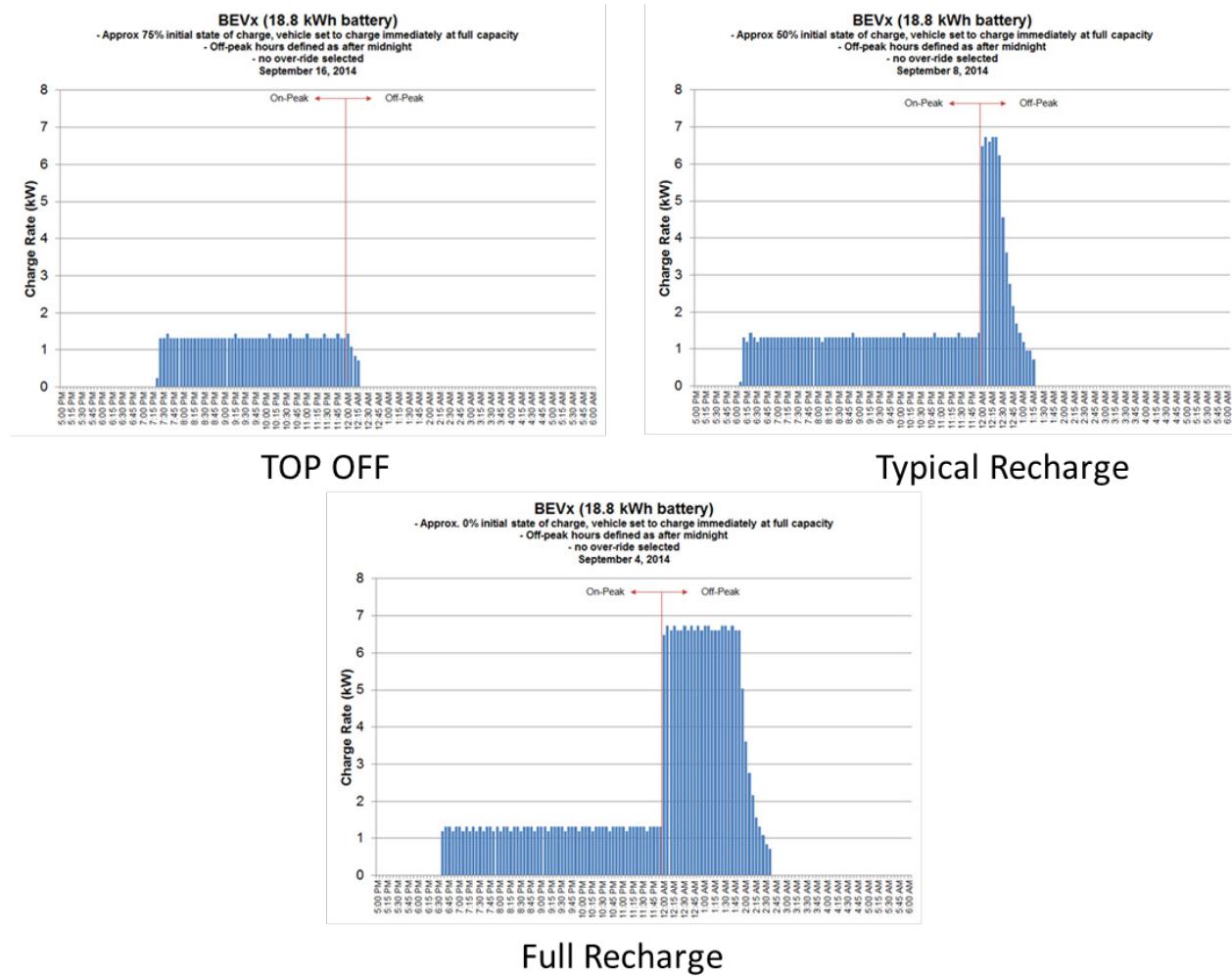
The commercial cost of the Clipper Creek EVSE is currently approximately \$2,550, but for this pilot program Eversource provides a subsidy and the EVSE cost to each subscriber is only \$500.

Eversource developed three research groups in the pilot:

- Group 1 – Collect charging data only to determine “baseline” charging profiles.
- Group 2 – Provide a \$10 monthly bill credit if customers allow Eversource to manage their daily charging. Customers are allowed to override Eversource control of charging but to qualify for the monthly incentive, no more than four overrides are allowed per month.
- Group 3 – Same as Group 2, but with unlimited overrides allowed.

Figure 3. Eversource PEV Managed Charge Profiles

Source: Eversource



Eversource developed three different managed charge load profiles during proof-of-concept testing, which they are using in the pilot program. Shown in Figure 3, these charge profiles are:

- Top Off – constant charge rate, with the vehicle fully charged by midnight.
- Typical Recharge – constant charge rate until midnight, with rate increased after midnight to ensure full charge by 1 a.m. Expected total energy delivered sufficient for 35-40 miles driving, with the majority delivered before midnight.
- Full Recharge – constant charge rate until midnight, with rate increased after midnight to ensure full charge by 3 a.m. Approximately two-thirds of total energy delivered after midnight.

3.2.3 Pepco Demand Management Pilot

Pepco created the Demand Management Pilot Program for Plug-In Vehicle Charging to encourage customers in Maryland to take advantage of off-peak charging. The pilot is available to Maryland residents who drive a Maryland-registered plug-in vehicle that can travel a minimum of 30 miles using electricity as fuel.

Participants in the pilot can choose either Pepco's whole house time-of-use rate (R-PIV Rate) or its plug-in vehicle rate (PIV Rate). The PIV Rate is limited to the first 250 qualified customers and requires the installation of a second meter at Pepco's cost. PIV Rate participants also have the option to purchase renewable or "green" energy to charge their vehicles.

The pilot program also offers discounted "Smart Level 2" EVSEs. Enrollment is limited to 50 customers, or sign up by October 31, 2015, whichever comes first. Pepco will also pay 50 percent of the charging station's cost, and the customer will be responsible for the remaining balance (approximately \$1,275). Pepco offers on-bill financing for EVSE installation cost.

Pepco will use the smart EVSE to test demand response events and calculate the load impact of each event. The pilot program is intended to validate smart EVSEs to support consumer engagement, demand response, time-of-use rates and embedded revenue-grade metering.

3.2.4 PG&E-BMW i ChargeForward Program

PG&E is working with BMW to test electric vehicle participation in demand response in the San Francisco Bay Area in California. The program, which will run from July 2015 through December 2016, will include up to 100 BMW i3 PEV owners who are also PG&E customers. During a demand response event, PG&E will send BMW an alert indicating the amount of load that needs to be cut and for how long. BMW will then send a signal to participating vehicles ordering them to stop charging. Another signal will be sent at the end of the event telling vehicles to resume charging. Participating i3 owners will receive information on the program through a mobile app that will allow them to opt in or out of demand response events.

Participating customers will receive a \$1,000 gift card at the beginning of the pilot. A second gift card, valued at up to \$540 based on customer participation in demand response events, will be awarded at the end of the program.

PG&E will develop a report at the end of the pilot detailing customer behavior and feedback, the technical requirements needed to scale up to a mass-market program, and an evaluation of the future viability of the program. The i3 pilot will run concurrent with another project involving PG&E load management of a bank of used PEV batteries installed at a BMW facility.

3.3 Consumer Charging Behavior and Grid Interaction (EV Project)

This section summarizes the key takeaways on charging behavior and grid interaction from The EV Project, the largest deployment and evaluation project of PEV and charging infrastructure to date. The EV Project involved the deployment of over 12,000 AC Level 2 (208-240V) charging units and over 100 dual-port DC fast chargers in 20 metropolitan areas. Approximately 8,300 PEVs were enrolled in the project.

During the data collection phase of the project (January 1, 2011- December 31, 2013), EV Project researchers collected and analyzed data from participant's vehicles and/or charging units, capturing almost 125 million miles of driving and four million charging events. Charging event data collected by the EV Project are categorized by location, charge power level, and time of day.

Idaho National Lab (INL) is responsible for analyzing the data collected and publishing results. INL has developed summary reports, maps, technical papers, and lessons learned on vehicle and charging unit use. This section summarizes key EV Project summary reports and data on charging behavior and discusses the implications for New York PEV charging price strategies.

3.3.1 PEV Owners Response to Time-Of-Use Rates

INL researchers evaluated how PEV owners respond to TOU rates [9]. Within the regions of The EV Project, eight electric utilities provide TOU rates: Arizona Public Service, Georgia Power, Los Angeles Department of Water and Power, Pacific Gas & Electric, Portland General Electric, Salt River Project, and San Diego Gas & Electric. Researchers found that the perceived value of the financial incentives associated with TOU rates play a major role in TOU rate adoption by EV Project participants. Greater than half (57 percent) of EV owners who responded to an EV Project survey changed their utility rate plan after obtaining an EV.

The researchers also compared customers of Portland General Electric (PGE) and Pacific Gas & Electric (PG&E) and their choice of PEV rates. While PG&E customers overwhelmingly chose a TOU rate, the PGE customers did not. As a result, PG&E customers delayed their charging to off-peak times, while PGE customers did not. The researchers found that a lack of knowledge of TOU plans and savings may be a major reason why EV owners do not adopt TOU rates. As a result, the researchers concluded that utility customer outreach and education efforts play a very important role. In addition, the INL researchers concluded that some did not adopt TOU rates because their vehicle needs made it inconvenient to charge off-peak.

3.3.2 Programming the PEV Charge

INL researchers also evaluated which programming method EV Project participants prefer – the EVSE or the vehicle [10]. The ability to program the vehicle or EVSE is a convenience that enables the EV driver to plug in when arriving home rather than having to plug in after the start of the TOU period. The researchers found that about half the participants prefer to program only their vehicle while one quarter prefer to program only their EVSE.

Over two-thirds of survey respondents in the PGE and PG&E service territories selected TOU rates (either whole-house or EV rate plans). A number of EV owners indicated that they program the charging of their EV but do not subscribe to TOU rates, suggesting EV drivers schedule charging for reasons other than financial incentives (such as driving schedule and/or awareness of and sensitivity to the lower environmental impact of off-peak charging).

3.3.3 Electric Miles Traveled

This study investigates the observed monthly distance traveled when powered solely by electricity, or electric vehicle miles traveled (eVMT) of Nissan Leafs and Chevrolet Volts in The EV Project. This study considers data from Leafs and Volts logged from October 1, 2012, through December 31, 2013 [11].

Even though the EPA-certified electric range of the Leaf is approximately double that of the Volt, Leaf drivers averaged only 6 percent more actual electric miles per month than Volt drivers. In fact, a large number of Volts averaged the same or higher monthly eVMT than many Leafs, despite having a much shorter electric range.

The disparity between electric range and eVMT can be explained by three reasons. First, Volt drivers charge more frequently, on average, than Leaf drivers. Second, Leaf drivers are less likely to realize their full electric range because of the impracticality of planning stops for charging precisely when the battery is fully depleted. Finally, Leaf drivers may have purchased their vehicles with the understanding that they do not require long driving range or they have the option of driving a different vehicle on long trips.

3.3.4 Type of Charging Infrastructure Used

INL researchers evaluated over 865,000 charging events for over 4,000 Nissan Leaf drivers over a 15 month period [12]. On average, these vehicles drove 32.4 miles per day and were charged 1.1 times per day on days when the vehicle was driven. The data indicated that the Leaf drivers relied on home charging for 84 percent of all charges and away from home for the remaining 16 percent of charges. The daytime charges were split relatively evenly between home and away.

Over 80 percent of home charging events were performed overnight and 20 percent were between trips during the day. Of the 16 percent performed away from home, 88 percent were daytime Level 1/Level 2 charges. DC fast charges were all away from home during the daytime and accounted for about one percent of charging events.

More than three quarters of energy consumed was associated with overnight charges at home. The researchers found a minority of Leaf drivers (approximately 20 percent) performed the majority (74 percent) of all the away from home charging events. Almost half of the drivers (48 percent) performed five percent or fewer of their charges away from home.

Most away-from-home charging occurred at Level 1 or Level 2. Vehicles that were charged away from home 35 percent of the time or less tended to use DC fast chargers for a higher percentage of their away-from-home charges than vehicles with more frequent away-from-home charging.

Vehicles that charged away from home between 30 and 60 percent of the time averaged 1.5 total charging events per day driven. This behavior enabled these vehicles to average 43 miles per day. These vehicles averaged enough energy consumption during charging to recharge over half the battery's capacity each day.

Home overnight charging resulted in an average state of charge (SOC) increase of around 40 percent per charge. All groups averaged around 25 percent SOC increase when charging at home during the day. Vehicles that were charged most frequently away from home are believed to have had access to workplace charging. These vehicles' charging energy was similar to home overnight charging energy for other groups. According to the researchers, this demonstrates the viability of workplace charging infrastructure for owners of PEVs that do not have access to home charging.

3.3.5 Workplace Charging

INL researchers evaluated the charging preferences of a group of 707 Nissan Leaf drivers who had the opportunity to charge at work [13]. Researchers found that drivers performed 65 percent of their charging events at home, 32 percent at work, and 3 percent at other locations over the period between January 1, 2012, and December 31, 2013.

On days when this study's drivers of Nissan Leafs went to work, they performed 98 percent of their charging events either at home or work and only 2 percent at other locations. On days when this study's drivers of Nissan Leafs did not go to work, they performed 92 percent of their charging events at home and 8 percent at other locations.

INL researchers also evaluated workplace charging at Facebook's office campus in Menlo Park, CA over a period of 75 work days for a total of 3,086 charging events [14]. The charging stations available to employees at Facebook included AC Level 1, AC Level 2, and DC fast charging. The charging data illustrated that Level 2 charging units were used for 83 percent of the charging events, while 11 percent used the DC fast charger and 6 percent used Level 1 charging. The Level 2 chargers were used 1.5 times per work day for 5.6 hours per charging event. Although vehicles were connected for an average of 8.7 hours per event, they average 4.4 hours of transferring power to a vehicle. This result indicates that the vehicles remained connected to Level 2 cords for several hours longer than was needed to completely charge their batteries.

The DC fast charger was used an average of 4.5 times per work day, with an average connection time of 22 minutes per charging event. The Level 1 outlets were used only 0.2 charging events per work day (or once every 5 work days). Drivers tended to keep their vehicles connected to Level 1 ports the longest, averaging 8.9 hours connected per charging event. Level 1 ports provided power to vehicles for 4.6 hours per charging event, on average.

3.3.6 Clustering Effects

The INL researchers looked at clustering of multiple EVs (2-3) in a single area that could result in adding significant load on the same residential transformer [15]. Clustering was found to result in higher peak loads, longer transformer operation at higher power, and high power demand during off-peak hours. Implications include damage to residential transformers by causing load to exceed the transformer's rating or depriving it of its cool-down period during off-peak hours. This may result in premature replacement of the transformer and the associated cost impacts on the utility and its customer base.

The summary report evaluates three areas in the San Francisco region. The researchers found that charging multiple PEVs in a cluster on the same transformer (at 3.3 kW) requires the neighborhood transformer to provide almost four times the amount of energy during off-peak times. If the charging capability was higher (7.2 kW), it would create higher peak loads over a shorter duration.

INL researchers found that TOU rates may in fact exacerbate PEV clustering issues by essentially creating a new peak demand. New PEVs with higher charging capabilities can worsen clustering issues by increasing power demand during charging. Managed or smart charging may be able to mitigate these impacts.

3.4 PEV Integration Costs

In May 2014, SAE International released a report by Berkheimer et al. on the costs of PEV adoption on the electric distribution grid within the Sacramento Municipal Utility District's (SMUD) service territory [16]. The main focus of the report are the costs of upgrading the distribution grid to account for and support PEV integration. Although the study's specific conclusions apply to SMUD, the general conclusions are likely relevant to other electric utilities.

In terms of general charging requirements in the SMUD service area, Berkheimer et al. determined the average customer's PEV charging needs can be met with moderate charging rates the majority of the time. Approximately 50 percent of charging needs could be met using 1.4 kW Level 1 charging for four hours, while 95 percent could be supported by 3.3 kW Level 2 charging over eight hours.

The study estimates that the average marginal infrastructure upgrade cost is approximately \$145 per vehicle (in 2013 dollars) for the next 20 years of projected PEV market growth. Avoided distribution infrastructure upgrade costs for a TOU incentive is approximately \$42/vehicle. The avoided distribution infrastructure upgrade costs for Smart Charging , when the PEV charge rate is controlled by the utility or a third party, is approximately \$92/vehicle.

3.5 Electricity System Costs and Renewables Integration

An October 2013 study by Weis et al. explored the impact of PHEV controlled charging on power generation costs in New York State [17]. Weis et al. also incorporated how these costs are influenced by wind power penetration. The study estimated that in scenarios with 10 percent PHEV penetration, controlled charging reduces system costs by between 1.5 and 2.3 percent, or \$65 million to \$110 million, compared to the uncontrolled charging scenario. This amount represents between 54 and 73 percent of the total cost of integrating PHEVs. Cost reductions are the result of controlled charging allowing grid operators to shift generation to less expensive plants and to off-peak hours. Savings are higher in scenarios that project capacity expansion as controlled charging helps offset the need for additional generation.

In most scenarios, Weis et al. found that controlled charging provides savings of \$100/vehicle/year when PHEV penetration is 10 percent or higher. Although the study did not examine customer willingness to participate in controlled charging programs, it suggests that system cost savings may be sufficient to allow for attractive payments to customers in exchange for program participation. However, the authors note that installation and maintenance of any controlled charging system would have to be relatively inexpensive, and if not paid by the customer would decrease the annual \$100/vehicle cost savings.

3.6 Implications for New York and PEV Pricing Strategies

Lessons learned from utility pilot programs, studies and the EV Project should inform New York's approach to the development of pricing strategies for PEV charging. Some fundamental lessons that should influence the design of New York's approach, as outlined here.

Time-of-Use Rates

- TOU rates provide an effective incentive for residential customers to charge during off-peak periods. Customers typically delay charging to align with the TOU rate periods to take advantage of low rates when charging their vehicles.
- Shifting PEV charging load to off-peak hours can be accomplished with a combination of price signals, customer education and outreach, and the use of scheduling functionality included in the EVSE and/or the vehicle.
- TOU rates could result in new early morning peak demand due to PEV charging and PEV clustering, resulting in negative impacts on transformers and related infrastructure. However, using the vehicle's "charge by" rather than the "begin charging at" feature can mitigate artificial peaks at the beginning of TOU periods.
- The utility-customer relationship should be leveraged to provide education on PEV charging needs and available rate options.

Vehicle Charging Location Preference

- PEVs averaged between 1.1 and 1.5 charging events per day driven.
- The majority of PEV charging (approximately 80 percent) typically occurs at home. Pricing strategies targeting residential customers are essential.
- PEV drivers utilize workplace charging when available for a significant share of their overall charging. Evidence suggests that workplace charging could aide with PEV drivers who do not have access to home charging. Engagement on workplace charging strategies should be a priority.
- In many dense urban areas public parking garages constitute work place parking locations so that "public" charging in these locations would be equivalent to workplace charging. Given that many people in these locations live in multi-unit high rise buildings, prioritization of workplace (public parking garage) charging in urban areas makes sense.

Mitigating Grid Impacts

- In the near term, the impacts of PEV charging on the distribution system are likely to be small. As PEV penetration increases, the added load could have a negative impact.
- Even at lower vehicle penetration rates, near term negative impacts could occur in neighborhoods where multiple PEVs are charging during off-peak periods (clustering), especially as PEV battery sizes and EVSE charging capacities increase over time.
- Utility notification of PEV registrations will aide in assessing likely impacts and should be formalized.
- Managed charging pilot programs, either through the EVSE or vehicle, should be explored to mitigate issues associated with TOU rates and grid impacts.

4 Analysis of NY PEV Charging Scenarios

This section summarizes the modeling approach utilized to evaluate total daily electricity use and the “typical” daily load profile for PEV charging in New York State over the time period 2015 to 2030.

The modeling started with development of low, medium, and high scenarios for PEV penetration in New York. These projections, along with assumptions about average daily PEV usage (miles) and efficiency (kWh/mile), were used to calculate daily energy requirements (MWh) for PEV charging under each penetration scenario for each year from 2015 through 2030.

To evaluate the effect of electricity rate policies on daily PEV charging load profiles (MW by time of day) a PEV charging model was developed based on the following factors:

- Where vehicles charge (at home only or at home and at work).
- The assumed distribution of when vehicles start charging in each location (plug-in time).
- The average charging load per vehicle (kW).
- Whether charging load proceeds at a constant rate until the battery is full or is controlled (variable) based on external conditions.

All of these variables can be affected by electricity tariffs or other utility actions and policies. Using the model, the effect on daily charging load was evaluated using three different options for PEV charging tariffs: 1) a business as usual base case assuming current NYS flat-rate consumer tariffs, 2) time-of-use rates or other incentives for off-peak charging, and 3) fully controlled charging to lower average charge rates and spread charging demand more evenly across the day.

The base case scenario assumes that current consumer flat-rate electric rate tariffs will be maintained throughout the analysis period, with no changes intended to modify or influence consumer charging behavior. The TOU rate scenario would vary the cost of electricity (\$/kWh) depending on the time of day, with higher rates for electricity used during a peak time period and lower rates for off-peak periods. Under the controlled charging scenario, the charge rate is assumed to be constant throughout the charge period for each vehicle, but just high enough to ensure completion of charging after eight hours.

For each case, the PEV charging model was applied to the PEV penetration scenarios to develop a PEV charging load profile for a typical day in 2020, 2025, and 2030 under each penetration scenario. PEV vehicle counts, energy usage (MWh) and load (MW) were all projected at the county level for each scenario, and aggregated to calculate totals for the state as a whole, as well as for each New York Control Area (NYCA) Load Zone. NYCA level data was also aggregated to calculate totals by service territory for the seven largest utility companies in the state.

A marginal cost curve (\$/MWh) and a marginal carbon dioxide (CO₂) emissions curve (grams [g] CO₂/kWh) was developed at each increment (MW) of total load for NYISO, based on current generating assets and an economic dispatch model. These curves were used to estimate average generating costs (\$/kWh) and average CO₂ emissions (g/kWh) for PEV charging on an assumed summer peak and summer 95th percentile peak day in 2020 under each PEV penetration scenario and each charging scenario.

The modeling indicates that if approximately 50 percent of all PEV owners delay the majority of their PEV charging to off-peak hours, then the daily statewide electric load in New York could be reduced by an average of 276 MW during summer peak hours (2 p.m. – 4 p.m.) in 2030 under the high penetration scenario. This level of off-peak charging adoption has been shown to be possible in other parts of the country. The benefits to the grid of this level of load reduction include reduced generating costs, reduced monthly generating capacity costs, and reduced infrastructure costs resulting from PEV clustering. The estimated value of these benefits to the grid on an aggregate level in a high penetration scenario for New York State would by 2030 result in an on-going savings of \$46 million annually, plus an additional savings of \$103 million in avoided grid upgrade costs. In addition to these financial benefits, off-peak PEV charging would reduce CO₂ emissions from PEV charging by approximately one kilogram per PEV per year and would reduce day-time NOx emissions by about 0.26 kilograms per PEV per year, compared to business as usual. In a high penetration scenario, this would amass a statewide CO₂ reduction in 2030 of approximately 755 metric tons and a statewide NOx reduction of approximately 196 metric tons.

4.1 Current and Projected PEV Penetration in New York

As of September 2014, 11,486 PEVs were registered in New York to a New York address,⁵ including 1,367 electric low speed vehicles (LSV),⁶ 2,286 full-sized battery electric cars (BEV), and 7,833 plug-in hybrid cars (PHEV). See Table 11 for a list of PEV registrations and PEV penetration rates (PEV per 1,000 registered vehicles) for select New York counties [18]. This table includes the 15 counties with the largest number of PEVs and the 15 counties with the smallest number of PEVs; the data is arranged in order from high to low based on the number of registered BEVs.

As shown, the county with the largest number of BEVs (461) is Westchester County, while the County with the largest number of PHEVs (1,802) is Suffolk County, both in the New York City metro area. Approximately 80 percent of current PEVs in New York are registered in counties that comprise the New York City metro area, or in counties with other large cities (Albany, Buffalo, Rochester, and Syracuse). One factor that drives greater BEV penetration in urban areas are relatively large government-owned fleets of BEVs in large cities, particularly New York City and Albany.

See Table 12 for a summary of PEV registrations and PEV penetration rates aggregated by the size of the county. As shown, penetration rates for BEVs are on average two and a half times higher in larger, more urban counties (greater than 100,000 registered vehicles) than in smaller, more rural counties (less than 100,000 registered vehicles); PHEV penetration rates are on average 1.6 times higher in the larger, more urban counties, while LSVs are more evenly distributed across the State. PHEVs are also significantly more numerous than BEVs; in large, urban counties there are approximately 3.3 PHEVs registered for every BEV, while in small, rural counties there are approximately 5.3 PHEVs registered for every BEV.

Starting with the 2014 data, three scenarios were developed for growth in PEV registrations in New York through 2030, denoted as low, medium, and high penetration scenarios. For each scenario, the model assumes that all small counties (less than 100,000 registrations) will have the same penetration rate for each type of PEV each year, as will all large counties (greater than 100,000 registrations). The model also assumes that the current ratio of penetration rates between large and small counties will be maintained, as well as the current ratio of PHEVs to BEVs.

⁵ There were also a handful of vehicles registered to out-of-state addresses.

⁶ Low speed vehicles are limited-use vehicles that are legal to operate in NYS only on roadways with posted speed limit of 35 mph or less; these vehicles typically resemble large golf carts.

Table 11. Partial List of PEV Registrations in New York by County as of September 2014

Source: New York Department of Motor Vehicles, MJB&A analysis

County	Major City	Sep 2014 Registered Vehicles			As of September 2014			Ratio PHEV/BEV	
		Total	PHEV	LSV	BEV	PEV per 1,000 Registrations	LSV		
WESTCHESTER	NYC Metro Area	601,162	546	19	461	0.91	0.03	0.77	1.18
NASSAU	NYC Metro Area	905,786	890	96	332	0.98	0.11	0.37	2.68
SUFFOLK	NYC Metro Area	1,080,010	1802	95	319	1.67	0.09	0.30	5.65
NEW YORK	Manhattan	221,916	225	157	178	1.01	0.71	0.80	1.26
ERIE	Buffalo	566,072	484	66	109	0.86	0.12	0.19	4.44
MONROE	Rochester	474,911	520	47	108	1.09	0.10	0.23	4.81
QUEENS	Queens	671,816	338	9	74	0.50	0.01	0.11	4.57
ROCKLAND	NYC Metro Area	195,026	220	6	70	1.13	0.03	0.36	3.14
ALBANY	Albany	181,651	146	392	57	0.80	2.16	0.31	2.56
KINGS	Brooklyn	408,007	180	14	50	0.44	0.03	0.12	3.60
ONONDAGA	Syracuse	284,614	265	83	47	0.93	0.29	0.17	5.64
SARATOGA	Saratoga Springs	159,869	183	8	44	1.14	0.05	0.28	4.16
DUTCHESS	Poughkeepsie	209,164	137	9	43	0.65	0.04	0.21	3.19
ORANGE	Newburgh	244,303	193	18	38	0.79	0.07	0.16	5.08
RICHMOND	Staten Island	247,692	108	2	38	0.44	0.01	0.15	2.84
HERKIMER		37,947	14	1	2	0.37	0.03	0.05	7.00
ST LAWRENCE		61,398	46	10	2	0.75	0.16	0.03	23.00
CHAUTAUQUA		79,059	47	17	2	0.59	0.22	0.03	23.50
LEWIS		15,884	3	1	1	0.19	0.06	0.06	3.00
SCHOHARIE		21,863	14	1	1	0.64	0.05	0.05	14.00
WYOMING		24,832	13	2	1	0.52	0.08	0.04	13.00
ALLEGANY		26,756	14	5	1	0.52	0.19	0.04	14.00
FRANKLIN		29,192	12	4	1	0.41	0.14	0.03	12.00
JEFFERSON		65,609	21	9	1	0.32	0.14	0.02	21.00
CATTARAUGUS		46,543	5	3	0	0.11	0.06	0.00	
CHEMUNG		55,187	30	2	0	0.54	0.04	0.00	
HAMILTON		4,010	1	0	0	0.25	0.00	0.00	
ORLEANS		25,514	11	1	0	0.43	0.04	0.00	
STEUBEN		62,401	44	1	0	0.71	0.02	0.00	
YATES		14,384	12	1	0	0.83	0.07	0.00	
STATE-WIDE TOTAL		9,057,176	7,833	1,367	2,286	0.86	0.15	0.25	3.43

Table 12. PEV Registrations and Penetration Rates in Small versus Large New York Counties

Source: New York Department of Motor Vehicles, MJB&A analysis

Counties w/ Registrations	Sep 2014 Registrations				PEV per 1,000 Registrations			Ratio of large/Small Counties
	TOTAL	PHEV	LSV	BEV	PHEV	LSV	BEV	
<50,000	872,550	448	149	81	0.51	0.17	0.09	
<100,000	1,639,460	949	251	185	0.58	0.15	0.11	
>100,000	7,417,716	6,884	1,116	2,101	0.93	0.15	0.28	
TOTAL	9,057,176	7,833	1,367	2,286	0.86	0.15	0.25	
					1.6	1.0	2.5	

The low penetration scenario is based on PEV sales projections for the mid-Atlantic region contained in the Energy Information Administration's Annual Energy Outlook 2014 [19], and assuming that half of all PEV sales in the mid-Atlantic region will be in New York.⁷ Under this scenario the annual increase in PEVs state-wide through 2030 is similar to the annual increase from 2012 to 2014.

The medium penetration scenario is a middle ground scenario approximately half-way between the high and low scenarios.

The high penetration scenario is based on New York meeting its goals under the Zero Emission Vehicle (ZEV) Action Plan memorandum of understanding signed by New York and seven other states.⁸ This action plan commits the states to ensuring the deployment of at least 3.3 million ZEVs and adequate fueling infrastructure within the eight states by 2025. Currently, approximately 19 percent of total vehicle registrations in the eight MOU states are in New York; therefore, New York's portion of the 3.3 million ZEV goal is approximately 637,000 vehicles. The high penetration scenario assumes that New York will meet this goal with PEVs.⁹ To achieve the penetration rates of the high scenario, annual PEV sales in New York over the next 20 years would need to be approximately four times higher than actual annual PEV sales in 2013 and 2014.

See Figure 4 for a summary of total projected PEVs state-wide under all three penetration scenarios, and Figure 5 for the split of LSV, BEV, and PHEV under the medium penetration scenario. Figure 6 maps the projected number of PEVs by county in 2030 under the high penetration scenario. Detailed data on projected PEV registrations by county each year under each scenario are included at Appendix A.

⁷ The EIA mid-Atlantic region includes New York, New Jersey, and Pennsylvania.

⁸ The states include California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont.

⁹ Under the MOU, hydrogen fuel cell vehicles also count as ZEVs.

Figure 4. Projected PEV Registrations in New York, Low, Medium, and High Penetration Scenarios

Source: New York Department of Motor Vehicles, MJB&A analysis

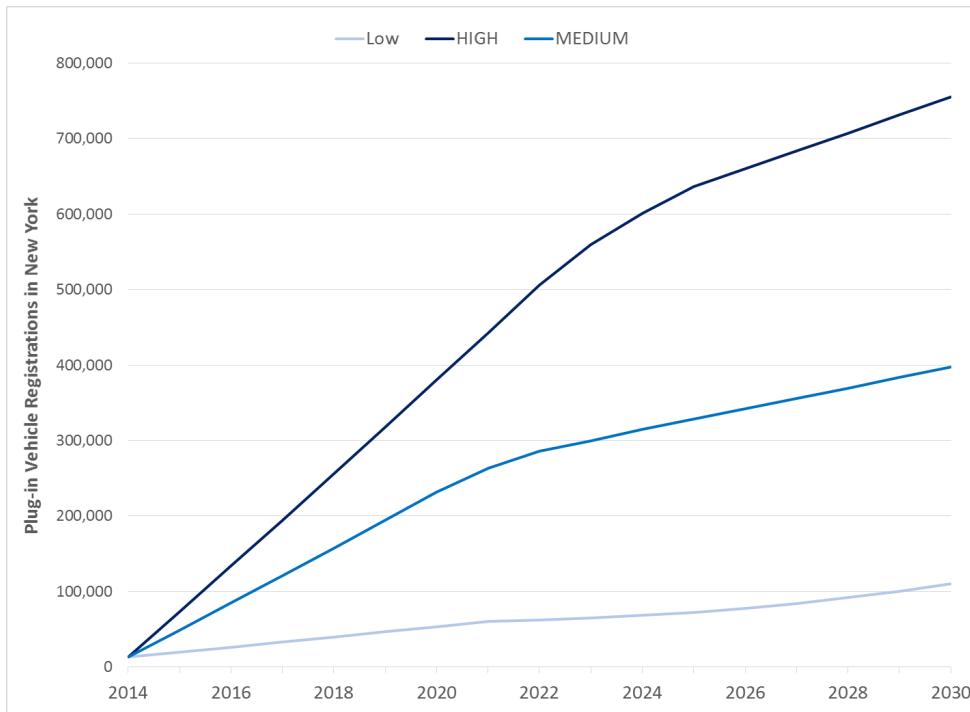


Figure 5. Projected LSV, BEV, and PHEV Registrations in New York, Medium Penetration Scenario

Source: New York Department of Motor Vehicles, MJB&A analysis

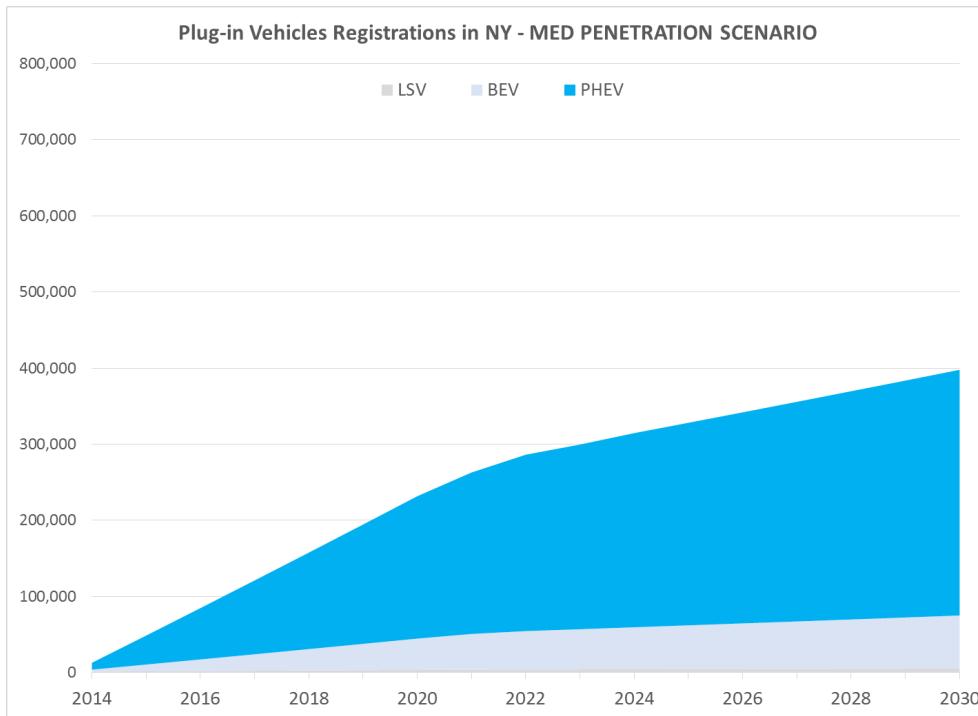
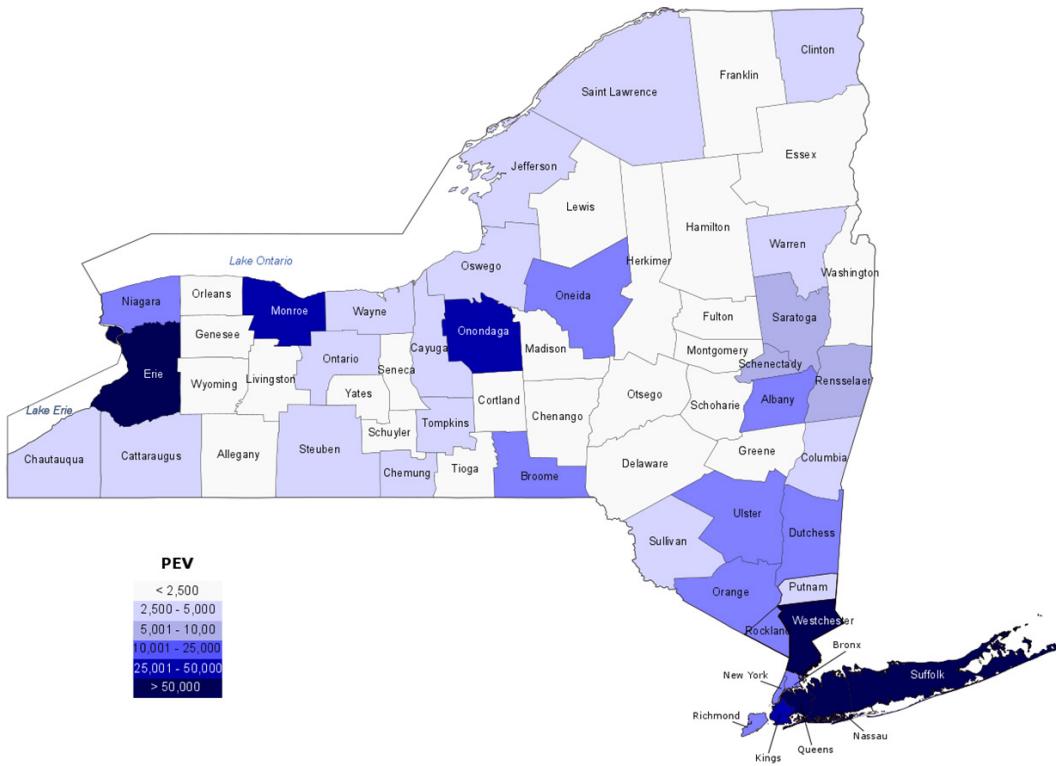


Figure 6. Projected PEVS by County in 2030 under High Penetration Scenario

Source: New York Department of Motor Vehicles, MJB&A analysis



As shown, total PEV registrations in 2030 are projected to be 110,000, 398,000, and 755,000 respectively under the low, medium, and high penetration scenarios. This equates to state-wide PEV penetration rates in 2030 of 1.1, 4.1 and 7.8 percent of total registrations, respectively.

Of the total 398,000 PEVs projected in 2030 under the medium penetration scenario, 5,000 are projected to be LSVs, 70,000 are projected to be BEVs, and 323,000 are projected to be PHEVs. There are similar proportions of the different PEV types projected under the other scenarios.

4.1.1 Projected PEV Energy Use

To calculate total energy required for PEV charging on a “typical day,” the projected number of PEVs of each type is multiplied by the average daily energy use per vehicle of that type. Average daily energy use (kWh) is based on average vehicle use (miles per day) multiplied by average efficiency (kWh/mi).

Table 13 summarizes the average PEV usage and efficiency factors used in this analysis.

Table 13. PEV Usage and Efficiency Assumptions

Source: MJB&A analysis

Metric		Unit	Value
Typical Weekday Average Usage	LSV	mi	10.0
	BEV	mi	29.5
	PHEV (EV mode)	mi	20.0
Average Energy Use per Mile	LSV	kWh/mi	0.20
	BEV	kWh/mi	0.35
	PHEV (EV mode)	kWh/mi	0.35
Average Energy Use per Typical Weekday	LSV	kWh	2.00
	BEV	kWh	10.33
	PHEV (EV mode)	kWh	7.00

These assumptions are consistent with data collected during PEV demonstration programs, and assumptions used in other grid impact studies found in the literature [20], as discussed in Section 1.

Note that average daily mileage of 29.5 miles per day for a BEV equates to 10,768 miles per year. This is approximately 17 percent less annual mileage than the current U.S. light-duty fleet average [21], consistent with current BEV usage patterns. As BEV and PHEV electric vehicle range increases, expected annual miles could increase to 12,000 miles per year, equivalent to an average light duty conventional gasoline vehicle.¹⁰ Also note that the assumption of 20 miles per day for a PHEV is electric-only miles, not total miles. Electric-only miles for PHEVs are a function of both driving patterns and vehicle capability. Currently available PHEVs from major auto manufacturers have a capability of between six and thirty eight electric-only miles between charging events [22].

Figure 7 summarizes the total projected energy (MWh) required for PEV charging in New York on a typical day under all three PEV penetration scenarios. As shown, projected total daily energy use for PEV charging in New York is currently 92 MWh, and in 2030 rises to 832 MWh, 2,990 MWh, and 5,378 MWh respectively under the low, medium, and high PEV penetration scenarios.

¹⁰ Several automakers have announced plans to introduce 200-mile BEVs in 2017 and Nissan has just announced that the upcoming model year Leaf will have a range of 120 miles.

Current net generation in New York averages approximately 372,000 MWh per day [23]. Projected incremental energy use required for PEV charging in 2030 therefore represents an increase of approximately 0.2, 0.8, and 1.4 percent in total state-wide energy use, respectively, under the low, medium, and high penetration scenarios.

Figure 8 shows the projected daily energy required for PEV charging by county in 2030 under the high penetration scenario. Detailed data on projected energy required for PEV charging each year under each penetration scenario for each county, NYCA load zone, and utility service territory are included at Appendix A.

Figure 7. Projected Energy Use (MWh) in New York for PEV Charging on a Typical Day

Source: MJB&A PEV Modeling Analysis

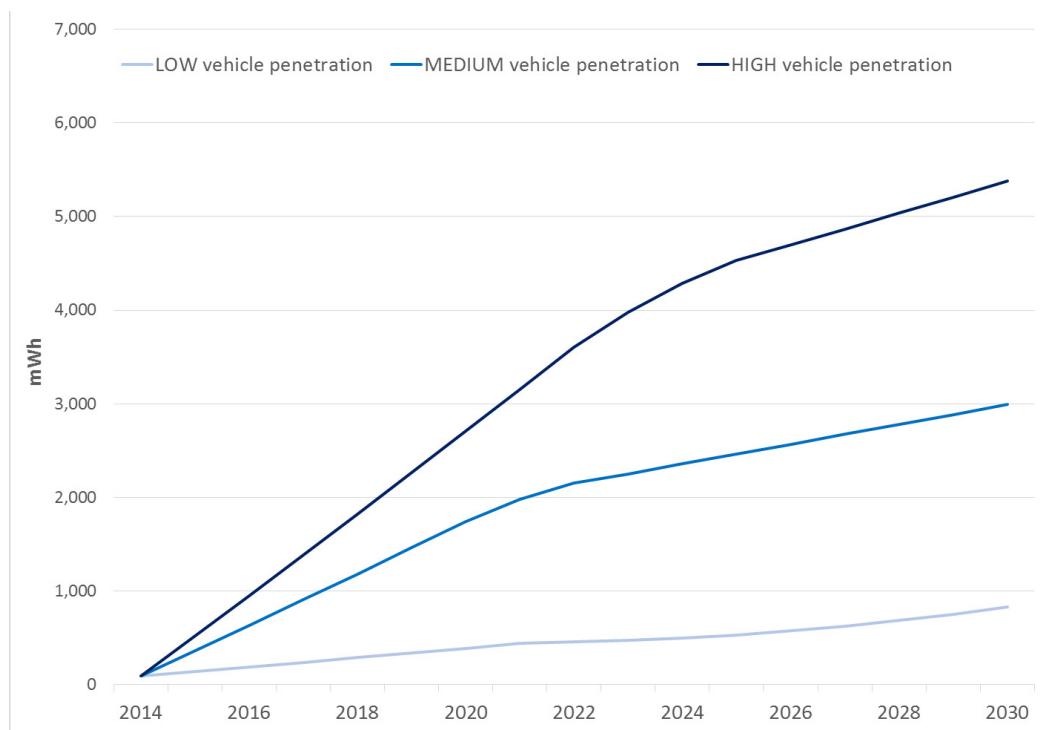
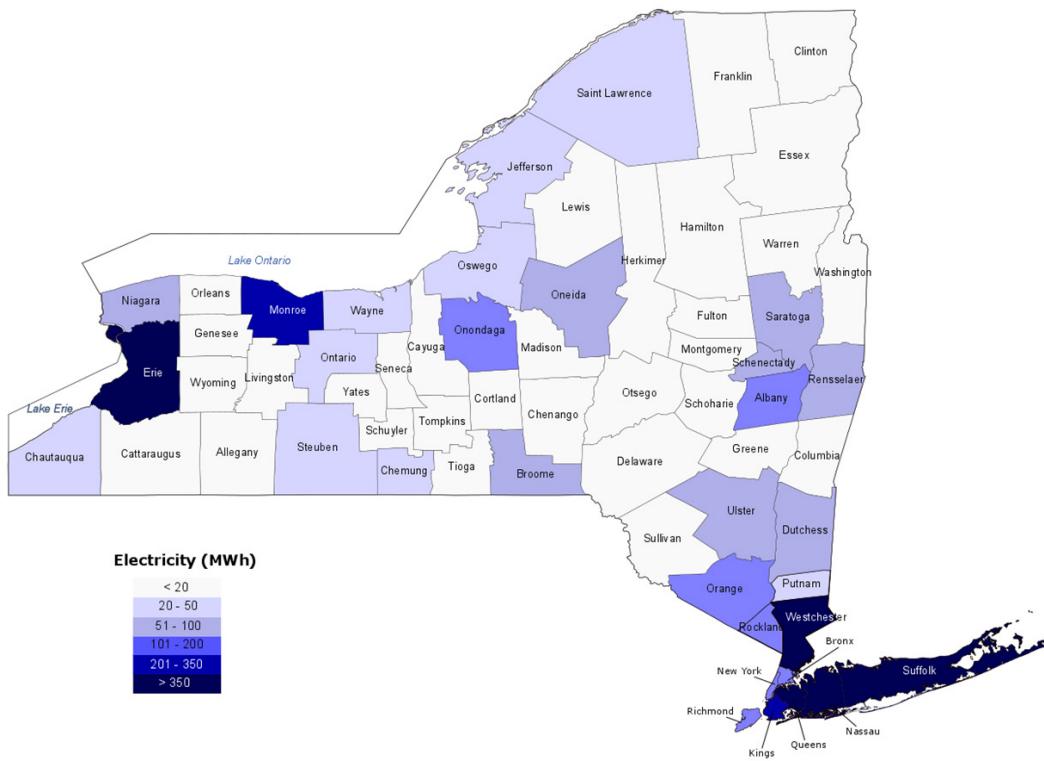


Figure 8. Projected Daily Energy Use (MWh) for PEV Charging in 2030, by County, High Penetration Scenario

Source: MJB&A PEV Modeling Analysis



4.1.2 Marginal Costs of PEV Charging

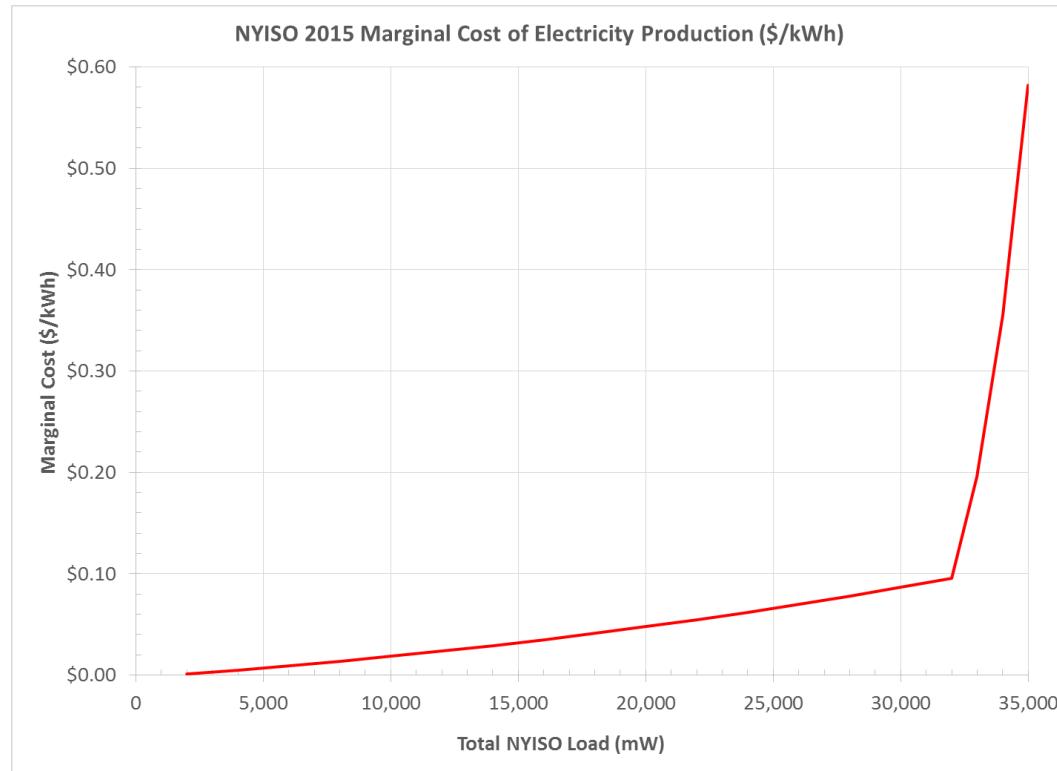
A 2015 marginal cost curve for NYISO electricity generation was created using data contained in the Ventyx Velocity Suite™ database [24]. This database uses market data to calculate the marginal cost of generation (\$/MWh) for every generating source in the NYISO territory, including fuel costs and variable operations and maintenance costs. The marginal cost curve is based on the concept of economic dispatch – that in general low cost generating sources will be dispatched prior to higher cost sources.

The marginal cost curve is shown in Figure 9. In this figure total NYISO load at any point in time is plotted along the horizontal axis, and the marginal cost of generation at that load (\$/MWh) is plotted on the vertical axis. As shown, there is a discontinuity in the cost curve at approximately 32,000 MW total load; above this load the rate of increase in the marginal cost of generation is much higher than at lower loads. Below 32,000 MW, total load most generating sources are renewable (wind, hydro) or are natural

gas combined cycle or combustion turbines. Above 32,000 MW total load most marginal generating sources are oil-fired and the fuel cost of these units is higher. Note that the costs shown in Figure 9 are for generation only. They represent the cost to the utility of purchasing power on the market. The costs shown in Figure 9 do not represent the full cost of power to a PEV owner, which includes utility charges related to installation, maintenance, and operation of the infrastructure required to deliver power to the user.

Figure 9. NYISO 2015 Marginal Cost Curve for Electricity Generation

Source: Ventyx Velocity Suite™ database, MJB&A analysis



For comparison to the marginal cost curve shown in Figure 9, representative data on actual 2014 NYISO daily load is shown in Figures 10 and 11 [25]. Figure 10 plots actual load on four different days in 2014: peak summer day, peak winter day, peak spring day, and peak fall day.¹¹

¹¹ Peak day is defined as the day with the highest peak load (MW) within that season. For this analysis the seasons are not equal in length, but rather are defined by changes in the shape of the typical daily load profile. For this analysis, summer is defined as May 1 – September 15, fall is defined as September 16 – October 31, winter is defined as November 1 – February 28, and spring is defined as March 1 – April 30.

As shown, significant differences exist in the daily load profile by season. Load is highest in the summer, peaking at almost 30,000 MW on the 2014 peak day, followed by winter (26,000 MW), spring (23,000 MW), and fall (21,000 MW). The shape of the daily load profile is also significantly different. In summer, load is relatively flat throughout the afternoon, and on any given day the actual peak hour can occur any time between 2 p.m. and 4 p.m. By contrast, the late afternoon load spike is sharper in the other seasons, with the peak hour consistently occurring between 6 p.m. and 7 p.m. during the winter and spring and between 7 p.m. and 8 p.m. in the fall.

Figure 10. 2014 NYISO Summer, Winter, Spring, and Fall Peak Load Days

Source: NYISO Load Data, MJB&A analysis

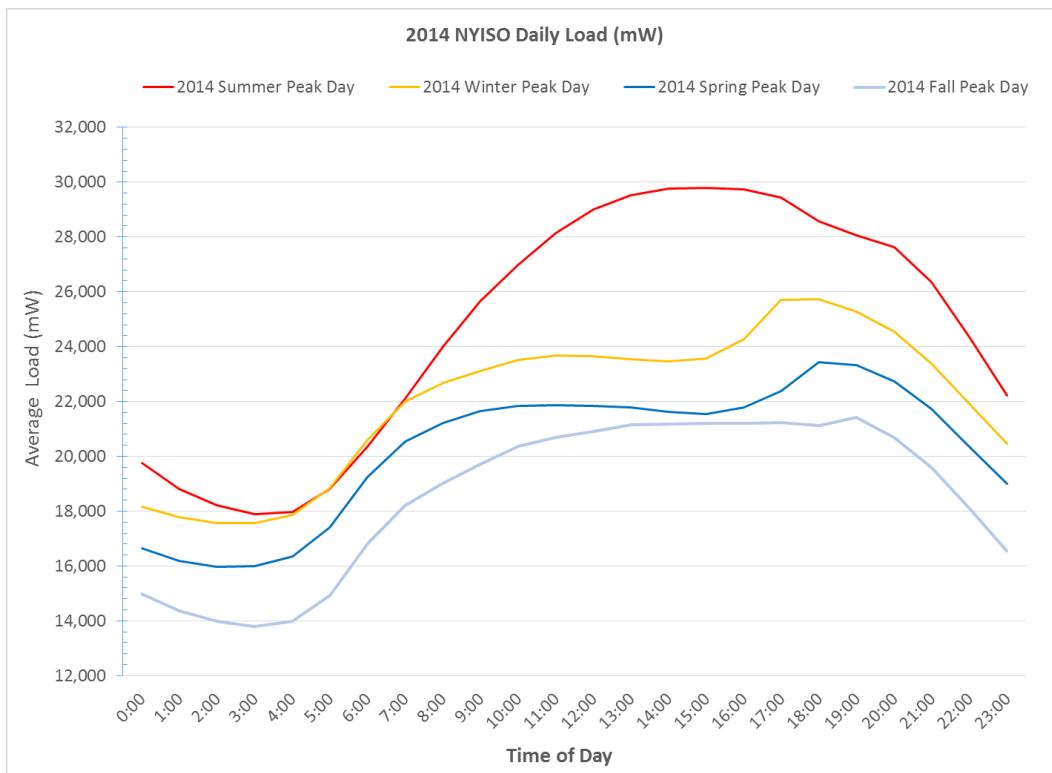
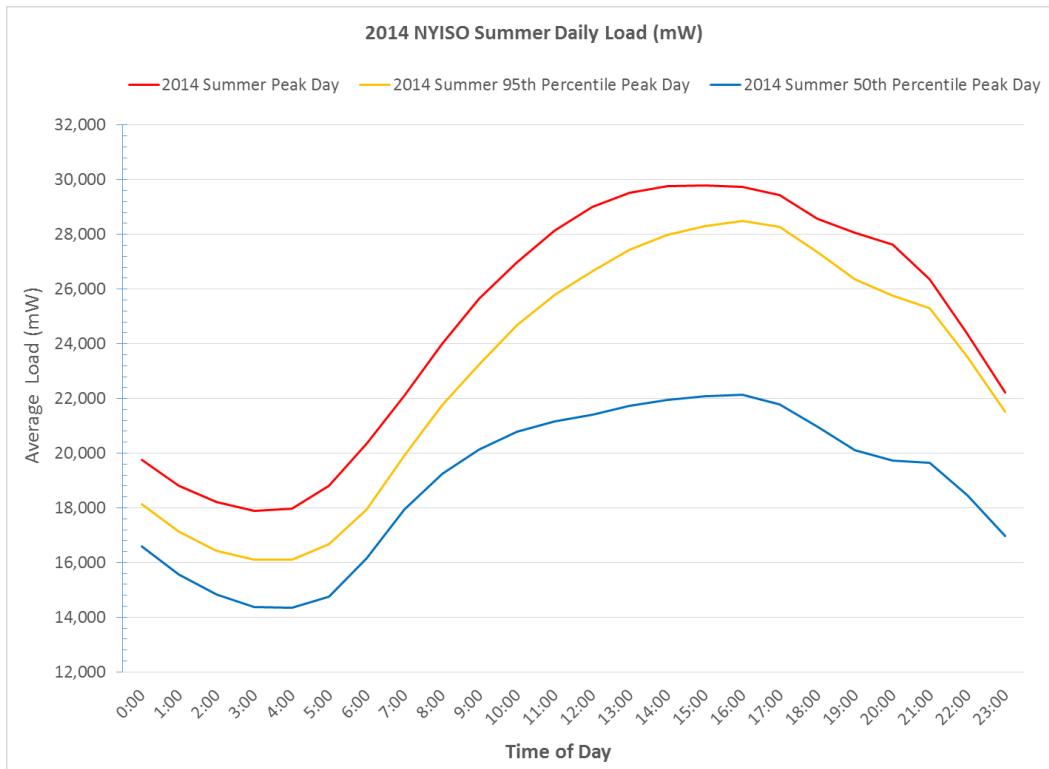


Figure 11. NYISO 2014 Representative Summer Day Loads

Source: NYISO Load Data, MJB&A analysis

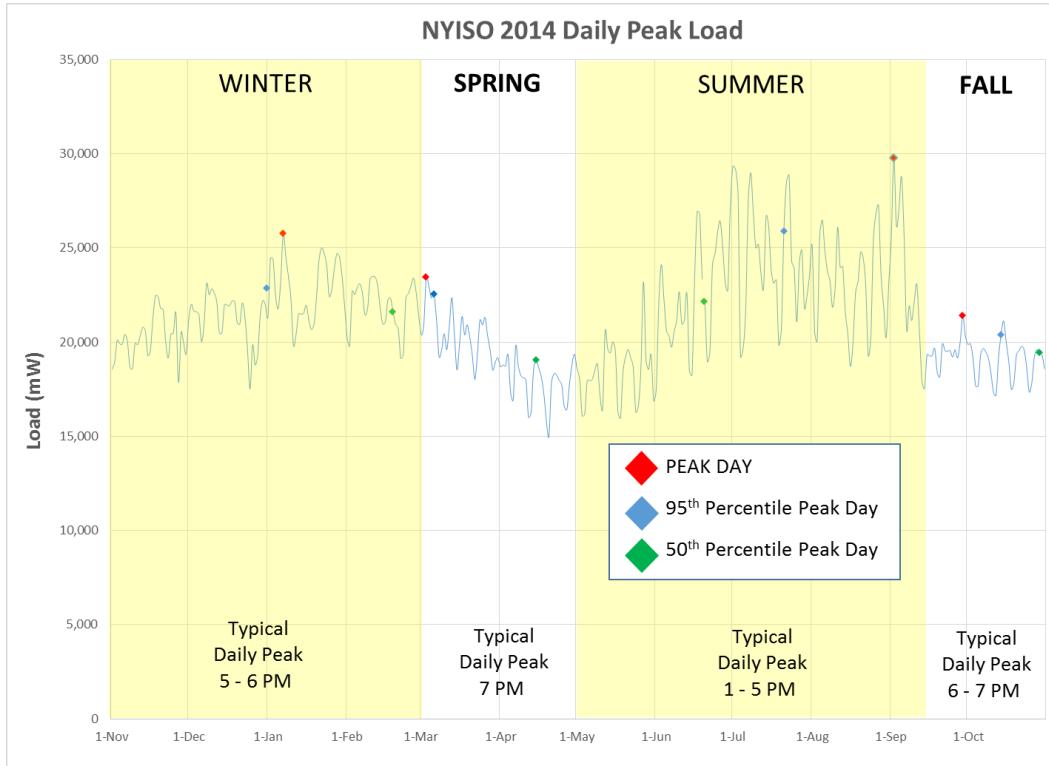


To provide perspective on day-to-day load variability, Figure 11 plots the NYISO load on three different days in summer 2014: the peak day, 95th percentile peak day, and 50th percentile peak day.¹² As shown, there is significant variability in day to day load even during the peak summer season. Although the peak hour load on the peak summer day in 2014 was almost 30,000 MW, peak hour load was less than 22,000 MW on 50 percent of the days that summer, similar to peak day peak hour loads during the other seasons. This variability in daily peak load is also seen in Figure 12, which plots daily NYISO peak hour load for every day in 2014. As shown, daily peak hour load was greater than 26,000 MW on only 33 days in 2014.

¹² 5 percent of summer days have higher peak load than the 95th percentile peak day; 50 percent of summer days have higher peak load than the 50th percentile peak day.

Figure 12. NYISO Daily Peak Hour Load 2014

Source: NYISO Load Data, MJB&A analysis



Data from the National Oceanic and Atmospheric Administration indicates that summer 2014 was significantly cooler than the summers of 2010 – 2013, but only slightly cooler than the long term average for New York [26]. Total cooling degree days¹³ in New York in 2014 were 598, compared to the normal average of 621 (four percent lower). However, total cooling degree days for 2010 through 2013 averaged 830 per year. A greater number of cooling degree days could result from significantly higher daily temperatures on a limited number of days (which would drive up annual peak day peak hour demand) and/or a smaller increase in daily temperature over a greater number of days (which would not increase the annual peak day peak hour load but would increase the number of days with near-peak load).

¹³ The number of degrees that a day's average temperature is above 65° Fahrenheit. For example, if New York's average temperature was 70°, that day's cooling degree day is 5.

The actual marginal cost of generating the electricity used for PEV charging will depend on where the charging falls on the marginal cost curve. As shown in Figures 10 and 11, current peak hour load on most days falls within the range of 15,000 to 25,000 MW – a range over which the marginal generation cost curve has a modest upward slope (Figure 9). As such, adding a relatively small additional load for PEV charging during peak hours will modestly increase the marginal and average cost of producing electricity. As discussed in Section 4.2, even on peak and near-peak days the projected additional load for PEV charging under the worst case baseline charge scenario does not push total load past 32,000 MW and into a portion of the cost curve where marginal costs would rise more quickly.

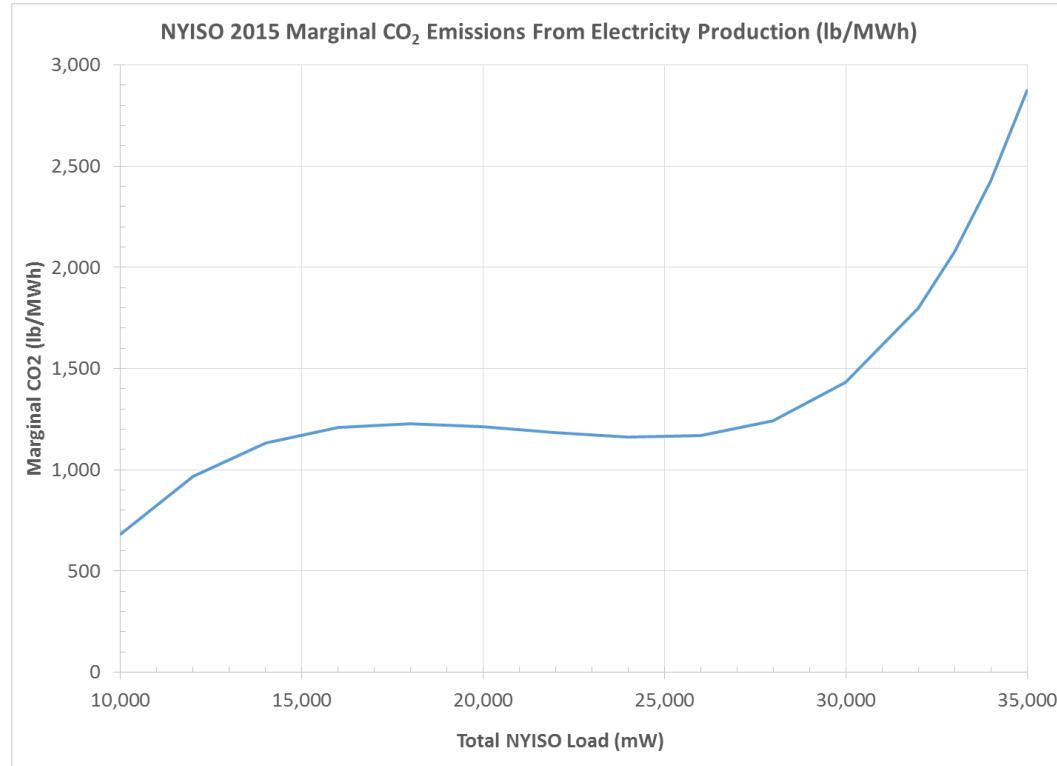
4.1.3 Marginal CO₂ Emissions Curve

A 2015 marginal CO₂ emissions curve for NYISO was created using data contained in the Ventyx Velocity Suite™ database [24]. Based on fuel type and average fuel rate, the CO₂ emissions rate (g/kWh) of each source was also calculated. As with the marginal cost curve, the marginal emission curve is based on the concept of economic dispatch – that in general low cost generating sources will be dispatched prior to higher cost sources. The marginal CO₂ emission curve is shown in Figure 13. Total NYISO load at any point in time is plotted along the horizontal axis, and the CO₂ marginal emissions rate at that load (g/kWh) is plotted on the vertical axis. Below approximately 10,000 MW, total load the marginal emission rate is essentially zero because most load is serviced by zero-emitting sources such as nuclear, wind and hydro. Between 10,000 and approximately 28,000 MW total load, most marginal generating sources are natural gas thermal plants or turbines and the marginal CO₂ emissions rate is in the range of 1,000 – 1,200 pounds per megawatt-hour (lb/MWh). Above about 28,000 MW total load, many marginal generating sources are oil-fired and the marginal CO₂ emission rate starts rising to 2,000 lb/MWh or more above 33,000 MW total load.

Actual CO₂ emissions from electricity generation used for PEV charging will depend on where the charging falls on the marginal emissions curve. As shown in Figures 10 and 11, current peak hour load on most days falls within the range of 15,000 to 25,000 MW – a range over which the marginal CO₂ emissions curve is relatively flat or even falling slightly (Figure 13). As such, adding a relatively small additional load for PEV charging during peak hours will not increase marginal and average CO₂ emissions from producing electricity on most days. However, as discussed in Sections 4.2 – 4.4, on peak and near-peak days the projected additional load for PEV charging during peak hours will slightly increase marginal CO₂ emissions because charging will happen when total load is in a part of the marginal emissions curve where CO₂ emission rates are rising (28,000 – 30,000 MW).

Figure 13. NYISO 2015 Marginal CO₂ Emissions Curve

Source: Ventyx Velocity Suite™ database, MJB&A analysis



4.1.4 Marginal NO_x Emissions Curve

The authors created a 2015 marginal NO_x emissions curve for NYISO, using data contained in the Ventyx Velocity Suite™ database [24]. Based on fuel type, average fuel rate, and installed emission controls the NO_x emissions rate (lb/MWh) of each source was also calculated. The marginal NO_x emission curve is also based on the concept of economic dispatch.

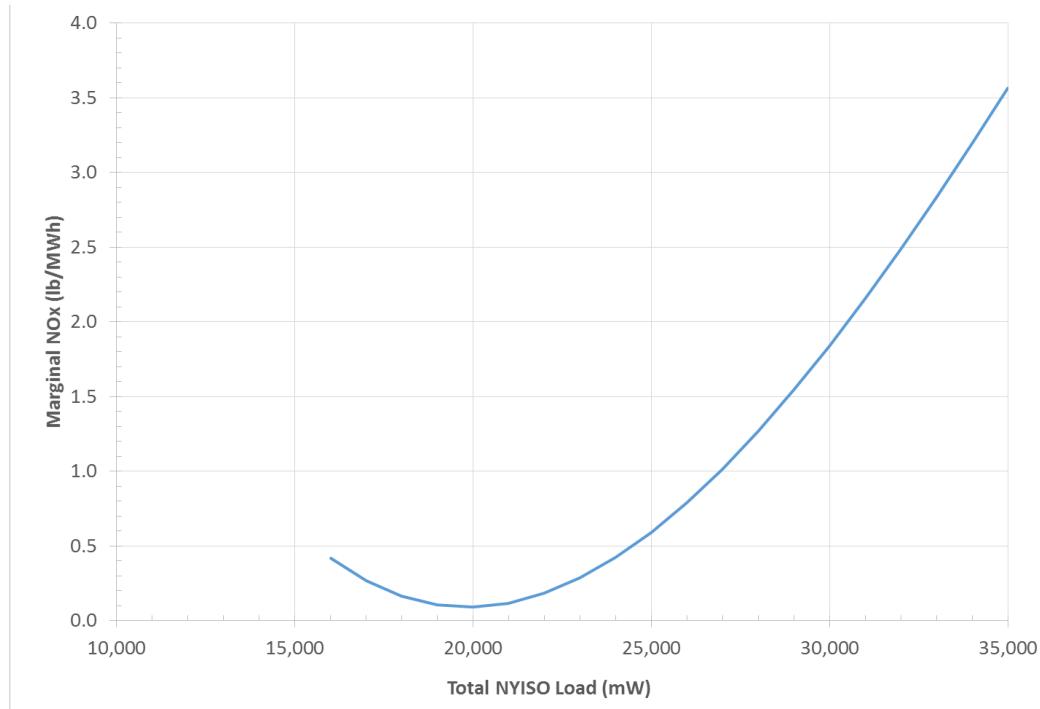
The marginal NO_x emission curve is shown in Figure 14. Total NYISO load at any point in time is plotted along the horizontal axis, and the NO_x marginal emissions rate at that load (lb/MWh) is plotted on the vertical axis. Below approximately 10,000 MW, total load the marginal emission rate is essentially zero because most load is serviced by zero-emitting sources such as nuclear, wind and hydro, as well as a few very low emitting combined cycle gas plants. Between 10,000 and 14,000 MW total load, most marginal generating sources are combined cycle gas plants and the marginal emission rate is generally below 0.4 lb/MWh. At about 14,000 MW total load, higher emitting gas turbines start to come on line and the

marginal emissions rate rises, but falls again through about 22,000 MW load. Above 22,000 MW total load the marginal emission rate starts to rise as higher-emitting gas turbines make up an increasing percentage of marginal generating sources. Above about 32,000 MW total load, the majority of marginal generating sources are oil-fired turbines and the marginal NO_x emission rate rises to 2.5 lb/MWh or higher.

Actual NO_x emissions from electricity generation used for PEV charging will depend on where the charging falls on the marginal NO_x emissions curve. As shown in Figures 10 and 11, current peak hour load on most days falls within the range of 15,000 to 25,000 MW; over the low end of this range the marginal NO_x emissions rate is falling as load increases, while at the high end the marginal NO_x emissions rate increases as load increases (Figure 14). As such, on most days, adding a relatively small additional load for PEV charging during peak hours could either increase or decrease marginal and average NO_x emissions from producing electricity, but the change would be small. However, on peak and near-peak days peak hour loads already approach 30,000 MW, and the marginal NO_x emission rate is high and increasing. As such, adding additional load for PEV charging during peak hours on peak and near-peak days will significantly increase marginal and average NO_x emissions.

Figure 14. NYISO 2015 Marginal NO_x Emissions Curve

Source: Ventyx Velocity Suite™ database, MJB&A analysis



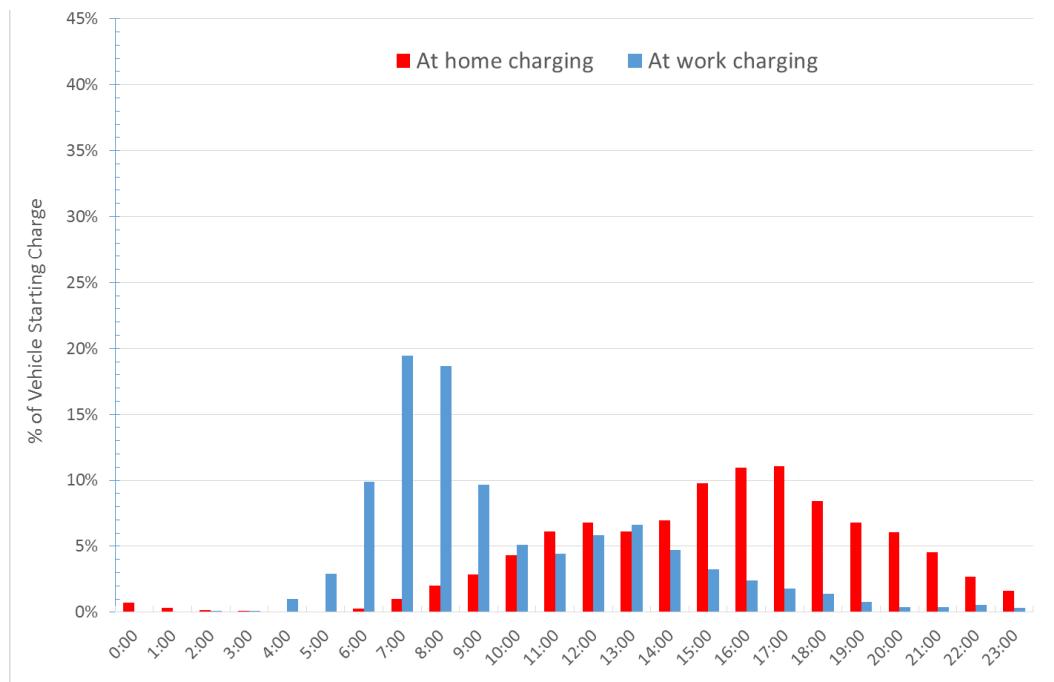
4.2 PEV Charging Load Under Current Electricity Tariffs – Business As Usual

This section discusses the modeled PEV charging load profile, marginal generation cost, and CO₂ emissions under a “business as usual” base case. This base case assumes that current consumer flat-rate electric rate tariffs will be maintained throughout the analysis period, with no changes intended to modify or influence consumer charging behavior.

Consistent with data in the literature on current PEV charging behavior this base case analysis assumes that 80 percent of BEVs and PHEVs in New York will be charged exclusively at home,¹⁴ while 20 percent will be charged both at home and at the owner’s work place. For those charged both at home and at work, 50 percent of daily charging is assumed to take place in each location, consistent with vehicle use primarily for work commuting.

Figure 15. Distribution of Daily PEV Charge Start Times, Base Case

Source: MJB&A PEV Modeling Analysis



¹⁴ 100 percent of LSVs are assumed to be charged exclusively at home.

As discussed in Section 1.1, current New York consumer electricity tariffs are based on a flat rate (\$/kWh) regardless of when energy is used, so they provide no incentive for PEV charging during off-peak periods. As such, the base case analysis assumes that consumers who charge exclusively at home will plug in their vehicle and start charging as soon as they arrive home from work, because there is no financial incentive for them to delay the start of charging. Similarly, for those vehicles charged at work it is assumed that PEV owners will plug in and start charging as soon as they arrive at work.¹⁵ The assumptions for PEV charge start time used in the base case analysis are shown in Figure 15. This data is consistent with at work and at home arrival times reported in the 2009 Annual Household Travel Survey by respondents from New York [27]. Figure 15 shows the distribution of at-home arrival and charge start times is shown in red and the distribution of at-work arrival and charge start times is shown in blue.

For both home and work charging the analysis assumes that for each vehicle, charging will proceed at a fixed rate (kW) until the battery is full and will then shut off.

The average charging rate for both BEVs and PHEVs is assumed to be 2.0 kW for nonhome charging and 2.7 kW for at home charging. These average charge rates are consistent with data from the literature on current PEV charging behavior as well as assumptions used in other grid impact studies. Note that some vehicles may in fact charge at higher rates and some at lower rates, but this variability is not meaningful to the over-all results when aggregating energy use and load at the county level. However, it is meaningful for local distribution system impacts due to clustering, as discussed in Section 4.5.

As shown in Table 13 (Section 4.1.1), the analysis assumes that average daily energy use will be 10.3 kWh for BEVs and 7.0 kWh for PHEVs; as such the base case assumes that the average daily charge time for vehicles charged exclusively at home will be 3.8 hours for BEVs and 2.6 hours for PHEVs. For BEVs charged both at work and at home average daily work charging will be 2.6 hours and average daily at home charging will be 1.9 hours. For PHEVs charged both at work and at home average daily work charging will be 1.8 hours and average daily at home charging will be 1.3 hours. Note that on any given day some vehicles may use more or less total energy and may require shorter or longer charge times. However this expected variability will likely be smoothed out when aggregating at the county level, so the use of average values is appropriate for this analysis.

¹⁵ This result assumes workplace charging by one vehicle per EVSE per day. Charging more than one vehicle per day will result in additional day time load for the second round of workplace charging.

4.2.1 PEV Charge Profile

The PEV charging profiles used in the baseline analysis that result from the assumptions discussed in Section 4.2 are shown in Figure 16. The average load (kW) per LSV, BEV, and PHEV in each hour of the day are plotted. To calculate total load in each hour the plotted curves are multiplied by the total projected number of PEVs of each type, and summed.

Figure 16. PEV Charging Load Profiles Used in Baseline Analysis

Source: MJB&A PEV Modeling Analysis

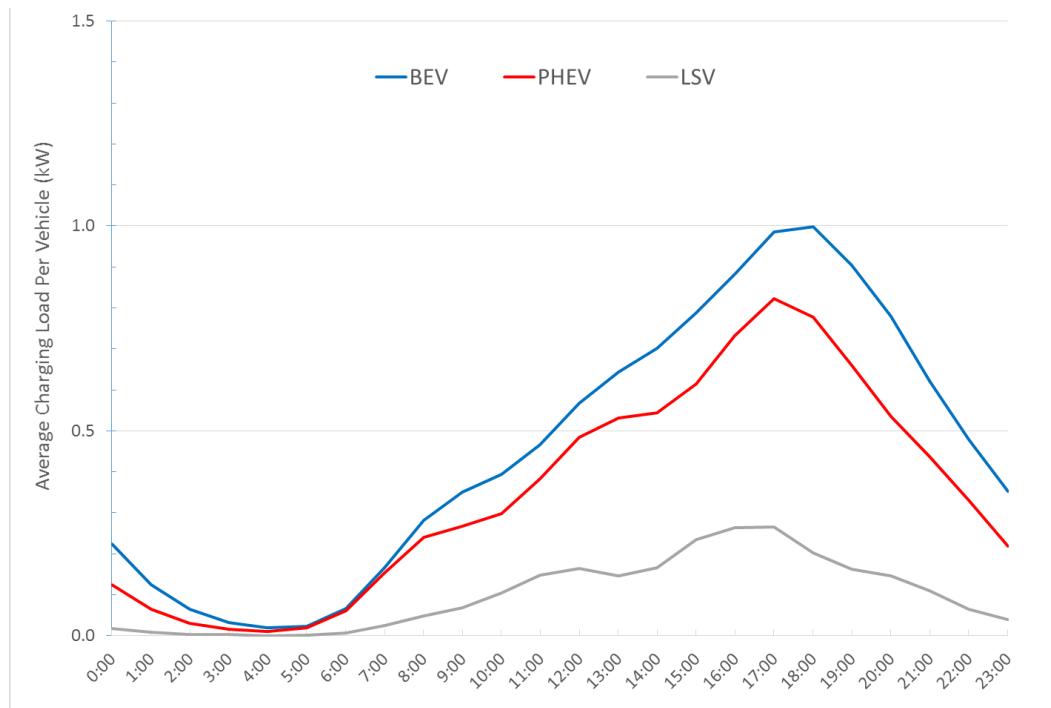


Figure 16 shows that the average daily peak charging load for BEVs is 1.0 kW per vehicle, which occurs between 6 p.m. and 7 p.m. For PHEVs, the average daily peak charging load is 0.8 kW per vehicle and it occurs one hour earlier, between 5 p.m. and 6 p.m. The average daily peak charging load for LSVs is 0.27 kW, also occurring between 5 p.m. and 6 p.m.

Peak daily load for each PEV type is affected both by the distribution of charge start time and the average charge rate; a higher average charge rate and/or a higher percentage of vehicles starting to charge at the same near-peak time would increase the magnitude of the peak. The timing of peak load is primarily determined by the distribution of charge start times. Figure 17 shows the largest percentage of vehicles are assumed to start charging (home portion) between 4 p.m. and 6 p.m., resulting in peak charging loads around this time.

Figure 17. Contribution of At-home and At-work Charging to Average Charge Load (kW) for a Full-sized BEV

Source: MJB&A PEV Modeling Analysis

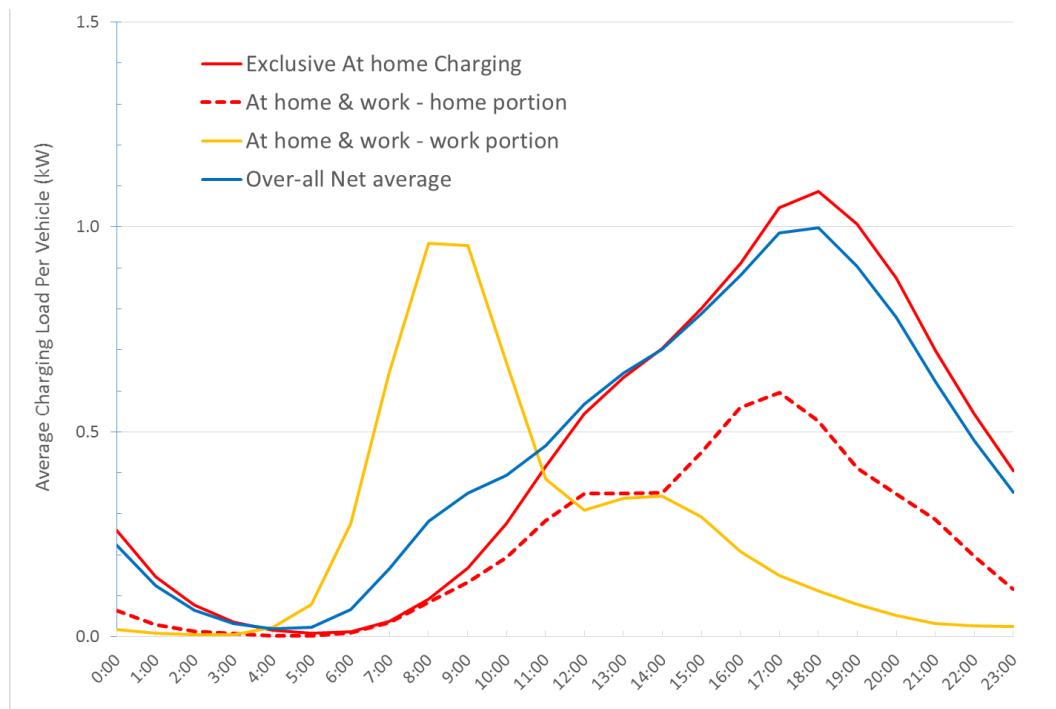


Figure 17 illustrates the effect of at-work charging on the magnitude and timing of the daily peak charging load, using BEVs as an example. In this figure, the solid yellow line is the average charge load for the at-work portion of charging for vehicles charged both at-home and at-work, and the dotted red line is the average load for the at-home portion of charging for these vehicles. The solid red line is the average charge load for vehicles charged exclusively at home. The solid blue line is the overall average charge load for all BEVs in the baseline analysis. As shown, compared to exclusive at-home charging, at-work and at-home charging pulls some load into the morning hours (5 a.m. – 10 a.m.) while slightly lowering the daily peak load between 6 p.m. and 7 p.m. The more charging that is done at work, the greater the reduction in the afternoon peak charging load.

4.2.2 PEV Charging Load on a Typical Day

The total projected PEV charging load for New York on a “typical day” in 2030 for all three PEV penetration scenarios is shown in Figure 18. For all three penetration scenarios, the daily peak charging load under the baseline charging scenario occurs between 5 p.m. and 6 p.m. For the low penetration scenario daily peak hour PEV charging load in 2030 is 92 MW, rising to 336 MW under the medium penetration scenario and 600 MW under the high penetration scenario.

Figure 18. Projected 2030 Daily PEV Charging Load (MW) for Entire State, Base Case

Source: MJB&A PEV Modeling Analysis

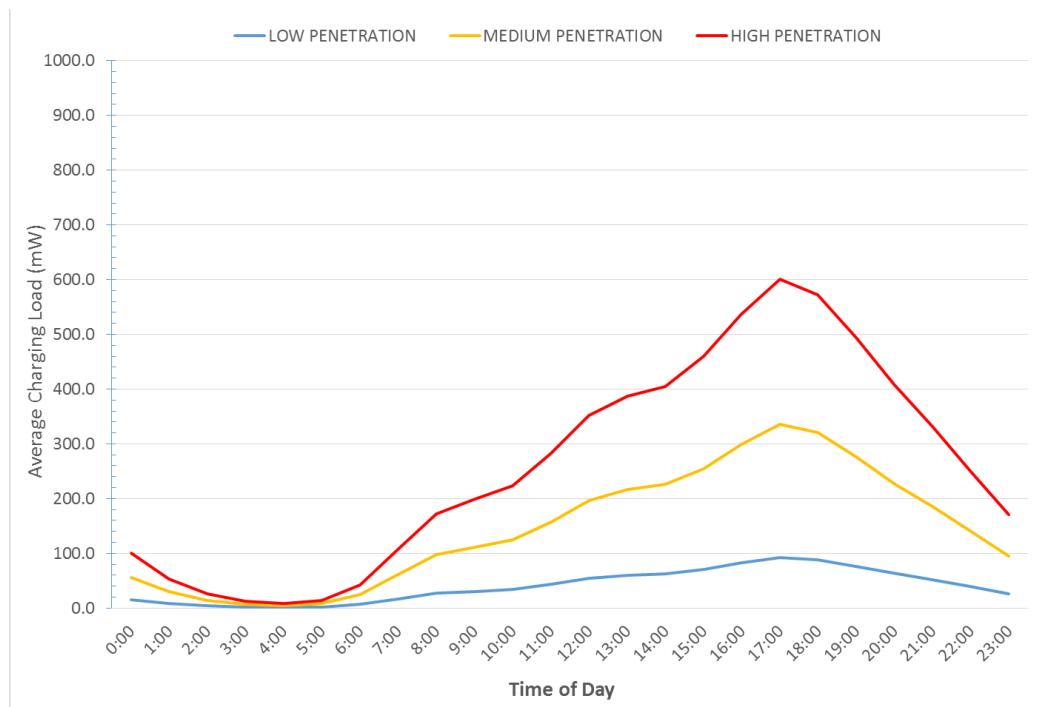
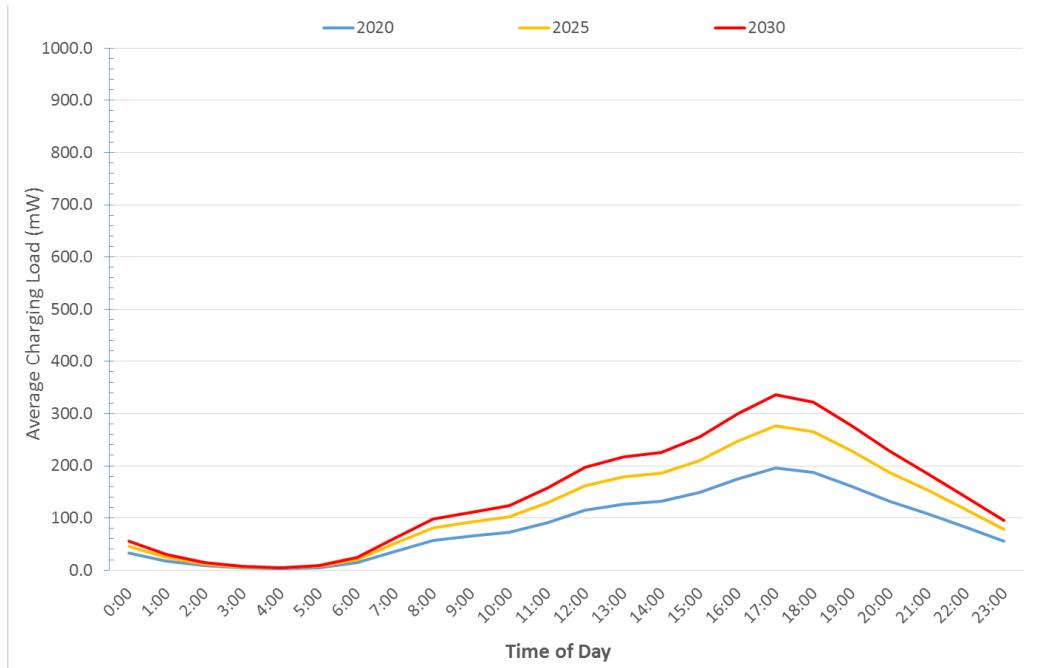


Figure 19. 2020, 2025, and 2030 Daily PEV Charging Load for Entire State, Medium Penetration Scenario, Base Case

Source: MJB&A PEV Modeling Analysis



The ramp-up of peak daily charging load over time is shown in Figure 19 using the medium penetration scenario as an example. As shown, the daily peak hour PEV charging load in 2020 under the medium penetration scenario is 195 MW, rising to 277 MW in 2025 and 336 MW in 2030.

Detailed tables of projected 2020, 2025, and 2030 daily charge loads under each penetration scenario are included at Appendix A, including aggregation of load for each county, NYCA load zone, and utility service territory. Note that the following analyses for marginal costs, CO₂ emissions, and NO_x emissions do not extend beyond 2020 due to significant uncertainty related to changes in New York generating sources and relative fuel costs, and therefore changes in the marginal cost and emissions curves, more than five years into the future.

4.2.3 Marginal Cost of PEV Charging

By comparing the 2014 NYISO daily load data shown in Figures 10 and 11 (Section 4.1.2) with the projected PEV charging loads shown in Figures 18 and 19, it is evident that under the baseline charging scenario projected PEV charging load generally lines up with, and will add to, existing daily load peaks. In the 2030 high penetration scenario, PEV charging under the baseline charge scenario could add 1.6 percent additional load during the peak hour on the summer peak day.

To quantify the potential effect of PEV charging on electricity generating costs the projected 2020 daily PEV charging load was added to the 2014 summer peak day and 95th percentile peak day loads and the 2015 marginal cost curve was used to estimate marginal power costs for PEV charging. The results are shown in Table 14. As shown, under all PEV penetration scenarios the average cost of electricity production (\$/kWh) for PEV charging is estimated to be about 9 percent higher on the summer peak day than on the 95th percentile peak day, due to higher total generating load and higher marginal generating cost at that higher load. For both the peak day and the 95th percentile peak day, the marginal cost of producing electricity for PEV charging is estimated to be about 1 percent higher under the high penetration scenario than the low penetration scenario due to the higher PEV charging load.

Table 14. 2020 Average Cost of Electricity production for PEV Charging, Summer Peak and 95th Percentile Peak Days, Business as Usual Charge Scenario

Source: MJB&A PEV Modeling Analysis

DAY	Penetration Scenario	Projected Average Cost of Power Generation (\$/kWh)
Summer Peak Day	Low	\$0.0770
	Medium	\$0.0774
	High	\$0.0777
95 th Percentile Peak Day	Low	\$0.0704
	Medium	\$0.0708
	High	\$0.0711

4.2.4 CO₂ Emissions from PEV Charging

A comparison of the 2014 NYISO daily load to the projected PEV charging loads shown in Figures 18 and 19, makes evident that under the baseline charging scenario projected PEV charging load generally lines up with, and will add to existing daily load peaks. In the 2030 high penetration scenario PEV charging under the baseline charge scenario could add 2 - 4 percent additional load during the peak hour each day. This increased load for PEV charging will not significantly affect marginal or average CO₂ emission rates on most days. However, on peak and near-peak days, the projected additional load for PEV charging under the baseline charge scenario will fall within the range in which marginal CO₂ emission rates are rising and will therefore increase average CO₂ emission rates slightly. Given that total annual CO₂ emissions from electricity generation in New York are capped under the Regional Greenhouse Gas Initiative (RGGI), a marginal increase in CO₂ emission rates would likely not increase total emissions, but would marginally increase the difficulty and cost of meeting RGGI emission targets.

Projected 2020 CO₂ emissions under the baseline scenario are shown in Table 15. As shown, marginal CO₂ emissions (g/kWh) from electricity production for PEV charging are estimated to be about 7 percent higher on the summer peak day than on the 95th percentile peak day, because of higher total generating load and higher marginal emission rates at that higher load. Even on the 95th percentile peak day, average CO₂ emissions (g/kWh) from electricity production for PEV charging are estimated to be about 1 percent higher under the high penetration scenario than the low penetration scenario due to the higher PEV charging load.

Table 15 also shows the estimated CO₂ emissions per unit distance (g/mi) traveled by a PEV, assuming 0.35 kWh/mi average efficiency (consistent with the PEV charging load assumptions). As shown, even under the worst case condition the baseline charging scenario results in average PEV CO₂ emissions of only 207 g/mi. This result equates to tailpipe emissions from a gasoline car that gets 42 miles per gallon (MPG), or wells-to-wheels¹⁶ emissions from a gasoline car that gets 54 MPG [28].

¹⁶ Wells-to-wheels emissions include tailpipe emission as well as upstream emissions from production and transport of the fuel used.

Table 15. 2020 Marginal CO₂ Emissions from PEV Charging, Summer Peak and 95th Percentile Peak Days, Business as Usual Charge Scenario

Source: MJB&A PEV Modeling Analysis

DAY	PENETRATION SCENARIO	PROJECTED AVERAGE CO ₂ EMISSIONS (g/kWh)	PROJECTED AVERAGE CO ₂ EMISSIONS (g/mi) ^a
Summer Peak Day	Low	586.0	205.1
	Medium	590.0	206.5
	High	593.0	207.5
95 th Percentile Peak Day	Low	549.4	192.3
	Medium	551.4	193.0
	High	553.0	193.5

^a Assumes 0.35 kWh/mi for PEVs

By way of comparison, the current U.S. light-duty fleet average fuel economy is 24.9 MPG [29]. The best in class model year 2015 compact cars with gasoline engines (Honda Civic, Ford Focus, Toyota Corolla) have an EPA combined fuel economy rating of 35 miles per gallon; the best in class model year 2015 compact car with a gasoline hybrid-electric drive system (Toyota Prius C) has an EPA combined fuel economy rating of 50 miles per gallon [30]. As such, even under the worst case baseline charging scenario, PEVs charged in New York in the next five years would have lower CO₂ emissions than all but the most efficient new hybrid cars.

4.2.5 NO_x Emissions from PEV Charging

In the 2030 high penetration scenario, PEV charging under the baseline charge scenario could add two to four percent additional load during the peak hour each day. This increased load for PEV charging will not significantly affect marginal or average NO_x emission rates on most days. However, on peak and near-peak days the projected additional load for PEV charging under the baseline charge scenario will fall within the range in which marginal NO_x emission rates are high and rising, and will therefore increase average NO_x emission rates significantly.

Projected 2020 NO_x emissions under the business as usual scenario are shown in Table 16. NO_x emissions from PEV charging are estimated separately for daylight hours (6 a.m. – 8 p.m.) and for overnight hours because NO_x is an ozone precursor. In the atmosphere, ground-level ozone forms during a chemical reaction between ambient NO_x and ambient volatile organic compounds (VOC) in the presence of sunlight. As such ozone production is impacted by both the magnitude and timing of NO_x emissions; NO_x emitted during daylight hours is more likely to result in ambient ozone formation than NO_x emitted during darkness. As shown, under the baseline charging scenario the majority of estimated NO_x emissions from PEV charging are emitted during daylight hours.

Both total and day-time marginal NO_x emissions (g/kWh) from electricity production for PEV charging are estimated to be about 5.8 times and 8.1 times higher on the summer peak and 95th percentile peaks days, respectively, than on the 50th percentile peak day, due to higher total generating load on-peak and near-peak days, and a much higher marginal NOx emissions rate at that higher load.

Table 16. 2020 Marginal NO_x Emissions from PEV Charging, Summer Peak, 95th Percentile Peak, and 50th Percentile Peak Days, Business as Usual Charge Scenario

Source: MJB&A PEV Modeling Analysis

DAY		BASELINE CHARGING			
		NOx Emissions (ton)			AVG NOx
NOx Emissions From PEV Charging (TON)	SUMMER PEAK DAY	DAY 6AM-8PM	NIGHT 8PM-6AM	TOTAL	g/kWh g/mi
	Low Penetration	0.514	0.032	0.546	1.276 0.447
	Medium Penetration	2.328	0.145	2.474	1.289 0.451
	High Penetration	3.650	0.228	3.877	1.300 0.455
	SUMMER 95th % Peak DAY	0.363	0.026	0.389	0.909 0.318
	Medium Penetration	1.647	0.118	1.765	0.920 0.322
	High Penetration	2.587	0.184	2.771	0.929 0.325
	SUMMER 50th % Peak DAY	0.052	0.014	0.066	0.156 0.054
	Medium Penetration	0.238	0.065	0.303	0.158 0.055
	High Penetration	0.376	0.100	0.477	0.160 0.056
NOx Emissions from Gasoline Cars (TON)		Low Penetration	0.193	0.017	0.209 NA 0.169
		Medium Penetration	0.856	0.073	0.929 NA 0.169
		High Penetration	1.356	0.116	1.473 NA 0.169

Table 16 also shows the estimated average NO_x emissions per unit distance (g/mi) traveled by a PEV, assuming 0.35 kWh/mi average efficiency (consistent with the PEV charging load assumptions). By way of comparison, estimated NO_x emissions from an equivalent number of gasoline cars are also included in Table 16, for each penetration scenario. These estimates are based on data in EPA's MOVES emissions model, which show estimated total emissions from all light-duty cars operating in New York State, on an August weekday in 2020 [31]. As shown, 2020 fleet-average NO_x emissions from gasoline cars operating in New York are estimated by EPA to be 0.169 g/mi. On the 50th percentile peak day average NO_x emissions from PEV charging are estimated to be about 66 percent lower than emissions from an equivalent number of gasoline cars, at between 0.054 and 0.056 g/mi. However, on the peak and 95th percentile peak days, respectively, average gram per mile NO_x emissions from PEV charging are estimated to be about 2.7 and 1.9 times higher than fleet-average gram per mile NO_x emissions from gasoline cars.

4.3 PEV Charging Load With Off-Peak Charging

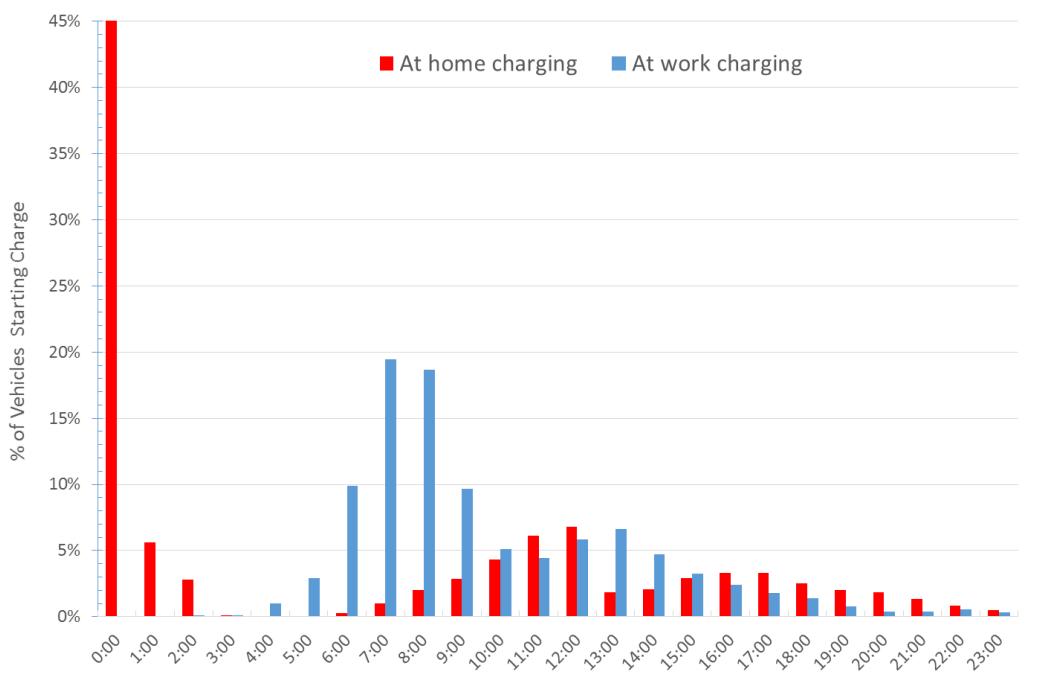
This section discusses the modeled PEV charging load profile, generating cost, and CO₂ emissions assuming a TOU electric rate or other incentive to get PEV owners to charge during off-peak hours. A TOU rate would vary the cost of electricity (\$/kWh) depending on the time of day, with higher rates for electricity used during a peak time period and lower rates for off-peak periods. Based on evidence in the literature [32], as discussed in Section 3, this scenario assumes that availability of a TOU rate or other incentive would incentivize a significant portion of PEV owners who charge their vehicles at home to delay the start of charging from when they first arrive at home from work (baseline) to sometime after the start of the lowest TOU rate period.

In comparison to the business as usual base case, the only thing that changes for this off-peak charging scenario is the distribution of PEV charge start times. All other assumptions, as discussed in Section 4.2, remain the same, including the percentage of vehicles charging both at home and at work, the percentage of total energy added at work for these vehicles, and average charge rates (kW) for each PEV type at home and at work.

The assumptions for PEV charge start time used in this off-peak charging case are shown in Figure 20. This charge start time distribution is based on a TOU rate with off-peak pricing starting at 12 a.m. and running through 8 a.m., and is consistent with observed behavior in response to TOU pricing cited in the literature [33]. This distribution assumes that 53 percent of PEV owners, who under the base case scenario arrive at home between 1 p.m. and midnight and start charging immediately upon arrival would, if available, sign up for a TOU rate and delay the start of at-home charging until after midnight each day. In this figure, the distribution of at-home charge start times is shown in red and the distribution of at-work charge start times is shown in blue. Note that the distribution of at-work charge start times for the off-peak charging scenario is the same as for the baseline scenario, as it is assumed that at-work charging will be unaffected by the availability of a household TOU rate or other incentive.

Figure 20. Distribution of Daily PEV Charge Start Times, Off-peak Charging Scenario

Source: MJB&A PEV Modeling Analysis



4.3.1 PEV Charge Profile

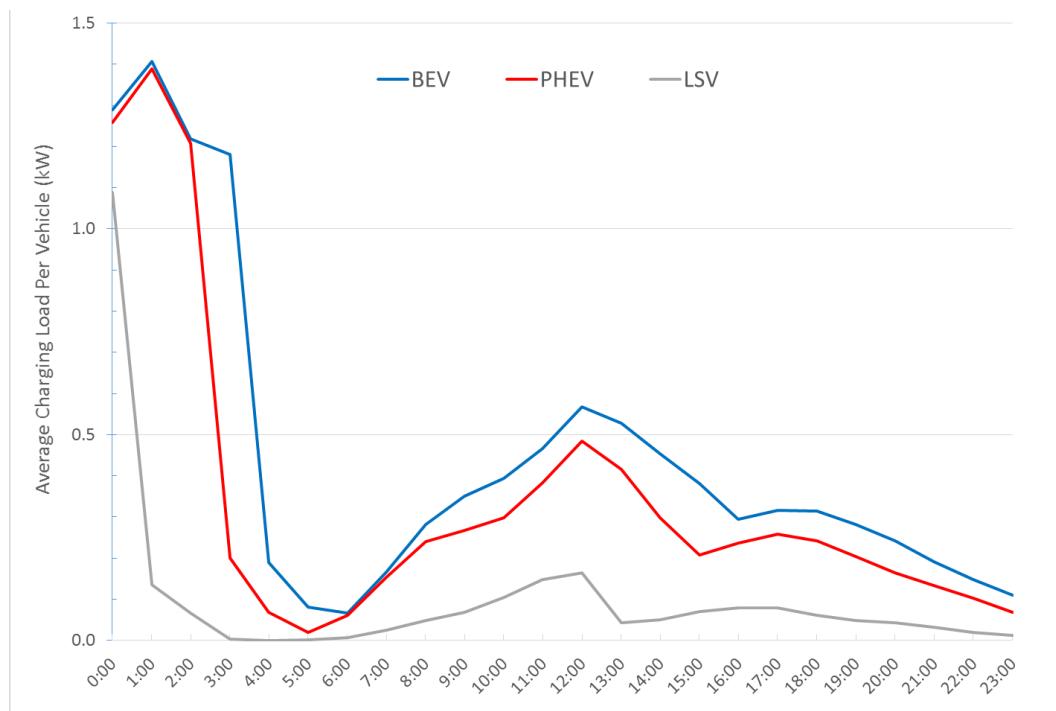
The PEV charging profiles used in the off-peak charging analysis that result from the TOU charge start time distribution shown in Figure 20 are shown in Figure 21. In this figure the average load (kW) per LSV, BEV, and PHEV in each hour of the day are plotted. To calculate total load in each hour, the plotted curves are multiplied by the total projected number of PEVs of each type, and summed.

As shown, for both BEVs and PHEVs the average daily peak charging load is 1.3 kW per vehicle and it occurs between 12 a.m. and 1 a.m. The average daily peak charging load for LSVs is 1.1 kW, also occurring between 12 a.m. and 1 a.m.

By comparing Figure 21 to Figure 16, it is seen that in comparison to the base case, a TOU rate for PEV charging will significantly shift the average daily charging profile for all PEVs.

Figure 21. PEV Charging Load Profiles Used in Off-Peak Charging Scenario

Source: MJB&A PEV Modeling Analysis



4.3.2 PEV Charging Load on Typical Day

The total projected PEV charging load for New York on a “typical day” in 2030 with a TOU rate, for all three PEV penetration scenarios, is shown in Figure 22. For all three penetration scenarios, the daily peak charging load under the off-peak charging scenario occurs between 1 a.m. and 2 a.m. For the low penetration scenario, daily peak hour PEV charging load in 2030 is 148 MW, rising to 547 MW under the medium penetration scenario and 942 MW under the high penetration scenario.

The ramp-up of peak daily charging load over time is shown in Figure 23 using the medium penetration scenario as an example. As shown, the TOU rate daily peak hour PEV charging load in 2020 under the medium penetration scenario is 318 MW, rising to 451 MW in 2025 and 547 MW in 2030.

Detailed tables of projected 2020, 2025, and 2030 daily charge loads under each penetration scenario are included at Appendix A, including aggregation of load for each county, NYCA load zone, and utility service territory.

Figure 22. Projected 2030 Daily PEV Charging Load (MW) for Entire State, Off-Peak Charging Scenario

Source: MJB&A PEV Modeling Analysis

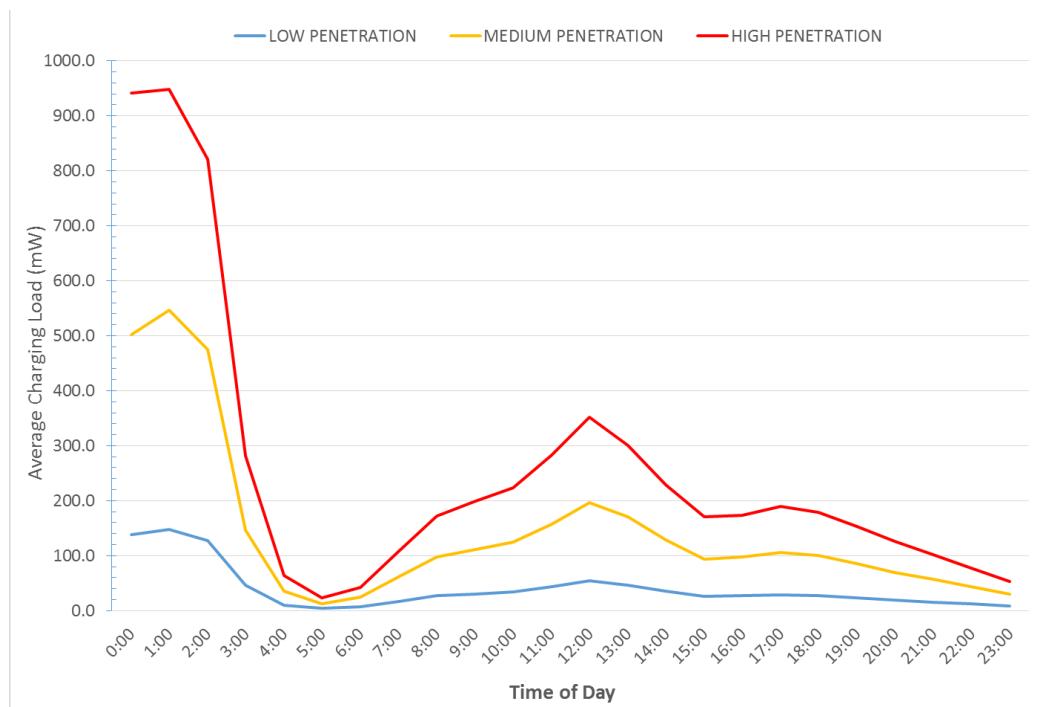
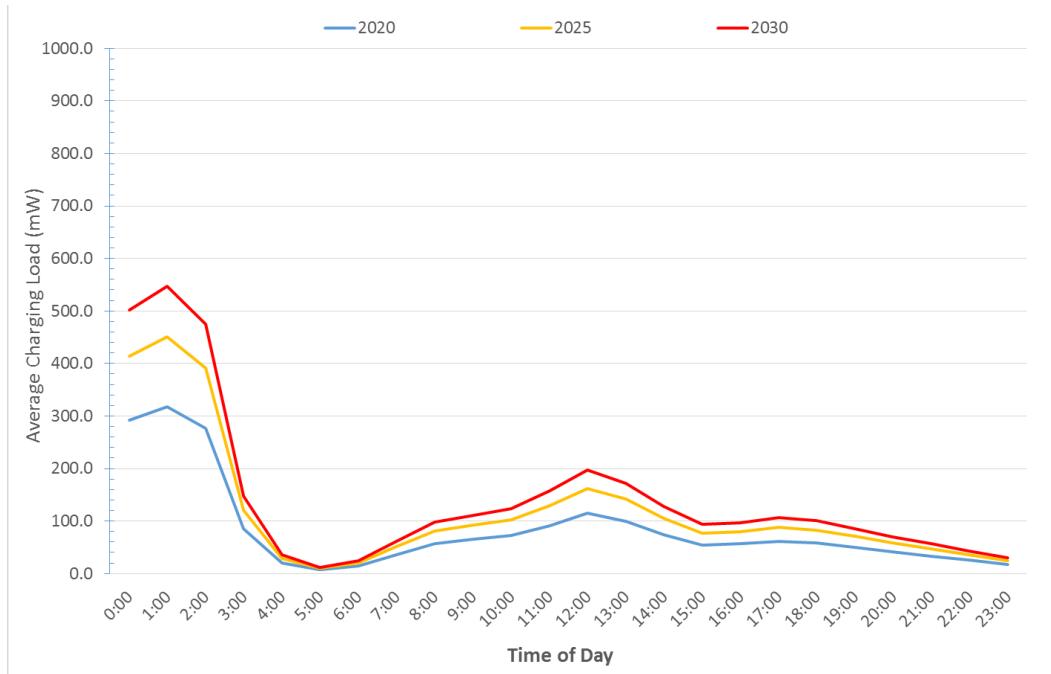


Figure 23. 2020, 2025, and 2030 Daily PEV Charging Load, Medium Penetration Scenario, Off-Peak Charging Scenario

Source: MJB&A PEV Modeling Analysis



By comparing the projected off-peak charging daily PEV charging load shown in Figures 22 and 23 with the projected business as usual daily PEV charging load shown in Figures 18 and 19, it becomes evident that off-peak charging would significantly shift the timing of daily peak PEV charging loads, from the early evening hours (baseline) to the early morning hours (TOU rate). This result would shift the peak daily PEV charging load away from the existing peak hours, thus reducing the impact of PEV charging on daily peak loads compared to the baseline.

4.3.3 Marginal Cost of PEV Charging

By comparing the 2014 NYISO daily load data shown in Figures 10 and 11 (Section 4.1.2) with the projected PEV charging loads shown in Figures 22 and 23, it is observed that under the off-peak charging scenario projected daily PEV charging load does not line up with existing daily load peaks. Because peak daily PEV charging loads happen in the early morning hours rather than in the early evening, PEV charging under the off-peak charging scenario adds significantly less load during daily peak hours than business as usual charging. In the 2030 high penetration scenario PEV charging under the off-peak charging scenario adds less than 0.6 percent additional load during the summer peak day peak hours, compared to 1.6 percent for the business as usual case.

The actual marginal cost of generating the electricity used for PEV charging will depend on where the charging falls on the marginal cost curve. Under the off-peak charging scenario, most of the additional load from PEV charging falls during non-peak periods every day when total system load is relatively low. Because the slope of the marginal cost curve is upward over the entire range of load on most days (Figure 9), the marginal cost of generation is lower during non-peak periods than during peak periods. The cost of electricity generation for PEV charging under the off-peak charging scenario will therefore always be lower than the cost of generation under the baseline scenario every day.

Table 17 provides an example for the projected marginal cost of electricity production for PEV charging on the summer peak and 95th percentile peak day under the off-peak charging scenario. As shown, under all penetration scenarios the marginal cost of electricity production is more than 20 percent lower under the off-peak charging scenario than under the business as usual scenario. This scenario would result in an average annual savings to the utility for electricity generation of approximately \$41.78 per PEV.¹⁷ This savings is in generation costs only – it does not account for any savings from avoided costs associated with a lower peak capacity requirement, which is discussed in Section 4.3.4.

Note that, as with the baseline analysis, this analysis and the following analyses for CO₂ and NO_x emissions do not extend beyond 2020 due to significant uncertainty as to changes in New York generating sources and fuel costs, and therefore changes in the marginal cost and emissions curves, more than five years into the future.

Table 17. 2020 Marginal Cost of Electricity Production for PEV Charging, Summer Peak and 95th Percentile Peak Days, Off-peak Charging Scenario

Source: MJB&A PEV Modeling Analysis

DAY	Penetration Scenario	Projected Marginal Cost of Electricity Production (\$/kWh)	Percent Change Compared to Base Case Business as Usual Charging
Summer Peak Day	Low	\$ 0.0608	-21.0%
	Medium	\$ 0.0613	-20.8%
	High	\$ 0.0616	-20.8%
95th Percentile Peak Day	Low	\$ 0.0543	-22.9%
	Medium	\$ 0.0547	-22.7%
	High	\$ 0.0551	-22.6%

¹⁷ -\$0.0161/kWh x 7.12 kWh/day x 365 days/year = - \$41.78/year

4.3.4 Reduced Capacity Costs

Table 18 gives an analysis of high penetration 2030 PEV charging load during summer daily peak hours (2 p.m. – 4 p.m.) under both the baseline and off-peak charging scenarios. As shown, compared to baseline charging, off-peak charging is projected to reduce daily peak load for PEV charging by an average of 276 MW, a reduction of 59 percent.

NYISO conducts capacity auctions for three distinct zones in New York: New York City (NYCA Load Zone J), Long Island (Load zone K), and NYCA (the rest of the state). The spot capacity clearing price for the NYCA averaged \$5.80 per kW-month in the summer 2013 capability period and \$3.51 per kW-month in the winter 2013-14 capability period. In New York City, spot prices averaged \$16.07 per kW-month in the summer 2013 Capability and \$9.72 per kW-month in the winter 2013-14 Capability period, while in Long Island, the spot price averaged \$7.14 per kW-month in the summer 2013 Capability Period and \$3.67 per kW-month in the winter 2013-14 Capability Period [34].

The use of a TOU rate or other incentive to move charging to off-peak periods would allow NYISO to purchase less capacity to accommodate PEV charging than they would have to do under the baseline charge scenario, due to lower daily peak load in both the summer and winter months. Table 19 gives an analysis of the projected savings in NYISO capacity costs compared to baseline charging under the 2030 high penetration scenario. As shown, the projected savings total \$14.6 million per year statewide, or an average of \$19.35 per PEV per year. Note that per-PEV projected savings are constant regardless of year and penetration scenario because the projected peak hour load reduction under the off-peak charging scenario is proportional to the number of PEVs.

Table 18. 2030 Summer Peak Hour PEV Charging Loads (MW) under Baseline and Off-Peak Charging Scenarios (high penetration)

Source: MJB&A PEV Modeling Analysis

NYCA LOAD Zone	BASELINE				TOU RATE				REDUCTION FROM BASELINE
	14:00	15:00	16:00	AVG	14:00	15:00	16:00	AVG	
A	53.65	61.02	71.38	62.02	30.31	22.71	23.10	25.38	36.64
B	15.02	17.08	19.98	17.36	8.49	6.36	6.47	7.11	10.26
C	31.03	35.34	41.38	35.92	17.42	13.04	13.38	14.61	21.30
D	1.64	1.87	2.20	1.90	0.90	0.67	0.71	0.76	1.14
E	20.47	23.33	27.33	23.71	11.44	8.56	8.83	9.61	14.10
F	28.79	32.79	38.38	33.32	16.17	12.10	12.41	13.56	19.76
G	33.53	38.17	44.66	38.79	18.89	14.14	14.45	15.83	22.96
H	4.34	4.93	5.76	5.01	2.46	1.85	1.87	2.06	2.95
I	29.72	33.77	39.48	34.32	16.86	12.64	12.79	14.09	20.23
J	87.82	99.79	116.66	101.42	49.81	37.35	37.78	41.65	59.77
K	98.16	111.54	130.40	113.37	55.68	41.75	42.23	46.55	66.81
TOTAL	404.17	459.63	537.61	467.14	228.44	171.17	174.00	191.21	275.93

Table 19. Annual Value of Reduced Capacity Requirement with Off-Peak Charging (2030, high penetration)

Source: MJB&A PEV Modeling Analysis

NYCA LOAD Zone	2013 Spot Capacity Clearing Price (\$/mW-month)		Months		ANNUAL TOTAL VALUE	NUMBER OF PEVS	AVERAGE ANNUAL VALUE PER TOU RATE
	Summer	Winter	Summer	Winter			
A	\$5,800	\$3,510	4	4	\$1,364,508	100,378	\$13.59
B	\$5,800	\$3,510	4	4	\$381,972	28,082	\$13.60
C	\$5,800	\$3,510	4	4	\$793,392	59,057	\$13.43
D	\$5,800	\$3,510	4	4	\$42,403	3,246	\$13.06
E	\$5,800	\$3,510	4	4	\$525,167	39,395	\$13.33
F	\$5,800	\$3,510	4	4	\$735,788	54,726	\$13.44
G	\$5,800	\$3,510	4	4	\$855,074	63,266	\$13.52
H	\$5,800	\$3,510	4	4	\$109,963	8,028	\$13.70
I	\$5,800	\$3,510	4	4	\$753,240	54,994	\$13.70
J	\$16,070	\$9,720	4	4	\$6,166,203	162,517	\$37.94
K	\$7,140	\$3,670	4	4	\$2,889,035	181,659	\$15.90
			TOTAL		\$14,616,746	755,349	\$19.35

4.3.5 CO₂ Emissions from PEV Charging

A comparison of the 2014 NYISO daily load data to the projected PEV charging loads shown in Figures 22 and 23 makes clear that under the off-peak charging scenario projected daily PEV charging load does not line up with existing daily load peaks. As previously described, PEV charging under the off-peak charging scenario adds significantly less load during daily peak hours than business as usual charging—less than 0.6 percent during summer peak compared to 1.6 percent for the business as usual in the 2030 high penetration scenario.

Actual CO₂ emissions from electricity generation used for PEV charging will depend on where the charging falls on the marginal emissions curve. Under the off-peak charging scenario the additional load from PEV charging falls during daily time periods when existing total load is generally less than 20,000 MW, even on peak days – a location on the load curve where the marginal CO₂ emissions curve is relatively flat or even falling slightly (Figure 13). As such, the additional load for PEV charging will not significantly affect marginal or average CO₂ emission rates except on peak days.

Table 20. 2020 Average CO₂ Emissions from PEV Charging, Summer Peak and 95th Percentile Peak Days, Off-Peak Charging Scenario

Source: MJB&A PEV Modeling Analysis

DAY	Penetration Scenario	Projected Average CO ₂ Emissions		Percent Change Compared to Base Case Business as Usual Charging
		(g/kWh)	(g/mi) ^a	
Summer Peak Day	Low	568.9	199.1	-2.9%
	Medium	569.5	199.3	-3.5%
	High	569.9	199.5	-3.9%
95 th Percentile Peak Day	Low	550.1	192.5	0.1%
	Medium	550.7	192.7	-0.1%
	High	551.1	192.9	-0.3%

^a Assumes 0.35 kWh/mi for PEVs

Table 20 gives projected average CO₂ emissions from PEV charging on the summer peak day and 95th percentile peak day under the off-peak charging scenario. As shown, on the peak day average CO₂ emissions are about 3 percent lower with off-peak charging than they are under the baseline charge scenario, under all three penetration scenarios. However, there is only a marginal change in CO₂ emissions on the 95th percentile peak day, including a slight increase under the low penetration scenario. Off-peak charging would only measurably effect marginal CO₂ emissions from PEV charging on a handful of peak days each year (less than 6) and total average annual CO₂ reductions from off-peak charging compared to the base case would likely be slightly less than 1 kilogram per PEV.¹⁸

4.3.6 NO_x Emissions from PEV Charging

Compared to the baseline charge scenario the reduction in peak hour load for PEV charging under the off-peak charging scenario will significantly reduce total NO_x emissions from PEV charging on peak and near-peak days by moving PEV charging load from times of the day when the marginal NO_x emission rate is very high to times of the day when the marginal NO_x emissions rate is much lower.

To quantify this effect, the projected 2020 daily PEV charging load was added to the 2014 summer peak day, 95th percentile peak day, and 50th percentile peak day loads and the 2015 marginal NO_x emissions curve was used to estimate marginal emissions from PEV charging. The results are shown in Table 21.

In table 21 NO_x emissions from PEV charging are estimated separately for daylight hours (6 a.m. – 8 p.m.) and for overnight hours. As shown, under the off-peak charging scenario 75-88 percent of estimated NO_x emissions from PEV charging on the peak and 95th percentile peak days are emitted during daylight hours. However, on the 50th percentile peak day only about 22 percent of estimated NO_x emissions from PEV charging are emitted during daylight hours, with the majority of NO_x emitted at night.

¹⁸ - 23.1 g/kWh x 7.12 kWh/day x 6 days/year = 987 grams/year = 0.987 kg/year

As shown in Table 21, marginal NO_x emissions (g/kWh) from electricity production for PEV charging are estimated to be about 1.8 times and 2.2 times higher on the summer peak and 95th percentile peaks days, respectively, than on the 50th percentile peak day, due to higher total generating load on-peak and near-peak days, and a higher marginal NO_x emissions rate at that higher load. However, on both the peak and 95th percentile peak day both day-time and total estimated NO_x emissions from off-peak PEV charging are almost 50 percent lower than estimated emissions under the baseline charging scenario. By comparison, on the 50th percentile peak day estimated day-time NO_x emissions from off-peak PEV charging are also almost 50 percent lower than estimated emissions under the baseline charging scenario, but total daily emissions are higher.

Table 21. 2020 Average NO_x Emissions from PEV Charging, Summer Peak, 95th Percentile Peak, and 50th Percentile Peak Days, Off-Peak Charging Scenario

Source: MJB&A PEV Modeling Analysis

DAY		OFF-PEAK CHARGING						
		NOx Emissions (ton)			% Change Compared to Baseline Charging		AVG NOx	
		DAY 6AM-8PM	NIGHT 8PM-6AM	TOTAL	DAY	TOTAL	g/kWh	g/mi
NOx Emissions From PEV Charging (TON)	SUMMER PEAK DAY	Low Penetration	0.263	0.035	0.298	-49%	-45%	0.696 0.244
	SUMMER PEAK DAY	Medium Penetration	1.188	0.152	1.340	-49%	-46%	0.699 0.244
	SUMMER PEAK DAY	High Penetration	1.853	0.233	2.086	-49%	-46%	0.699 0.245
	SUMMER 95th % Peak DAY	Low Penetration	0.175	0.062	0.237	-52%	-39%	0.554 0.194
	SUMMER 95th % Peak DAY	Medium Penetration	0.793	0.267	1.060	-52%	-40%	0.552 0.193
	SUMMER 95th % Peak DAY	High Penetration	1.238	0.402	1.640	-52%	-41%	0.550 0.192
	SUMMER 50th % Peak DAY	Low Penetration	0.028	0.111	0.140	-46%	110%	0.327 0.114
	SUMMER 50th % Peak DAY	Medium Penetration	0.129	0.481	0.610	-46%	101%	0.318 0.111
	SUMMER 50th % Peak DAY	High Penetration	0.201	0.727	0.928	-47%	95%	0.311 0.109
NOx Emissions from Gasoline Cars (TON)		Low Penetration	0.193	0.017	0.209	NA		0.169
		Medium Penetration	0.856	0.073	0.929	NA		0.169
		High Penetration	1.356	0.116	1.473	NA		0.169

Compared to baseline charging, off-peak charging would significantly reduce day-time NO_x emissions on-peak days (about 6) and near-peak days (about 30) and would slightly reduce day-time NO_x emissions on the remaining days of the year. Based on the data shown in Table 21, average annual NO_x emissions from PEV charging would be about 0.26 kilograms per PEV lower under the off-peak charging scenario than under the baseline charging scenario.

Also shown in Table 21 are the estimated average NO_x emissions per unit distance (g/mi) traveled by a PEV, assuming 0.35 kWh/mi average efficiency (consistent with the PEV charging load assumptions). By way of comparison, estimated NO_x emissions from an equivalent number of gasoline cars are also included in Table 21, for each penetration scenario. These estimates are based on data in EPA's MOVES emissions model, which show estimated total emissions from all light-duty cars operating in New York State, on an August weekday in 2020 [31].

As shown, 2020 fleet-average NO_x emissions from gasoline cars operating in New York are estimated by EPA to be 0.169 g/mi. On the 50th percentile peak day average NO_x emissions from PEV charging are estimated to be about 34 percent lower than emissions from an equivalent number of gasoline cars, at between 0.109 and 0.114 g/mi. On the peak and 95th percentile peak days, respectively, average gram per mile NO_x emissions from PEV charging are estimated to be about 44 percent and 14 percent higher than fleet-average gram per mile NO_x emissions from gasoline cars.

Figure 24. Change in Hourly NO_x emissions for PEVs charged off-peak, Compared to Gasoline Vehicles

Source: MJB&A PEV Modeling Analysis



However, despite somewhat higher total emissions on-peak and near-peak days PEVs charged off-peak may still provide net air quality benefits relative to gasoline cars by shifting emissions from daylight to night-time hours. This effect is seen in Figure 24, which plots the estimated change in hourly NO_x emissions for PEVs charged off-peak, compared to gasoline cars, under the high penetration scenario.

As shown, on the 50th percentile peak day off-peak PEV charging produces higher hourly NO_x emissions than gasoline cars between midnight and 4 a.m., but then lower hourly emissions for the rest of the day, including during all daylight hours. On the peak and 95th percentile peak day off-peak PEV charging also produces higher hourly NO_x emissions than gasoline cars between midnight and 4 a.m., and lower hourly emissions between 4 a.m. and 9 a.m., but higher hourly emissions for the rest of the day. Evaluating the actual effect of these differences in hourly NO_x emissions on ambient ozone production would require atmospheric photochemical modeling, which is beyond the scope of this project.

4.4 PEV Charging Load with Fully Controlled PEV Charging

This section discusses the modeled PEV charging load profile, generating cost, and CO₂ emissions assuming fully controlled PEV charging. Under controlled charging, the utility can vary the rate of charging (kW) for individual PEVs over the charge period to manage load.

Controlled charging could be implemented in various ways, as discussed in Section 3. For this project, a fairly simple scenario designed to show the potential for how controlled charging could affect daily PEV charging loads was modeled. Under this controlled charging scenario, the ratio of at-home and at-work charging, and the distribution of at-home and at-work charge start times (Figure 15) is the same as for the baseline charge scenario. But for each type of PEV, the assumed average rate of charging (kW) is lower. For each PEV type, the charge rate is assumed to be constant throughout the charge period for each vehicle, but just high enough to ensure completion of charging after eight hours, for both at-home and at-work charging. By comparison, the assumed charge rates under the base case result in completion of at-home charging in under four hours for a BEV and under three hours for a PHEV. As such, this controlled charging scenario takes advantage of a significant portion of the time typically available for charging to spread out the charging load, rather than assuming that each PEV will charge quickly and then sit for a number of hours with a full battery (baseline). This spreading out of load over time is the major intent of controlled charging.

The controlled charging scenario modeled here is fairly simplistic and is only one of many potential controlled charging scenarios – for example one could imagine a controlled charging scenario in which a small charging load (less than 0.5 kW) begins as soon as a vehicle is plugged in, with that load increased significantly (to 3 kW or more) sometime after midnight, to allow completion of charging by 5 or 6 a.m. Fully controlled charging could also vary by day, or even by vehicle within a day, based on a utility's variable load profile. As such, the controlled charging scenario modeled here is intended to be illustrative only, and may underestimate the potential benefits of fully controlled charging.

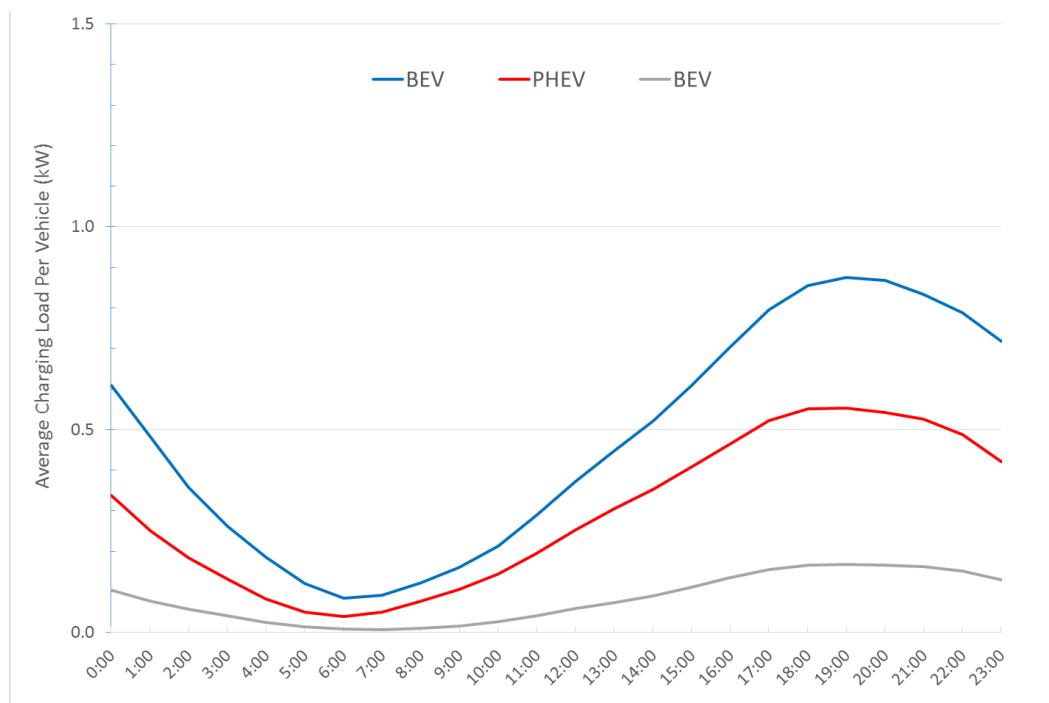
4.4.1 PEV Charge Profile

The PEV charging profiles used in the controlled charging scenario are shown in Figure 25, where the average load (kW) per LSV, BEV, and PHEV in each hour of the day are plotted. To calculate total load in each hour, the plotted curves are multiplied by the total projected number of PEVs of each type, and summed.

As shown, for BEVs the average daily peak charging load is 0.88 kW per vehicle and it occurs between 7 p.m. and 8 p.m. For PHEVs the average daily peak charging load is 0.55 kW per vehicle and it occurs between 6 p.m. and 8 p.m.. The average daily peak charging load for LSVs is 0.17 kW, occurring between 6 p.m. and 9 p.m. Compared to the baseline scenario average, daily peak charging loads per vehicles are 12, 31, and 37 percent lower, respectively, for BEVs, PHEVs, and LSVs. The peak load hour is also shifted about one hour later in the day for each PEV type.

Figure 25. PEV Charging Load Profiles Used in Controlled Charging Scenario

Source: MJB&A PEV Modeling Analysis



4.4.2 PEV Charging Load on Typical Day

The total projected PEV charging load for New York on a “typical day” in 2030 with fully controlled charging is shown in Figure 26 for all three PEV penetration scenarios. For all three scenarios the daily peak charging load under the controlled charging scenario occurs between 7 p.m. and 8 p.m. For the low penetration scenario daily peak hour PEV charging load in 2030 is 67 MW, rising to 241 MW under the medium penetration scenario and 435 MW under the high penetration scenario.

The ramp-up of peak daily charging load over time is shown in Figure 27 using the medium penetration scenario as an example. As shown, with controlled charging the daily peak hour PEV charging load in 2020 under the medium penetration scenario is 140 MW, rising to 199 MW in 2025 and 241 MW in 2030.

Detailed tables of projected 2020, 2025, and 2030 daily charge loads under each penetration scenario are included at Appendix A, including aggregation of load for each county, NYCA load zone, and utility service territory.

Controlled charging shifts the timing of daily peak PEV charging loads by two hours, from 5 p.m. to 7 p.m., according to comparing the projected controlled charging daily PEV charging load shown in Figures 24 and 25 with the projected business as usual daily PEV charging load shown in Figures 18 and 19. More importantly, controlled charging reduces the size of the peak; in the 2030 high penetration scenario the peak hour PEV charging load is reduced from 600 MW under the baseline to 425 MW with controlled charging, a reduction of 175 MW (-29 percent).

Figure 26. Projected 2030 Daily PEV Charging Load (MW) for Entire State, Controlled Charging Scenario

Source: MJB&A PEV Modeling Analysis

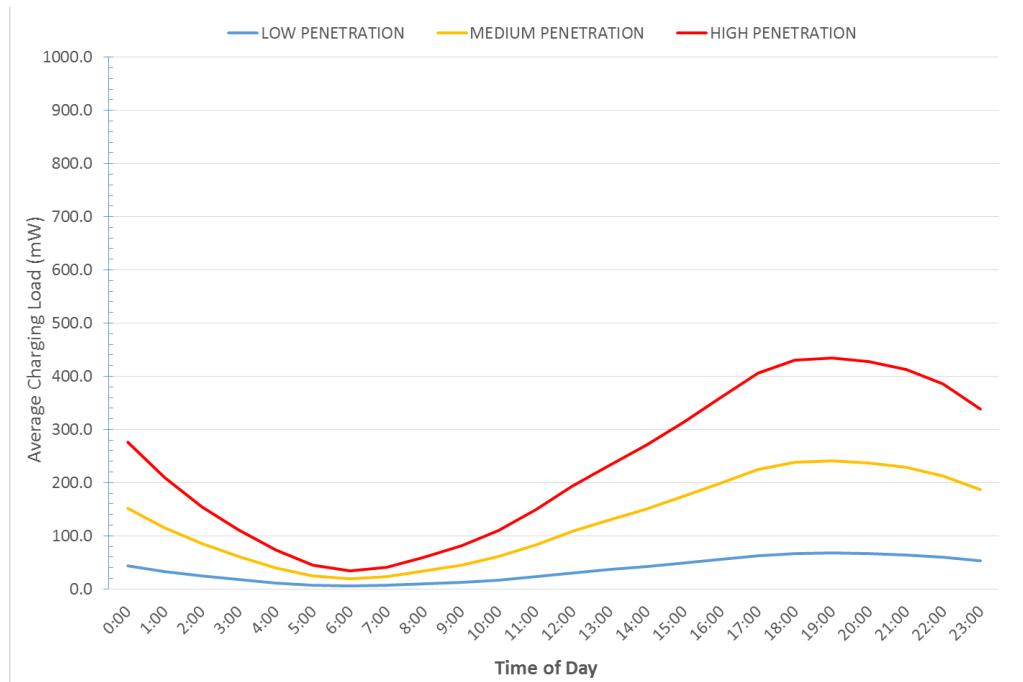
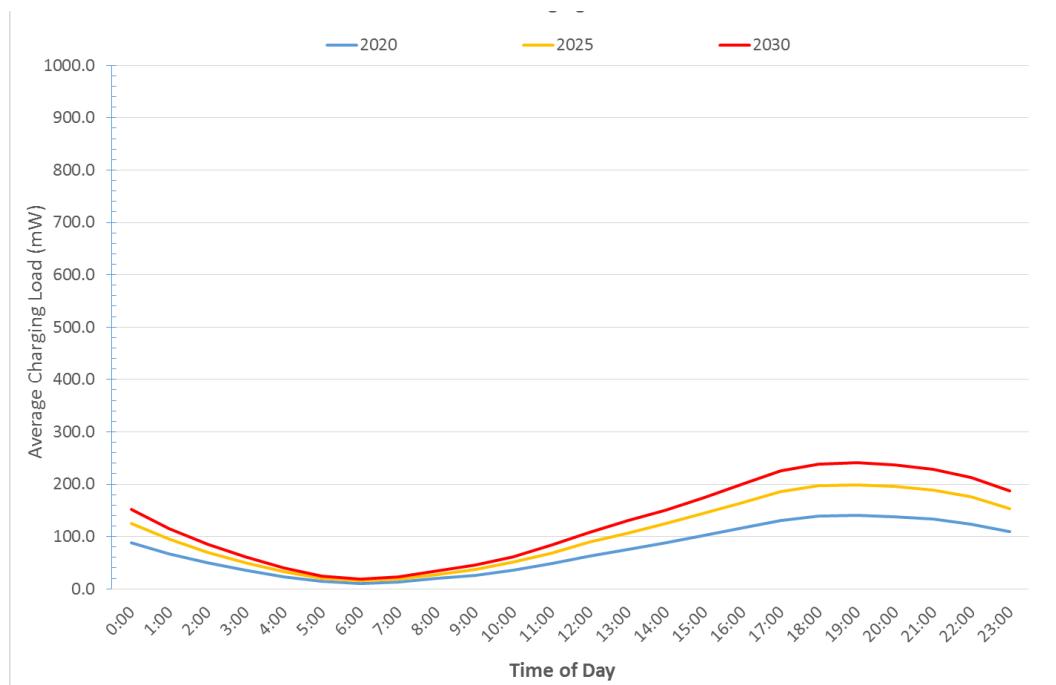


Figure 27. 2020, 2025, and 2030 Daily PEV Charging Load, Medium Penetration Scenario, Controlled Charging Scenario

Source: MJB&A PEV Modeling Analysis



4.4.3 Marginal Cost of PEV Charging

Comparing the 2014 NYISO daily load data shown in Figures 10 and 11 (Section 4.1.2) with the projected PEV charging loads shown in Figures 26 and 27 shows that under the controlled charging scenario projected daily PEV charging load generally lines up with existing daily load peaks, but not as directly as charging loads under the baseline charge scenario. The shift of the peak hour PEV charging load two hours later in the evening reduces the impact of PEV charging on daily peak demand compared to the baseline. By spreading PEV charging load out over the day controlled charging further reduces the impact of PEV charging on daily peak hour demand. In the 2030 high penetration scenario PEV charging under the controlled charging scenario adds about 1.1 percent additional load during the summer peak day peak hours, compared to 1.6 percent for the business as usual case.

The actual marginal cost of generating the electricity used for PEV charging will depend on where the charging falls on the marginal cost curve. Compared to the baseline scenario the controlled charging scenario reduces total system load during peak periods; because the slope of the marginal cost curve is upward over the entire range of load on most days (Figure 9), the marginal cost of generation will therefore always be lower with controlled charging than under the baseline charge scenario.

Table 22. 2020 Marginal Cost of Electricity Production for PEV Charging, Summer Peak and 95th Percentile Peak Days, Controlled Charging Scenario

Source: MJB&A PEV Modeling Analysis

DAY	Penetration Scenario	Projected Marginal Cost of Electricity Production (\$/kWh)	Percent Change Compared to Base Case Business as Usual Charging
Summer Peak Day	Low	\$ 0.0714	-7.2%
	Medium	\$ 0.0718	-7.3%
	High	\$ 0.0719	-7.5%
95th Percentile Peak Day	Low	\$ 0.0655	-7.1%
	Medium	\$ 0.0658	-7.1%
	High	\$ 0.0659	-7.3%

Table 22 shows the projected marginal cost of electricity production for PEV charging on the summer peak and 95th percentile peak day under the controlled charging scenario. As shown, under all penetration scenarios the marginal cost of electricity production is approximately 7 percent lower under the controlled charging scenario than under the business as usual scenario, but it is not as low as it is under the TOU rate scenario. Compared to the baseline, controlled charging would result in an average annual savings to the utility for electricity generation of approximately \$13.48 per year per PEV.¹⁹ This savings is in generation costs only – it does not account for any savings from avoided costs associated with a lower peak capacity requirement, which is discussed in Section 4.4.4.

Note that as with the baseline and off-peak analyses, this analysis and the following analyses for CO₂ and NO_x emissions do not extend beyond 2020 due to significant uncertainty as to changes in New York generating sources and fuel costs, and therefore changes in the marginal cost and emissions curves, more than five years into the future.

4.4.4 Reduced Capacity Costs

Table 23 gives an analysis of the high penetration 2030 PEV charging load during summer daily peak hours (2 p.m. – 4 p.m.) under both the baseline and controlled charging scenarios. As shown, compared to baseline charging, controlled charging is projected to reduce daily peak load for PEV charging by an average of 152 MW, a reduction of 33 percent.

The use of controlled charging would allow NYISO to purchase less capacity to accommodate PEV charging than they would have to do under the baseline charge scenario, due to lower daily peak load in both the summer and winter months. See Table 24 for an analysis of the projected savings in NYISO capacity costs compared to baseline charging under the 2030 high penetration scenario. As shown, the projected savings total \$8 million per year state-wide, or an average of \$10.67 per PEV per year. Note that per-PEV projected savings are constant regardless of year and penetration scenario because the projected peak hour load reduction under the TOU Rate changing scenario is proportional to the number of PEVs.

¹⁹ -\$0.0052/kWh x 7.12 kWh/day x 365 day/year = \$13.48/year

Table 23. 2030 Summer Peak Hour PEV Charging Loads (MW) under Baseline and Controlled Charging Scenarios (High Penetration)

Source: MJB&A PEV Modeling Analysis

NYCA LOAD Zone	BASELINE				CONTROLLED CHARGE				REDUCTION FROM BASELINE (mW)
	14:00	15:00	16:00	Avg	14:00	15:00	16:00	Avg	
A	53.65	61.02	71.38	62.02	35.89	41.71	47.72	41.77	20.24
B	15.02	17.08	19.98	17.36	10.05	11.68	13.36	11.70	5.66
C	31.03	35.34	41.38	35.92	20.68	24.03	27.49	24.07	11.85
D	1.64	1.87	2.20	1.90	1.08	1.26	1.44	1.26	0.64
E	20.47	23.33	27.33	23.71	13.60	15.81	18.09	15.83	7.88
F	28.79	32.79	38.38	33.32	19.19	22.30	25.51	22.33	10.98
G	33.53	38.17	44.66	38.79	22.39	26.02	29.77	26.06	12.73
H	4.34	4.93	5.76	5.01	2.91	3.38	3.87	3.39	1.62
I	29.72	33.77	39.48	34.32	19.93	23.16	26.49	23.19	11.13
J	87.82	99.79	116.66	101.42	58.89	68.44	78.29	68.54	32.88
K	98.16	111.54	130.40	113.37	65.83	76.50	87.52	76.61	36.75
TOTAL	404.17	459.63	537.61	467.14	270.44	314.29	359.56	314.76	152.37

Table 24. Annual Value of Reduced Capacity Requirement with Controlled Charging (2030, High Penetration)

Source: MJB&A PEV Modeling Analysis

NYCA LOAD Zone	2013 Spot Capacity Clearing Price (\$/mW-month)		Months		ANNUAL TOTAL VALUE CONTROL	NUMBER OF PEVS	AVERAGE ANNUAL VALUE CONTROL
	Summer	Winter	Summer	Winter			
A	\$5,800	\$3,510	4	4	\$753,832	100,378	\$7.51
B	\$5,800	\$3,510	4	4	\$210,950	28,082	\$7.51
C	\$5,800	\$3,510	4	4	\$441,256	59,057	\$7.47
D	\$5,800	\$3,510	4	4	\$23,966	3,246	\$7.38
E	\$5,800	\$3,510	4	4	\$293,370	39,395	\$7.45
F	\$5,800	\$3,510	4	4	\$409,036	54,726	\$7.47
G	\$5,800	\$3,510	4	4	\$473,935	63,266	\$7.49
H	\$5,800	\$3,510	4	4	\$60,491	8,028	\$7.53
I	\$5,800	\$3,510	4	4	\$414,361	54,994	\$7.53
J	\$16,070	\$9,720	4	4	\$3,392,053	162,517	\$20.87
K	\$7,140	\$3,670	4	4	\$1,589,270	181,659	\$8.75
			TOTAL		\$8,062,519	755,349	\$10.67

4.4.5 CO₂ Emissions from PEV Charging

By comparing the 2014 NYISO daily load data with the projected controlled charging PEV charging loads, it is evident that under the controlled charging scenario projected daily PEV charging load generally lines up with existing daily load peaks, but not as directly as charging loads under the baseline charge scenario. The shift of the peak hour PEV charging load two hours later in the evening reduces the impact of PEV charging on daily peak demand compared to the baseline. By spreading PEV charging load out over the day controlled charging further reduces the impact of PEV charging on daily peak hour demand. In the 2030 high penetration scenario, PEV charging under the controlled charging scenario adds about 1.1 percent additional load during the summer peak day peak hours, compared to 1.6 percent for the business as usual case.

Under the controlled charging scenario, the additional load from PEV charging falls during daily time periods when existing total load is generally less than 20,000 MW, even on-peak days – a location on the load curve where the marginal CO₂ emissions curve is relatively flat or even falling slightly (Figure 13). The additional load for PEV charging will therefore not significantly affect marginal or average CO₂ emission rates except on peak days.

Table 25 shows projected average CO₂ emissions from PEV charging on the summer peak day and 95th percentile peak day under the controlled charging scenario. As shown, on the peak day average CO₂ emissions are about 2 percent lower with controlled charging than they are under the baseline charge scenario, under all three penetration scenarios. There is also a marginal reduction in CO₂ emissions on the 95th percentile peak day under all three penetration scenarios. Interestingly, on the peak day reductions in CO₂ emissions compared to the baseline are lower for controlled charging than they are with a TOU rate, but on the 95th percentile peak day CO₂ reductions are greater with controlled charging than they are with a TOU rate. Nonetheless, as with a TOU rate, controlled charging is likely to measurably affect marginal CO₂ emissions from PEV charging on only a handful of near-peak days each year (less than 20) and total average annual CO₂ reductions compared to the base case would likely be less than 0.7 kilograms per PEV.²⁰

²⁰ -4.8 g/kWh x 7.12 kWh/day x 20 day/year = 683 g/year = 0.683 kg/year

Table 25. 2020 Average CO₂ Emissions from PEV Charging, Summer Peak and 95th Percentile Peak Days, Controlled Charging Scenario

Source: MJB&A PEV Modeling Analysis

DAY	Penetration Scenario	Projected Average CO ₂ Emissions		Percent Change Compared to Base Case Business as Usual Charging
		(g/kWh)	(g/mi) ¹	
Summer Peak Day	Low	576.0	201.6	-1.7%
	Medium	578.2	202.4	-2.0%
	High	579.8	202.9	-2.2%
95 th Percentile Peak Day	Low	547.7	191.7	-0.3%
	Medium	548.8	192.1	-0.5%
	High	549.7	192.4	-0.6%

¹ Assumes 0.35 kWh/mi for PEVs

4.4.6 NO_x Emissions from PEV Charging

As discussed above, by spreading PEV charging load out over the day controlled charging reduces the impact of PEV charging on daily peak hour demand. In the worst case (2030 high penetration scenario) PEV charging under the controlled charging scenario adds about 1.1 percent additional load during the summer peak day peak hours, compared to 1.6 percent for the business as usual case.

Compared to the baseline charge scenario the reduction in peak hour load for PEV charging under the controlled charging scenario will reduce total NO_x emissions from PEV charging on peak and near-peak days, by moving PEV charging load from times of the day when the marginal NOx emission rate is very high, to times of the day when the marginal NO emissions rate is lower.

To quantify this effect the projected 2020 daily PEV charging load was added to the 2014 summer peak day, 95th percentile peak day, and 50th percentile peak day loads and the 2015 marginal NO emissions curve was used to estimate marginal emissions from PEV charging. The results are shown in Table 26.

In Table 26 NO_x emissions from PEV charging are estimated separately for daylight hours (6 a.m. – 8 p.m.) and for overnight hours.

As shown, under the controlled charging scenario 84-87 percent of estimated NO_x emissions from PEV charging on the peak and 95th percentile peak days are emitted during daylight hours. However, on the 50th percentile peak day only about 44 percent of estimated NO_x emissions from PEV charging are emitted during daylight hours, with the rest of the estimated NO_x emitted at night.

As shown in Table 26, marginal NO_x emissions (g/kWh) from electricity production for PEV charging are estimated to be about 3.8 times and 5.2 times higher on the summer peak and 95th percentile peaks days, respectively, than on the 50th percentile peak day, due to higher total generating load on-peak and near-peak days, and a higher marginal NO_x emissions rate at that higher load. However, on both the peak and 95th percentile peak day estimated daytime NO_x emissions from controlled PEV charging are almost 25 percent lower than estimated emissions under the baseline charging scenario, and estimated total daily NO_x emissions are about 15 percent lower. By comparison, on the 50th percentile peak day estimated daytime NO_x emissions from off-peak PEV charging are also about 25 percent lower than estimated emissions under the baseline charging scenario, but total daily emissions are 30 percent higher.

Compared to baseline charging, controlled charging would significantly reduce daytime NO_x emissions on peak days (about 6) and near-peak days (about 30) and would slightly reduce daytime NO_x emissions on the remaining days of the year. Based on the data shown in Table 26, average annual NO_x emissions from PEV charging would be about 0.13 kilograms per PEV lower under the controlled charging scenario than under the baseline charging scenario. Table 26 also shows estimated average NO_x emissions per distance (g/mi) traveled by a PEV and estimated NO_x emissions from an equivalent number of gasoline cars.

Table 26. 2020 Average NO_x Emissions from PEV Charging, Summer Peak, 95th Percentile Peak, and 50th Percentile Peak Days, Off-peak Charging Scenario

Source: MJB&A PEV Modeling Analysis

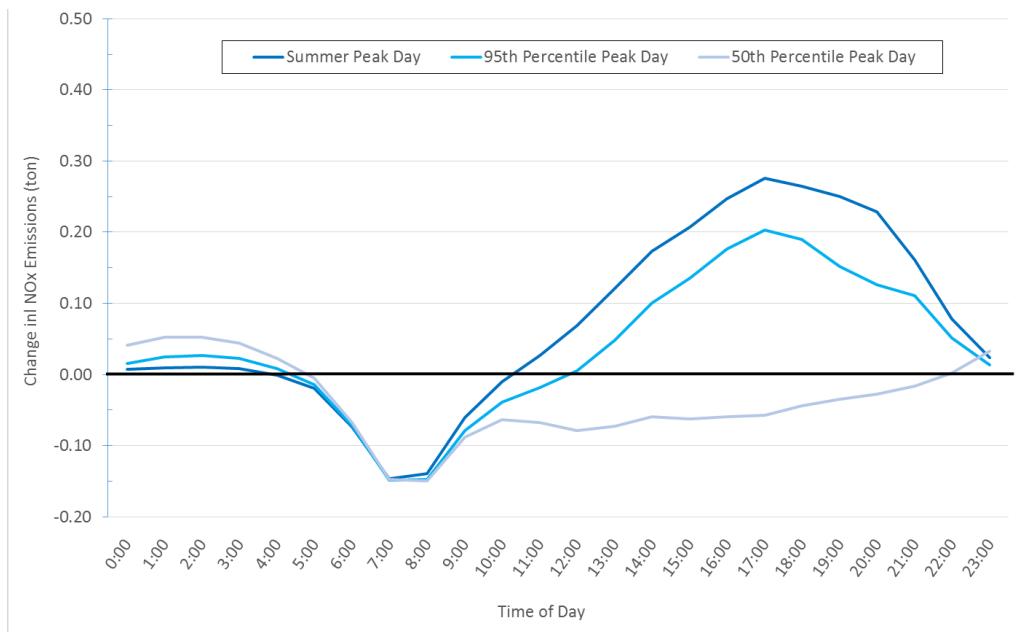
DAY		CONTROLLED CHARGING						
		NOx Emissions (ton)	DAY	NIGHT	TOTAL	% Change Compared to Baseline Charging	DAY	
NOx Emissions From PEV Charging (TON)	6AM-8PM	8PM-6AM				g/kWh	g/mi	
SUMMER PEAK DAY	Low Penetration	0.395	0.055	0.451	-23%	-17%	1.054	0.369
	Medium Penetration	1.790	0.251	2.041	-23%	-17%	1.064	0.372
	High Penetration	2.789	0.394	3.183	-24%	-18%	1.067	0.374
SUMMER 95th % Peak DAY	Low Penetration	0.281	0.053	0.334	-22%	-14%	0.781	0.273
	Medium Penetration	1.276	0.238	1.514	-23%	-14%	0.789	0.276
	High Penetration	1.990	0.375	2.365	-23%	-15%	0.793	0.277
SUMMER 50th % Peak DAY	Low Penetration	0.039	0.049	0.088	-25%	33%	0.206	0.072
	Medium Penetration	0.177	0.219	0.396	-26%	31%	0.206	0.072
	High Penetration	0.277	0.341	0.618	-26%	30%	0.207	0.073
NOx Emissions from Gasoline Cars (TON)	Low Penetration	0.193	0.017	0.209			NA	0.169
	Medium Penetration	0.856	0.073	0.929			NA	0.169
	High Penetration	1.356	0.116	1.473			NA	0.169

As shown, 2020 fleet-average NO_x emissions from gasoline cars operating in New York are estimated by EPA to be 0.169 g/mi. On the 50th percentile peak day average NO_x emissions from controlled PEV charging are estimated to be about 57 percent lower than emissions from an equivalent number of gasoline cars, at between 0.072 and 0.073 g/mi. On the peak and 95th percentile peak days, respectively, average gram per mile NO_x emissions from PEV charging are estimated to be about 220 and 63 percent higher than fleet-average gram per mile NO_x emissions from gasoline cars. However, despite higher total emissions on-peak and near-peak days controlled PEV charging may still provide net air quality benefits relative to gasoline cars by shifting emissions from daylight to night-time hours. This effect is seen in Figure 28, which plots the estimated change in hourly NO_x emissions for PEVs charged under the controlled charge scenario, compared to gasoline cars, under the high penetration scenario.

As shown in Figure 28, on the 50th percentile peak day controlled PEV charging produces higher hourly NO_x emissions than gasoline cars between midnight and 4 a.m., but then lower hourly emissions for the rest of the day, including during all daylight hours. On the peak and 95th percentile peak day controlled PEV charging also produces higher hourly NO_x emissions than gasoline cars between midnight and 4 a.m., and lower hourly emissions between 4 a.m. and 10 a.m., but higher hourly emissions for the rest of the day. Evaluating the actual effect of these differences in hourly NO_x emissions on ambient ozone production would require atmospheric photochemical modeling, which is beyond the scope of this project.

Figure 28. Change in Hourly NO_x emissions for PEVs charged off-peak, Compared to Gasoline Vehicles

Source: MJB&A PEV Modeling Analysis



4.5 PEV Clustering

The analysis of PEV charging scenarios discussed in Sections 4.2 – 4.4 only considers gross effects on peak load and capacity at the county level or higher. However, at a more local level the effects of PEV “clustering” could potentially strain local distribution infrastructure and incur utility costs for upgrades. Clustering refers to the phenomenon of multiple PEVs charging simultaneously at houses in close proximity, and in particular at houses served from the same neighborhood service transformer.

The effects of PEV clustering are highly variable and localized, and therefore hard to quantify. As an illustrative example, consider a “typical” suburban neighborhood of single-family homes where nine houses are served from a 50-kVA service transformer, which could provide an average of approximately 6.4 kW per house before being dangerously overloaded²¹ [16]. Each home (without a PEV) might have an average peak summer load of approximately 5 kW during the late afternoon hours, but a load of only about 2 kW during the early morning hours [35]. In such a neighborhood the existing service transformer would have only about 12 kW of available capacity to accommodate PEV charging during late afternoon hours (4 p.m. – 8 p.m.) but would have as much as 39 kW of capacity to accommodate PEV charging during early morning hours (12 a.m. – 6 a.m.).

The existing service transformer in this neighborhood of nine houses could accommodate only four PEVs charging simultaneously at average rates during the late afternoon without overloading²². However, the same transformer could potentially accommodate eight or more PEVs charging simultaneously during the early morning hours even if one or more were charging at a much higher than average rate.

It is clear that the negative effects of PEV clustering on local service infrastructure would be reduced if the electricity rate structure incentivized off-peak PEV charging, or if charging was fully controlled by the utility.

The potential for negative PEV clustering effects increases with increasing PEV “density” (average PEVs per household), and is likely to be significant in locations where there are more than 300 PEVs per 1,000 housing units (more than 3 PEVs per 10 households).

Figure 29 summarizes the current density of PEV registrations in New York by ZIP code. As shown, current PEV density is low in most ZIP codes, with only a handful of ZIP codes with density above 20 PEVs per 1,000 housing units [36]. As such, the current probability of negative effects from PEV clustering is low.

²¹ Assuming overload occurs at 115 percent of rated capacity.

²² Assuming the average charge rate of 2.7 kW used for this analysis.

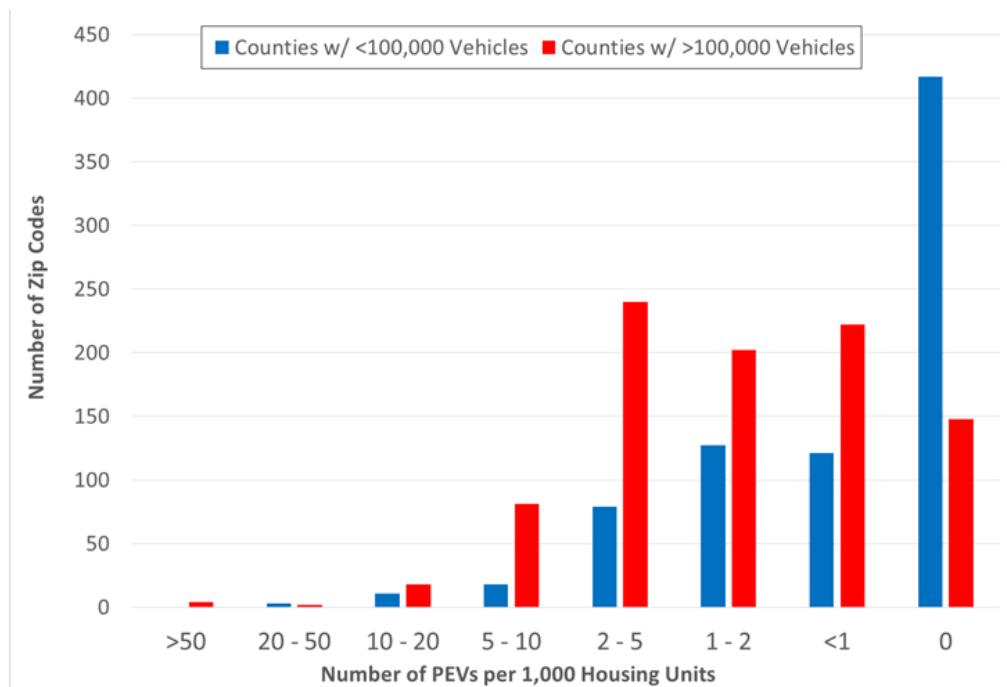
However, the projected number of PEVs in 2030 under the high penetration scenario is 58 times greater than current PEV registrations. If current patterns of PEV adoption continue, by 2030 under the high penetration scenario there could be more than 130 ZIP codes state-wide with PEV density greater than 300 PEVs/1,000 housing units. These ZIP codes, many in denser, more urban counties, have about 350,000 housing units. Assuming one local service transformer for every nine houses and using the high penetration scenario, then by 2030 as many as 39,000 local service transformers could be at a significantly elevated risk of requiring upgrade due to overload from PEV charging. If only 33 percent of these “at risk” transformers required upgrade, at a cost of \$8,000 per transformer²³ [37], the total cost would be \$103 million, or an average of \$135 per PEV. At best, that estimate is an order of magnitude for the potential local infrastructure upgrade costs that might result from PEV clustering under the baseline charging scenario, but it is broadly consistent with other estimates of these costs in the literature [16].

As previously discussed, many of these local infrastructure upgrade costs could likely be avoided under alternative charging scenarios which incentivized home PEV charging during off-peak hours or in which charging was fully controlled by the utility.

²³ This assumes a single phase pole-top or URD silo transformer in Westchester County, and includes purchase and installation costs. Costs for three-phase pole-top or silo transformers could be up to \$10,000 higher. Costs for underground networked systems, such as those installed in New York City, would be significantly higher.

Figure 29. 2014 Concentration of PEV Registrations by ZIP Code in New York

Source: New York Department of Motor Vehicles, MJB&A analysis



5 Utility and Stakeholder Outreach

This section summarizes the information gathered during outreach to various stakeholders with an interest in PEV adoption in New York. These stakeholders included New York electric utility distribution companies, NYISO, nongovernmental organizations, and manufacturers of electric vehicles and electric vehicle supply equipment (EVSE).

5.1 New York State Utilities

Four of the largest electric distribution utilities in New York participated in this project: Consolidated Edison, PSEG Long Island, National Grid (Niagara Mohawk), and Central Hudson Gas & Electric. These four utilities provide electric delivery services to approximately 80 percent of all New York customers. In addition, the New York Power Authority (NYPA) also participated. NYPA is America's largest state power organization, with 16 generating facilities and more than 1,400 circuit-miles of transmission lines. NYPA does not provide distribution services directly to residential customers; NYPA-generated power is distributed primarily to large and small businesses, not-for-profit organizations, community-owned electric systems and rural electric cooperatives, and government entities via distribution infrastructure owned by the distribution utilities.

All of the distribution utilities consulted expressed concerns about uncontrolled PEV charging during daily peak hours, though there was little concern about its effects on overall system load; the greatest concerns were over potential localized effects on distribution infrastructure due to PEV clustering. Concern is greatest for the near-suburbs around New York City (Nassau, Suffolk, Westchester, Rockland, Orange, and Putnam counties) as well as Albany (Albany), Erie (Buffalo), Monroe (Rochester) and Onondaga (Syracuse) counties. There is less concern for New York City itself, due to the structure of the existing distribution network there. There is also less concern about the potential for significant problems in more rural areas.

In all areas, the distribution utilities believe that the most likely system components to be overloaded by PEV clustering will be above-ground infrastructure such as service transformers and secondary side service conductors. Substations and underground primary side conductors have significant excess capacity and are unlikely to be negatively affected.

All distribution utilities expressed strong support for pricing strategies that will incentivize off-peak PEV charging. From the utility's perspective, the simplest mechanism would be adoption of whole-house TOU rates by PEV owners. As discussed in Section 2.2, all major New York utilities currently have voluntary residential TOU rates available. Conversion to TOU rates requires the utility to change or reprogram the customer's meter, and utilities are prepared to do so. Distribution of the costs involved among customers is supported by PSC regulations.

However, all utilities agree that the current voluntary residential TOU rates are unpopular with customers, including PEV owners. There was some disagreement among utilities as to whether the rates are unpopular because they are poorly optimized for PEV owners (i.e., do not provide sufficient actual benefits), or whether they do provide significant benefits but are not being promoted properly to customers by the utilities.²⁴ Regardless of the reason and without restructuring and/or better customer communications, the utilities agree that these existing voluntary whole-house residential TOU rates are unlikely to be effective in mitigating negative grid effects from PEV charging because they are unlikely to be adopted by many PEV owners.

None of the distribution utilities are enthusiastic about developing PEV-only TOU rates to boost participation by PEV owners, due to the significant regulatory and financial barriers involved. Their biggest concern is the need to install a second utility-grade meter to measure the PEV charging load for billing purposes, separate from other household loads. Current PSC regulations require the customer to open a second account when a second meter is installed at a residence, except under specific, limited circumstances.

The cost to the customer of a second utility-grade meter to measure PEV charging loads could be \$1,000 or more per house in upfront cost to install as second meter pan, plus \$150 - \$360 per year in additional monthly service charges for the second account. All utilities expressed skepticism that customers would be willing to pay this cost. Similarly, they were skeptical that the benefits to the grid of a TOU rate would justify a decision to change current PSC rules to allow utilities to provide a second meter to PEV owners without charging a second monthly service charge, and to absorb the increased operating and maintenance costs into the broader rate base. If the second meter could not be provided with no additional costs to the customer, and if customers were unwilling to pay the increased costs, the

²⁴ See Section 2.3. Based on the analysis discussed there only the current TOU rates offered by Con Edison would be likely to provide net cost reductions for most PEV owners unless they were able to shift other household loads away from peak summer hours.

utilities believe that a PEV-only TOU rate would not be effective in mitigating grid effects from PEV charging because few customers would adopt it. Without distributing the cost of a second meter among customers, utilities believe that a PEV-only TOU rate would be no more effective at mitigating grid effects from PEV charging than the current whole-house TOU rates.

The utilities also expressed concern that PEV-only TOU rates would complicate customer billing, and increase administrative costs, because their internal systems do not allow them to aggregate charges from two different meters onto the same bill.

As an alternative to whole-house or PEV-only TOU rates, all utilities expressed support for some kind of rebate program that would provide a monthly credit or rebate in exchange for off-peak or controlled PEV charging, similar to the pilot programs being conducted by Eversource and PEPCO (see Section 3.2). While this type of rebate would require hardware to monitor, report, and in the case of controlled charging control charging behavior (i.e., charge start time, charge rate), it would not require the utility to measure PEV charging electricity use for billing purposes – so it would not require a second utility-grade meter. As such, hardware costs could be significantly lower than hardware costs to implement a PEV-only TOU rate. The rebate could also be handled separately from the customer’s electric bill, perhaps by a third party, which would make administration of the program easier and potentially less costly for utilities.

The utilities believe that a rebate program to incentivize off-peak PEV charging would be analogous to existing load control programs (see Section 2.3); there is significant experience and familiarity with these programs in New York by both utilities and the PSC. While implementation of such a rebate program would require PSC approval, the regulatory burden is lower than for development of new rate structures, including PEV-only or PEV-optimized residential TOU rates.

5.2 NYISO

NYISO was also consulted and expressed no concerns about the level of projected PEV penetration and charging scenarios. Similar to the utilities, NYISO had little concern about its effects on overall system load especially due to the fact that load is flat to slightly falling around the state. However, NYISO did agree that local distribution level impacts could be a concern for utilities.

NYISO developed its own EV forecast for inclusion in its 10-year load and energy forecast. The vehicle penetration and energy use estimates developed for this report, as discussed in Section 4, are in line with NYISO estimates. Given that actual EV penetration to date is lower than originally assumed by NYISO, system wide load impacts are forecast by NYISO to be lower today than the forecasts included in their 10-year plan.

NYISO is not anticipating near term PEV penetration in NYISO demand response programs. How and whether PEVs could participate in these growing markets remains to be determined by two factors: 1) can PEVs provide services more cheaply than alternatives, and 2) will regulators and market operators structure market rules that enable PEV owners to earn revenues in exchange for grid services. Even at a 1 MW cutoff, a minimum fleet size of roughly 100 EVs charging *simultaneously* on Level 2 EVSE would be needed to participate in a market. Therefore, fleet applications would likely be the most feasible to pursue. NYISO also noted that fleets of PEVs could be attractive to utilities as a resource to address location specific needs such as frequency regulation.

5.3 NGOs

Generally speaking, non-governmental organizations (NGOs) encourage utilities to help increase PEV market development through PEV education and outreach, charging pricing strategies, and infrastructure investment. NGOs indicated that there has been significant experience with each of these areas that should be considered when developing a pricing strategy for New York customers. NGOs also pointed to the current utility PEV proposals under discussion in California, which include real time pricing, managed charging, and EVSE installations.

One NGO encouraged the utilities to go beyond whole house TOU rates and develop a pricing solution specific to PEVs. The organization noted that TOU rates have been effective at providing the necessary incentives to get PEV customers to charge at off-peak periods for the vast majority of their charging. According to the NGO, TOU rates are a foundational element to any EV pricing strategy but as PEV penetration increases, active management of that flexible load will likely be necessary.

Another NGO noted that New York should evaluate where the State needs to go from a long term climate perspective; including consideration of renewables and the flexible load of PEVs. The NGO noted there are opportunities to align PEV charging with off-peak wind resources or on-peak solar resources to maximize the environmental benefit of PEVs.

Several NGOs are involved with the REV proceeding. As REV has evolved, the PSC and Cuomo Administration officials are placing increased emphasis on executing demonstration projects. The idea is to begin implementing aspects of REV now by encouraging utilities to incorporate these "trials" in rate cases. The guidance document released by the PSC on December 12, 2014, outlines principles for REV demonstrations. One NGO suggested that a PEV pricing strategy may fit well as a demonstration in this context.

5.4 Automakers

Automakers continue to focus on reducing the barriers to PEV adoption, including reducing the costs of the vehicles to the consumer. Several areas mentioned as critical to address include: 1) multi-unit dwellings (MUDs), 2) residential charging, and 3) workplace charging. PEV charging at MUDs, such as apartment complexes and condos where people may not have garages, presents big challenges. This area should not be overlooked, especially in and around the NYC area, given the density of MUDs.

Residential charging is foundational for any program because that is where the majority of PEV charging occurs. Automakers felt TOU rates have been successful in sending the right financial signals to PEV customers and should be part of the offering. EV manufacturers stated New York could also consider EVSE financial incentives or even providing EVSE for free to residential customers.

Automakers suggested PEV pilots should not be overly complicated and any PEV pricing strategy in New York should be kept simple. Customers are easily confused and overwhelmed with too many choices and too much information. The overall objective of the policy should be to reduce the costs of purchasing and charging a PEV. Not only does the customer pay a premium for the PEV, they also must purchase an EVSE for their home and make well informed choices on when they charge their vehicle.

Although a straightforward, simple TOU rate option for the customer could result in lower electricity rates for PEV charging, the need for the installation of a second meter would increase the customer's costs unnecessarily. These added costs imposed on the customer should be avoided.

The technology capability for smart and managed charging exists today. PEVs are already equipped with controls for smart charging where the customer sets their charging preferences. Additional demonstrations and pilots will be critical to address utility concerns regarding grid impacts, customer costs, and integration into the distribution system.

As a complementary measure, New York State should encourage utilities to engage with customers to educate them on PEVs. Utility personnel are trusted as a source of information on PEVs, more so than automaker or dealerships, and utilities should use existing customer relationships to provide information on PEVs. For example, Florida Power and Light hosts over 100 targeted ride and drive events at businesses and has been widely successful.

Several automakers mentioned the open standards based platform developed by EPRI and Sumitomo Electric Industries called Open Vehicle Grid Integration Platform (Open VGI Platform) software system. The Open VGI Platform is designed to facilitate communication between utilities and PEVs, enabling utilities to take advantage of the smart charging capabilities built into the vehicle. This will enable the utility to send a signal to the vehicle to adjust charging loads up or down or even to start or stop charging.

5.5 EVSE Manufacturers

From the EVSE manufacturer perspective, the most important regulatory issue is how to enable the utility to invest in EV “make ready” infrastructure to promote EV adoption and enable market participation. A significant EV infrastructure gap exists, particularly in developing multi-unit dwellings and workplace charging. The key accelerator for building out EV infrastructure will be targeted support by investor-owned utilities in major urban areas and leveraging that support to expand private investment in smart charging equipment and services.

In an optimal pilot or infrastructure development proposal, the distribution utility will offer “make ready” infrastructure, including trenching and panel upgrades and installation, to utility customers that are willing to invest in “smart” EV charging stations that are enabled for managed charging to maximize customer return and minimize impacts on the grid.

Whole-house rates are appropriate for some contexts (single house residential) but they do not facilitate many of the benefits of separately metered EV load. Separately metering EV loads (whether for an individual customer or at a multi-unit location) provides numerous advantages, including participation in EV tariff programs and demand response, and subscription to managed charging, which optimizes the timing of individual or aggregated charging locations to avoid impacts on the grid and generate revenue for the customer.

EVSE-embedded metering offers numerous advantages over a second utility meter. An equipment integrated submeter is significantly less expensive than a stand-alone utility meter. Embedded submeters are integrated into the EVSE, and so are better designed to interface with the service provider's software, advanced cloud-to-cloud network communications systems, and customer smart phone applications. Standards are being developed for EVSE submeters and should be available over the next few years. The EVSE submeter in residential locations offers a valuable measure of the EV load in residential locations. The submeter may be more valuable to the utility in monitoring load and using it for demand response purposes rather than just as a billing mechanism.

Emerging technology that allows for Wi-Fi enabled EVSE connects PEV owners with the utility via a mobile or Web app. Wi-Fi capabilities could give owners and the utility the ability to control charging in real time and allow consumers to view past power consumption. In the future, this technology could be considered required equipment for a monthly credit PEV owners might receive for participating in off-peak charging programs.

5.6 Charging Station Hosts

One stakeholder interviewed is in the process of installing charging stations at their retail locations in New York. The PEV charging is provided for free and does not require activation from the customer. The business owner views the charging stations as a public benefit and part of their commitment to sustainability. Currently, the costs associated with providing free electricity is immaterial to business; however when the business evaluates the installation of higher capacity EVSEs, they will need to reevaluate pricing options.

6 Recommended PEV Charging Pricing Strategy

This section describes the recommended PEV charging pricing strategy for New York, based on the research and analysis described in Sections 2 – 5.

6.1 Success Criteria

The following criteria guided the development of the recommended PEV charging pricing strategies described here. The recommended strategies are intended to:

- Facilitate the adoption of PEVs in New York.
- Minimize the costs and distribution system impacts associated with PEV integration.
- Maximize the environmental benefits of PEV adoption.
- Maximize the grid benefits of intelligent PEV integration.
- Be actionable for New York utilities in the near term.
- Take into account emerging technologies and utility pilots that are underway to manage PEV charging through the EVSE and the PEV.
- Provide customers with easy to understand electricity pricing options that afford an opportunity to maximize fuel cost savings relative to gasoline.
- Provide customers with control over when their vehicle is charged.
- Ensure the reliability of PEV charging infrastructure.

6.2 Specific Recommendations

Based on the research and analysis conducted for this project it is recommended that New York utilities and the PSC pursue the following approach to electricity pricing for PEV charging:

- Continue to offer voluntary whole-house TOU rates to PEV owners, and do not prioritize development of PEV-only TOU rates.
- As an alternative to whole-house TOU rates also offer customers the option of a rebate program for off-peak charging. Such a program would provide a monthly rebate if, for a minimum number of days in the month, the customer's PEV was not drawing power for charging between the hours of 1 p.m. and 12 a.m.

In addition to the above major recommendations, the following supplementary recommendations are necessary actions to implement this pricing strategy:

- New York utilities should collect data on the daily/monthly household energy demand for customers with and without PEVs to evaluate the actual net benefits or dis-benefits of using existing voluntary whole-house TOU rates compared to standard rates.
 - If most customers, especially PEV owners, would not experience savings with existing TOU rates, utilities should develop revised rate structures tailored to PEV owners that would consistently provide net benefits if PEVs were charged off-peak. Such rates could likely be revenue neutral for the majority of customers but provide a small net savings to PEV owners who charged off-peak, in recognition of the resulting savings to the distribution utility, as projected in this report.
 - In developing revised TOU rates, utilities should consider simplifying the structures, compared to current rates, to make them more understandable to customers.
 - If current or revised TOU rates do consistently provide net benefits to PEV owners, utilities should develop marketing materials and an outreach program in conjunction with PEV and EVSE retailers, to educate PEV buyers as to the benefits of TOU rates and off-peak charging.
- New York utilities should conduct customer outreach and pilot program(s) to help determine the most optimal structure for an off-peak charging PEV rebate program. Issues to be explored in customer research and the pilot programs should include:
 - Minimum value of monthly rebate required to drive high levels of adoption (more than 50 percent).
 - Relationship between the number of “opt out” days allowed per month and adoption.
 - Relationship between the number of “opt out” days allowed per month and actual off-peak charging compliance.
- While for most customers a rebate program focused on off-peak charging will likely provide the greatest net benefits, a rebate program for utility controlled charging may be warranted in certain locations, particularly those with high potential for PEV clustering. Under such a program the customer would get a monthly rebate for allowing the utility to control PEV charging within set parameters, but would be allowed a maximum number of “overrides” of utility control per month. Implementation costs for full utility control of charging would be higher than for a rebate program to incentivize off-peak charging, but would potentially allow the utility to better manage negative effects of PEV clustering.

6.2.1 Regulatory Implications

The proposed PEV charging rate strategy could be implemented in New York under the current regulatory structure with no changes. Both a PEV off-peak charging rebate program and any changes to existing voluntary whole-house TOU rates to better optimize them for PEV owners would require PSC approval. However, the procedures required for requesting PSC approval are already in place and well understood by both utilities and the PSC. Requested changes to TOU rates could be incorporated into a future rate case filing. Approval of an off-peak PEV charging rebate program would be analogous to approval of other load control programs.

6.2.2 Grid Benefits

The modeling discussed in Section 3 indicates that if approximately 50 percent of all PEV owners delay the majority of their PEV charging to off-peak hours, because of either adoption of a whole-house TOU rate or signing up for an off-peak charging rebate program, then the daily statewide electric load in New York could be reduced by an average of 276 MW during summer peak hours (2 p.m. – 4 p.m.) in 2030 under the high penetration scenario. This level of off-peak charging adoption has been shown to be possible in other parts of the country.

The benefits to the grid of this level of load reduction include reduced generating costs, reduced monthly generating capacity costs, and reduced infrastructure costs resulting from PEV clustering. The estimated value of these benefits per PEV, based on the modeling described in Section 3, is summarized in Table 27. Although not the focus of this report, off-peak or controlled PEV charging will also result in improved generating asset utilization and facilitate the integration of variable renewable resources, such as wind and solar [17].

Table 27. Grid Benefits of Off-Peak PEV Charging per PEV, 2030 High Penetration Scenario

Source: MJB&A PEV Modeling Analysis

Element	Benefits per PEV		
	Annual	One-time	Life-time ¹
Reduction in generating costs	\$42	NA	\$336
Reduction in monthly generating capacity costs	\$19	NA	\$152
Reduction in infrastructure upgrade costs due to PEV clustering	NA	\$135	\$110
TOTAL	\$61	\$135	\$623
Assumes average vehicle life of 8 years			

These estimated benefits to the grid on an aggregate level in a high penetration scenario for New York State would by 2030 result in an on-going savings of \$46 million annually, plus an additional savings of \$103 million in avoided grid upgrade costs, as summarized in Table 28.

Table 28. Grid Benefits of Off-Peak PEV Charging, 2030 High Penetration Scenario

Source: MJB&A PEV Modeling Analysis

Element	Aggregate Benefits of PEV in New York State in 2030 (millions)	
	Annual	One-time
Reduction in generating costs	\$31,710	NA
Reduction in monthly generating capacity costs	\$14,345	NA
Reduction in infrastructure upgrade costs due to PEV clustering	NA	\$102,960
TOTAL	\$46,055	\$102,960

In addition to these financial benefits, based on the current NYISO marginal CO₂ and NO_x emissions curves, off-peak PEV charging would reduce CO₂ emissions from PEV charging by approximately one kilogram per PEV per year and would reduce day-time NO_x emissions by about 0.26 kilograms per PEV per year, compared to business as usual.

In a high penetration scenario, this practice would amass a statewide CO₂ reduction in 2030 of approximately 755 metric tons, equivalent to CO₂ emissions from nearly 70 homes' energy use over one year in New York State. In a high penetration scenario, this would amass a statewide NO_x reduction in 2030 of approximately 196 metric tons, equivalent to fleet average annual NO_x emissions from almost 300,000 gasoline vehicles.

6.2.3 Technology Implications and Costs

The recommended PEV charging pricing strategy involves incentivizing off-peak charging using both whole-house TOU rates and off-peak charging rebate programs (each PEV owner could choose which program to participate in). Each of these options for incentivizing off-peak PEV charging have different technology implications and costs, as discussed as follows.

6.2.4 Whole-House TOU Rate

All current PEVs on the market include the capability for the owner to program the start time of charging, independent of when the vehicle is plugged in. As such, virtually all PEV owners could easily delay their charging to off-peak hours when using a whole-house TOU rate, without needing to buy “smart” EVSE; the incremental technology costs for the customer to be able to adopt a whole-house TOU rate are therefore zero.

Adoption of a whole-house TOU rate usually requires the utility to replace the customer’s existing utility meter with a new utility meter of a different type. The utility’s cost of this meter change-out could be as high as \$2,000 per house. However, under existing PSC rules this cost is either absorbed into the general rate base or is recouped by the utility via higher monthly service charges for TOU rates compared to standard rates.

6.2.5 Off-Peak Charging Rebate Programs

To implement an off-peak charging rebate program, the utility must be able to determine, on a daily basis, when each customer’s PEV is and is not drawing power from the grid. This functionality does not require fully capable “smart” EVSE with two-way communication and control capability, or the ability to accurately measure real-time power flow. However, at a minimum it does require the ability to continuously monitor current in the charging circuit and one-way communication to collect and centrally record the monitored signal.

A utility could implement this capability in various ways with commercially available hardware. Currently, costs for such monitoring capability are estimated to be between \$500 and \$1,500 per house, but may be reduced to less than \$500 in the near future.

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