PSEG LONG ISLAND

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Electric Vehicles On Long Island

Costs And Benefits

The Opportunities And Potential Impact Of Widespread Vehicle Electrification On Long Island

Prepared For PSEG Long Island By Gabel Associates, Inc.
& Energy Initiatives Group, LLC.

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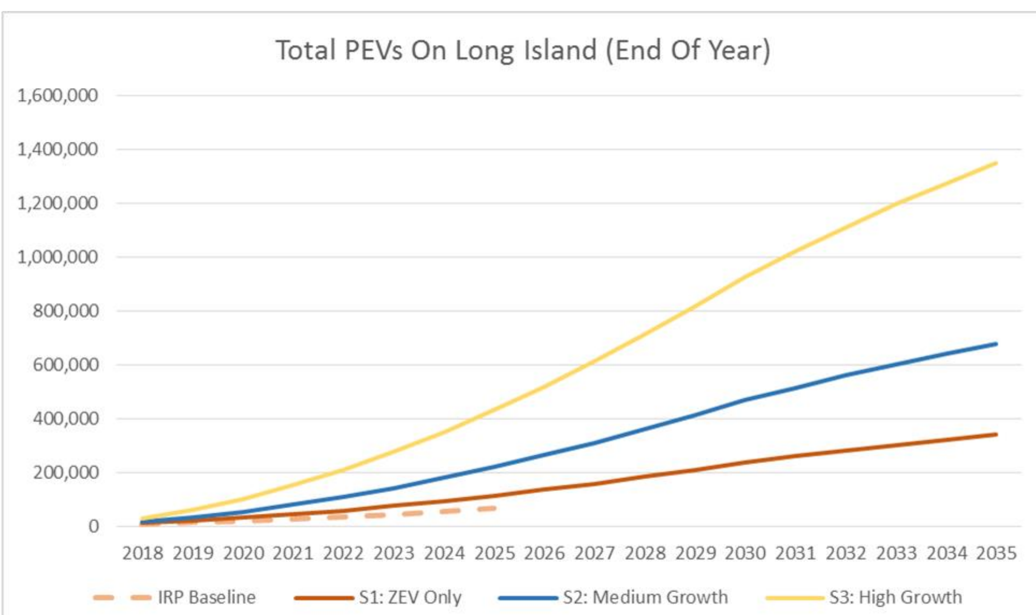
1 Executive Summary

Due to the rapid development and growing acceptance of Electric Vehicles (EVs), Long Island drivers can now fuel their cars with electricity rather than petroleum. This transition is not just a transportation innovation, but a profound shift in how energy is used with direct economic, environmental, and other strategic implications. New York State has been a leader in setting EV adoption goals, and Long Island has been at the forefront of EV adoption for the state. There is an opportunity for the electric utility, in concert with other market participants, to expand and accelerate EV adoption and help realize a broad portfolio of benefits for Long Island residents

The study provides a comprehensive assessment of current EV market conditions on Long Island, and quantifies the impacts, costs, and potential benefits of widespread EV adoption over time. The scope of the study includes analysis of the economic costs and benefits, environmental impacts, and implications for utilities and electricity infrastructure. This analysis is unique because it is based on detailed simulation modeling of both impacted energy markets and physical infrastructure loading, tuned specifically for conditions on Long Island. Primary focus is on the opportunities and challenges faced by the electric utility (and its rate payers) as EV usage increases, and identification of a synergistic role for utility efforts with existing market development activities.

The study identifies various levels of potential EV adoption in order to quantify benefits and other implications. Four scenarios have been defined, including a baseline consistent with existing PSEG-LI long range planning assumptions, and three adoption scenarios representing basic ZEV compliance (as defined in Section 4.1), medium growth, and high growth adoption trajectories from 2018 to 2050. Analysis focused on results through 2035, as summarized in the following chart.

Executive Summary – 1



Most EV impacts - for the utility, ratepayers, and society at large - arise from the affect vehicle charging has on energy markets and infrastructure. The energy impact of EV usage depends heavily on WHEN vehicle charging takes place. While there is some charging throughout the day, most EV drivers will "fuel" their vehicle the way they charge their mobile phone: mostly at home, mostly overnight. The study examined two different charging patterns: "natural charging" in which most charging happens in the early evening and "managed charging" in which charging is more evenly distributed over the off-peak hours at night. Loading impacts on the grid are minimized, and economic impacts are more beneficial, if managed charging becomes the dominant usage pattern. The study quantified the energy impacts of these scenarios as follows:

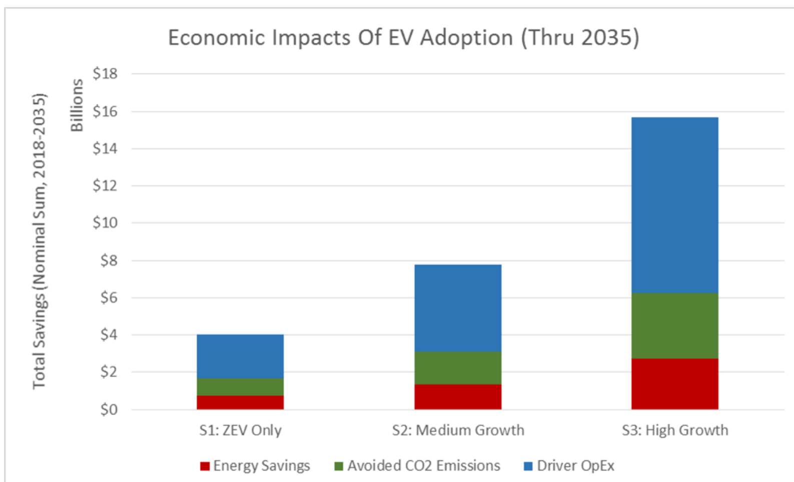
Executive Summary - 2

	2018	2019	2020	2021	2022	2023	2024	2025
Number Of PEVs (on the road, by Year End)								
Scenario One (ZEV Only)	15,669	23,414	33,579	46,358	61,148	77,801	96,237	116,377
Scenario Two (Medium Growth)	20,769	36,258	56,589	82,147	111,727	145,033	181,904	222,184
Scenario Three (High Growth)	30,967	61,947	102,607	153,723	212,884	279,496	353,238	433,798
EFFECTIVE Number Of PEVs								
Scenario One (ZEV Only)	13,120	19,542	28,497	39,969	53,753	69,475	87,019	106,307
Scenario Two (Medium Growth)	15,669	28,513	46,423	69,368	96,937	128,380	163,468	202,044
Scenario Three (High Growth)	20,769	46,457	82,277	128,165	183,303	246,190	316,367	393,518
Electricity Required For Charging (MWhrs/YR)								
Scenario One (ZEV Only)	35,925	54,276	80,532	114,741	156,457	204,673	259,161	323,972
Scenario Two (Medium Growth)	42,824	79,101	131,178	199,187	282,205	378,215	486,761	615,528
Scenario Three (High Growth)	56,620	128,750	232,469	368,080	533,702	725,298	941,960	1,198,640
Incremental Peak Associated With Charging (MW, coincident with NYISO peak)								
Natural Charging Schedule								
Scenario One (ZEV Only)	4.7	7.1	10.4	14.6	19.7	25.5	31.8	38.4
Scenario Two (Medium Growth)	5.6	10.3	16.9	25.4	35.6	47.2	59.8	73.0
Scenario Three (High Growth)	7.5	16.8	29.9	46.9	67.3	90.5	115.7	142.1
Managed Charging Schedule								
Scenario One (ZEV Only)	2.2	3.1	4.3	5.7	7.2	8.7	10.2	11.1
Scenario Two (Medium Growth)	2.6	4.5	7.0	9.9	13.0	16.1	19.2	21.1
Scenario Three (High Growth)	3.4	7.3	12.3	18.2	24.6	31.0	37.2	41.1

PSEG Long Island has taken initial steps to support the growth of the EV market within its territory, in parallel with actions by others, including formal goal setting and ZEV framework participation by the state, a vehicle purchase rebate, and infrastructure development incentives. Sales are already beginning to grow based on those incentives and the availability of second generation vehicles that offer longer range and lower prices. But as demonstrated by other jurisdictions with higher levels of adoption, there is an opportunity to further increase uptake over the sales rate emerging naturally. Achieving the medium growth adoption path (Scenario Two) identified in this study would result in approximately 34% of new sales being fueled through a plug, and conversion of about 22% of the fleet, by 2035.

EV adoption brings both economic and environmental benefits. Even after accounting for the estimated costs of market development programs and potential grid upgrades that may be required, there are NET economic benefits that accrue to utility customers through lower electricity costs. These lower electricity costs result from reduced average wholesale prices due to more optimal loading, and dilution of fixed costs through higher electricity usage. Additional economic benefits are realized by EV drivers through reduced operating costs. In 2018, each electrically fueled mile will average 7.68 cents/mile (for a pure battery electric vehicle), compared with an estimated 11.17 cents/mile for average gasoline vehicles[a]. "Fueling" with electricity rather than gasoline cuts that expense by about a third on average, resulting in a substantial increase in disposable income for Long Island families once the incremental vehicle cost (if any) is covered. EV adoption also improves air quality, especially through CO_2 and NO_x reductions. On Long Island, where the generation fleet is relatively clean (and becoming cleaner over time), every electrically fueled mile is 82% lower in CO_2 emissions than a gasoline fueled mile in 2018. The following chart summarizes the economic benefit (without consideration of costs) of these impacts.

Executive Summary – 3



These benefits are based on detailed simulation modeling of the generation assets needed to support the incremental EV charging load (compared with a no-EV baseline), and the associated impacts on cost of electricity, the value of reduced emissions, and reductions in vehicle operating expense compared with a traditional vehicle, over the period 2018 through 2035 (as a nominal sum). These benefits accrue to different populations: energy savings are realized by utility rate payers through reduced costs, savings on vehicle operating expense are realized by EV owners, and the environmental benefit of reduced emissions is delivered to society at large. The energy savings are described in detail in Section 5.3.1, savings for EV drivers are outlined in Section 5.3.2, and the environmental benefits are quantified in Section 5.3.3.

Along with these benefits there are potential costs that have been estimated as part of this study. Physical impacts on the grid are relatively modest in the short term, and well within existing operating

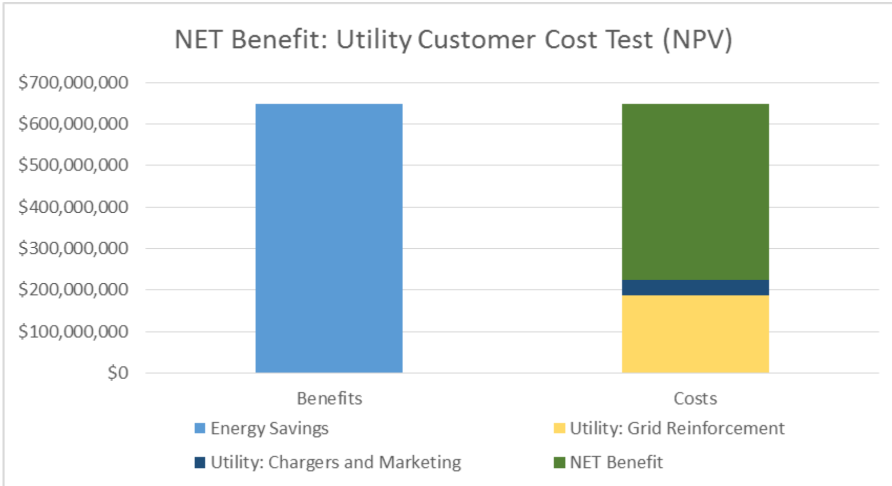
[a] Key assumptions for 2018: average gasoline vehicle 22.1 MPG, cost of gasoline $2.468/gallon; an average BEV gets 3.5 miles per KWH, average residential electricity rate 20.411 cents/KWH, including EVs paying the equivalent of the NY State gas tax for transportation infrastructure funding.

profiles. However, extreme loading conditions will become evident at relatively low levels of adoption (when EVs represent ~6% of the light duty vehicle population), and will emerge quickly past that point. There will likely be the need for significant reinforcement, especially of single-phase distribution transformers, by the time the market achieves ~30% adoption. Managed charging, which encourages residential charging to happen at more optimal times, can help amplify economic benefit, and both defer and reduce impacts on generation, transmission, and distribution assets.

In addition to these basic grid reinforcement costs, there is an opportunity for utility investment in growing the EV market and meeting the associated needs for vehicle charging infrastructure and managed charging programs that reduce the impact of vehicle charging on the grid and maximize benefits. Given actions already being taken by others (especially the state, NYSERDA, and the competitive market), a primary opportunity for utility involvement on Long Island is through low power (level two) charging infrastructure for routine "fueling" of EVs with electricity. This focus aligns with natural utility strengths and responsibilities, and reinforces the need to ensure appropriate integration of charging infrastructure with the grid. The primary focus area is on managed residential charging, which helps grow EV adoption by addressing consumer needs for a home charging solution, but also a) minimizes the loading impact on the grid short term, and b) creates an opportunity to use vehicle charging as a dispatchable load that enables loading optimization. Medium term, there may be opportunities for other market development programs where the utility can play a unique supporting role, especially regarding public charging infrastructure and key segments with unmet needs.

A preliminary five year plan has been identified for initial utility program focus, which leverages utility strengths and complements the efforts of other market participants. That initial $25M program focuses on managed residential charging, a continuation of the workplace charging program, and a strong consumer awareness building campaign. The study concludes that the costs required for basic grid reinforcement and the proposed charging infrastructure and marketing investment are more than offset by the economic benefits that EVs deliver. The following chart summarizes the NET benefit for the medium growth (Scenario Two) adoption profile, considering just the costs incurred by the utility and the benefits that would accrue to utility customers through reduced electricity costs:

Executive Summary – 4



2 Introduction

Personal mobility is an essential characteristic of life on Long Island. Light duty vehicles, fueled mostly by gasoline, provide the foundation upon which Long Island's economy and quality of life depend. But along with the enormous benefit realized by fossil fueled transportation, there have been significant costs and consequences.

Due to the rapid development of Electric Vehicles (EVs), Long Island drivers can now fuel their cars with electricity rather than petroleum. This transition is not just a transportation innovation, but a profound shift in how energy is used with direct economic, environmental, and other strategic implications. New York State has been a leader in setting EV adoption goals, and Long Island[b] has been at the forefront of EV adoption compared with the rest of the state. Despite that strong start, however, New York State has not achieved the level of per capita EV use demonstrated in other leading states, which suggests that there is an untapped opportunity for even greater levels of EV adoption if market development initiatives were implemented. Those investments would bring a broad portfolio of benefits to New York residents, including Long Island. Recent actions by the state, especially the new vehicle purchase rebate program, have demonstrated early success increasing EV adoption – the first year of the rebate program grew adoption 67% over the prior year[1]. The EV market in New York is accelerating, and there is an opportunity for the electric utility, along with other market actors, to serve and encourage increased EV use.

This study was commissioned by PSEG Long Island, who operates the public electric infrastructure under contract to Long Island Power Authority (LIPA). The study explores the opportunity for EV adoption in Long Island and quantifies the wide range of costs and benefits that would result. Opportunities and challenges related to increased EV use for the utility are also identified. A key focus is on the interplay between EV adoption and impacts on electricity costs, utility infrastructure, and the Long Island residents.

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[b] Throughout this document, all statistics that refer to "Long Island" or the LIPA Territory are based on the sum of Nassau and Suffolk counties.

The study was conducted by Gabel Associates, a consulting firm with well-established expertise in energy, environmental, utility, and policy research, in partnership with Energy Initiatives Group, an engineering firm with specialized expertise in electric utility infrastructure. Given the strong linkages between EV use and electricity markets and infrastructure, the impact of EVs can best be quantified through their energy and environmental implications.

A note on terminology: The focus of this study is on light duty vehicles powered by electricity. This vehicle class includes pure Battery Electric Vehicles (BEVs) that do not have a petroleum fueled engine of any kind, and Plug-In-hybrid vehicles (PHEVs) that make use of both an electric motor and a fueled engine for motive power. Both vehicle types provide for charging of an on-board battery or similar storage device from primary energy sources external to the vehicle, and are collectively called Plug-In Electric Vehicles – i.e. all vehicles with a plug. **Throughout this document, the term Plug-In Electric Vehicles (PEVs) and Electric Vehicles (EVs) are used synonymously and interchangeably.** This vehicle group purposefully does not include traditional hybrid vehicles (without a plug for charging), or other alternative fuel vehicles such as compressed natural gas (CNG), hydrogen, or liquefied petroleum gas (LPG).

3 The Opportunity For Electric Vehicles On Long Island

The use of EVs is exploding globally[c], and Long Island is a prime market for high levels of EV adoption. At the current time, however, Long Island demonstrates untapped potential for increased EV use based on per capita penetration benchmarks (details in section 3.3). This section explores the current state of the Long Island EV market[d] and quantifies the potential for expanded and accelerated adoption of EVs.

3.1 Why Now: New Market Developments

Many of the first automobiles were electric, and by 1900, a third of all vehicles on U.S. roads were driven by electric motors[2]. However, innovations that made gasoline powered vehicles easier to use and more powerful, inter-city roadway development that motivated longer range travel, and the availability of low cost gasoline eventually combined to limit the growth of early EV technology. As a result, fossil fueled transportation became the foundation of the explosion of mobility that dominated the 20th century.

That trend has shifted significantly over the last decade, and new technology and supportive policies have made vehicle electrification a primary driver of transportation innovation. The window of opportunity for mainstream EV adoption growth is now opening based on the availability of practical vehicles with longer range and lower prices. As summarized below, several factors suggest that EVs are

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[c] Especially in China, India, and Europe, and leading states in the US like California.

[d] Throughout this study, "Market" is used as an umbrella term to capture the ecosystem of actors that own, drive, supply, and support EV use, including stakeholders committed to advancing programs and policies to increase EV adoption and use, and policy makers that can affect development of this ecosystem. Primary focus is on a) vehicle owners and drivers, b) vehicle manufacturers and retailers, and c) a variety of entities, including utilities, that provide vehicle charging infrastructure.

now ready for mainstream adoption, and that they will sustain that growth on a long term basis to achieve a high level of fossil-fueled vehicle displacement.

- **New Vehicles with Mainstream Appeal:** Beginning in the fourth quarter of 2016, EVs are now available that combine practical design, longer range, and price points within reach of many mainstream buyers. This second generation of vehicles builds on over six years of early market innovation (with the Tesla Model S, the Nissan Leaf, and the Chevy Volt) since 2010, but represent a significant departure in design, range, and price configuration compared with first generation EVs. These vehicles offer over 200 miles of range[e], at a price between $30K-$35K before incentives. That range serves the typical driving needs of most consumers, at a price that is competitive with mainstream vehicle pricing (~ $33K average in the U.S., 2016).

  Most major automotive manufacturers now offer an EV of some type (approximately 30 vehicles as of the end of 2016), including both pure battery electric vehicles and plug-in hybrids[3]. EV designs are beginning to expand into other popular vehicle types, such as mini vans (e.g. the Chrysler Pacifica), cross-over vehicles and SUVs. These vehicles include highly desired design and safety features and are enjoyable to drive. In many cases, consumers don't buy these products because they are electric cars – they are prompted by the attractive vehicle offerings that just happen to have electric drive trains. This represents a profound shift in vehicle capability and enables more widespread acceptance by mainstream customers.

- **EV Cost Reductions and Price Parity:** One of the biggest barriers to mainstream adoption of EVs has been price. EV pricing has been driven by a combination of relatively small industrial scale, limited competition, and most importantly, the high cost of batteries. Battery costs have dropped sharply over the last few years, and reductions are expected to continue past the point where EVs will be competitive with traditional internal combustion vehicles across all vehicle types. There is emerging consensus from both auto makers and industry analysts that EVs will achieve price parity by 2025, possibly sooner for some vehicles[4].

- **Automotive Industry Commitments:** Given the combination of consumer interest, policy drivers, improving cost position, and competitive factors, electrification has become a "must do" element of the strategic plan for most automakers. Most global OEMs have announced significant commitments to overall vehicle electrification, and they have committed to specific EV offerings that will hit the market over the next several years. Some manufacturers, such as Volvo, have formally announced their intention to be 100% electrified by 2019, and the emerging consensus is that approximately 30% of new vehicle sales globally will be plug-ins by 2025 - 2030[5]. There are approximately 30 PEVs available in the U.S. market today, and based on announcements already made, that number is expected to approximately double over the next few years.[6]

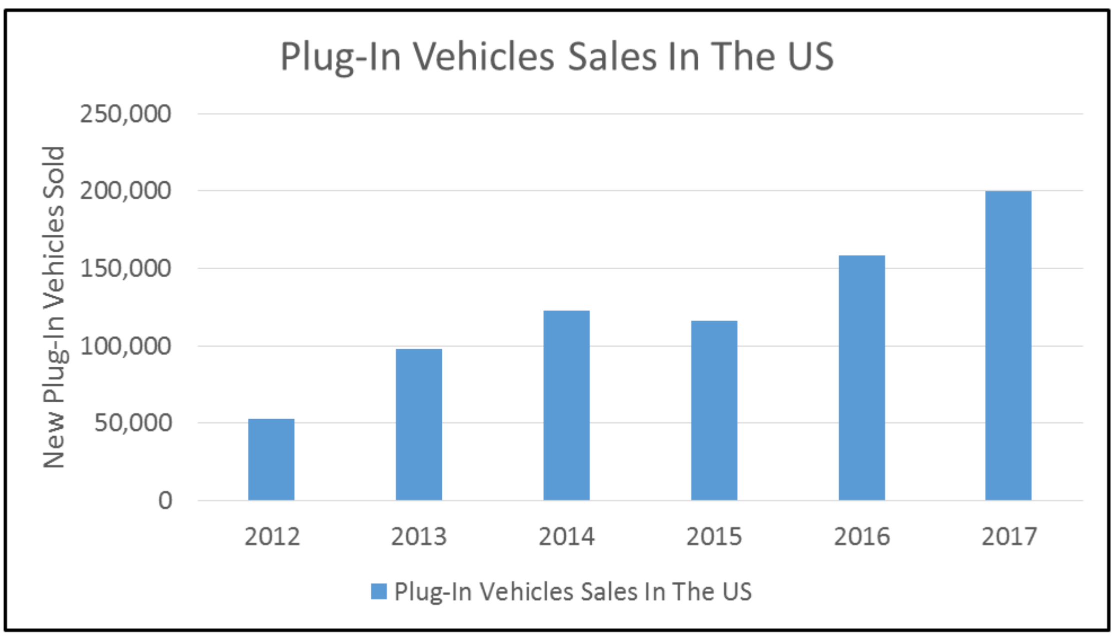
- **Global Policy Drivers:** New vehicle innovations and industry focus have been reinforced by extraordinary policy commitments intended to ensure widespread EV adoption, especially in

[e] The 2018 Nissan Leaf offers 150 miles of range, available in the U.S. beginning in the first quarter of 2018, with an upgraded version capable of an estimated 225 miles of range available in the third quarter of 2018.

Asia and Europe. A tipping point has been reached in 2017, with several countries now committing to mandates that will eliminate the sale of new petroleum fueled vehicles by 2025 – 2040, including Norway[7], the Netherlands[8], France[9], India[10], and the UK[11]. China[12] (the largest vehicle market in the world) recently implemented a Zero Emissions Vehicle (ZEV) program, and has indicated that they are considering a full Fossil-fueled-vehicle moratorium in the same timeframe. These global developments will drive PEV availability in the United States as well. In response to these global policy drivers, more bullish industry analysts project that PEVs could represent as much as 60% of new vehicle sales in the 2040-2050 timeframe[13]. OPEC – which is typically optimistic about long term petroleum demand - recently released revised projections that show a dramatic recalibration of global EV impacts on petroleum demand: reductions of as much as 82% by 2040[14].

- **US Market Results:** The dynamics outlined above – including the availability of second generation vehicles with longer range and lower price, increased industry focus, and strong policy drivers that affect all global automakers – have combined to encourage strong plug-in sales in the U.S. over the last few years. Sales increased sharply in 2017, approximately 26% over the already strong sales in 2016. In 2017, for the first time, PEVs represent more than 1% of new light duty vehicle sales in the U.S., and are likely to exceed 10% of new vehicle sales by approximately 2025 if these sales growth rates continue.[15] See Figure 3.1 – 1 for a summary of historical sales in the US.

Figure: 3.1 – 1: Historical PEV Sales In The US



Source: InsideEVs.com

In summary: the availability of advanced new vehicles with longer range and lower prices, increasing industry focus and growing commitment to the plug-in market, rapidly falling battery costs, expanding industry scale, and global competition create the conditions necessary for widespread plug-in vehicle adoption by mainstream consumers. The positive impact of these drivers is demonstrated by strong U.S. sales, and confirmed with emerging consensus from both automaker and industry analysis that forecasts price parity and dominant plug-in sales in the 2025-2030 timeframe. As summarized in the points noted above, there is good reason to believe these robust sales results will be sustained long term, given strong consumer satisfaction with EVs and global policy commitments that reinforce industry and consumer developments. After several false starts, conditions are now in place for strong, sustained growth of EVs in the U.S. – including on Long Island.

3.2 Long Island Market Conditions

New York State has been a leader in Electric Vehicle adoption since the earliest days of the market, and Long Island benefits from those statewide initiatives[f]. This section summarizes the state context for EV market growth on Long Island, and characterizes opportunities for expanded and accelerated growth of EV use within the LIPA territory as a subset of EV growth within New York State overall.

3.2.1 The New York EV Market, And Implications For Long Island

New York State has implemented a variety of initiatives that provide context for the EV market opportunity on Long Island.

- **Section 177 Waiver (ZEV Compliance Program):** As allowed under the federal Clean Air Act, New York State opted-in to the California Zero Emission Vehicle compliance program. New York is one of nine states that have opted into that framework, and is therefore referred to as a "Section 177" state in reference to the enabling Clean Air Act provision. This framework requires that large volume automobile manufacturers ensure that a certain percentage of new vehicle sales are based on zero emission vehicles (ZEVs, such as fuel cell or pure battery electric cars), or transition zero emission vehicles (TZEVs such as plug-in hybrids) each year. The percentage of ZEVs and TZEVs increases each year, and is managed through a "credit" system. New York's participation in the ZEV program helps in setting state adoption goals, but also has a real and significant practical implication for the PEV market: automobile manufacturers prioritize allocation of PEVs to ZEV states like New York, thereby making stronger PEV adoption feasible. The ZEV program in New York is covered in more detail in Section 4.1 below.

[f] In the US, the EV market was pioneered by California which is (at a high level) at least 10 years ahead of all other states in terms of focused policy support for market development. There has emerged a "second tier" of fast-follower states that within the last few years have become more focused on specific EV market development goals, policies, and programs, most of which have opted into the California ZEV program. Many of these ZEV states, including New York, have taken initial steps for market development, but are still in early stages of seeing strong EV adoption growth.

- **ZEV State MOU:** In 2013, the governors of eight ZEV (Section 177) states – including New York – joined together to execute a Memorandum Of Understanding regarding zero emission market development In addition to New York, participating states include California, Connecticut, Maryland, Massachusetts, Oregon, Rhode Island, and Vermont. The MOU establishes a variety of goals and priorities for joint market development, including putting 3.3 million ZEVs on the road by 2025. Following the initial MOU, the signatories developed a multi-state ZEV action plan to guide market development. A cross-member task force is in place to further implementation of the MOU and the supporting action plan[16].

- **Formal State Goals:** Consistent with New York State's Section 177 and MOU commitments, the state has established formal goals for EV adoption and charging infrastructure development. Governor Cuomo has set a statewide goal for 30,000 – 40,000 PEVs in New York State by 2018, and at 800,000 to 1 million PEVs by 2025 . These vehicle electrification goals operate within a context of aggressive greenhouse gas reduction objectives that reinforce EV market development: 40% reduction by 2030, 80% reduction by 2050. A wide variety of specific initiatives have been implemented in support of these overall goals, making New York one of the most active ZEV states. If the overall New York State goals are translated to Long Island, the goals for 2025 within the LIPA territory become 120,000 ZEVs if scaled by population, or 176,000 ZEVs if scaled by vehicle ownership. PEVs, as addressed within this study, are expected to be the dominant vehicle used to achieve these objectives.

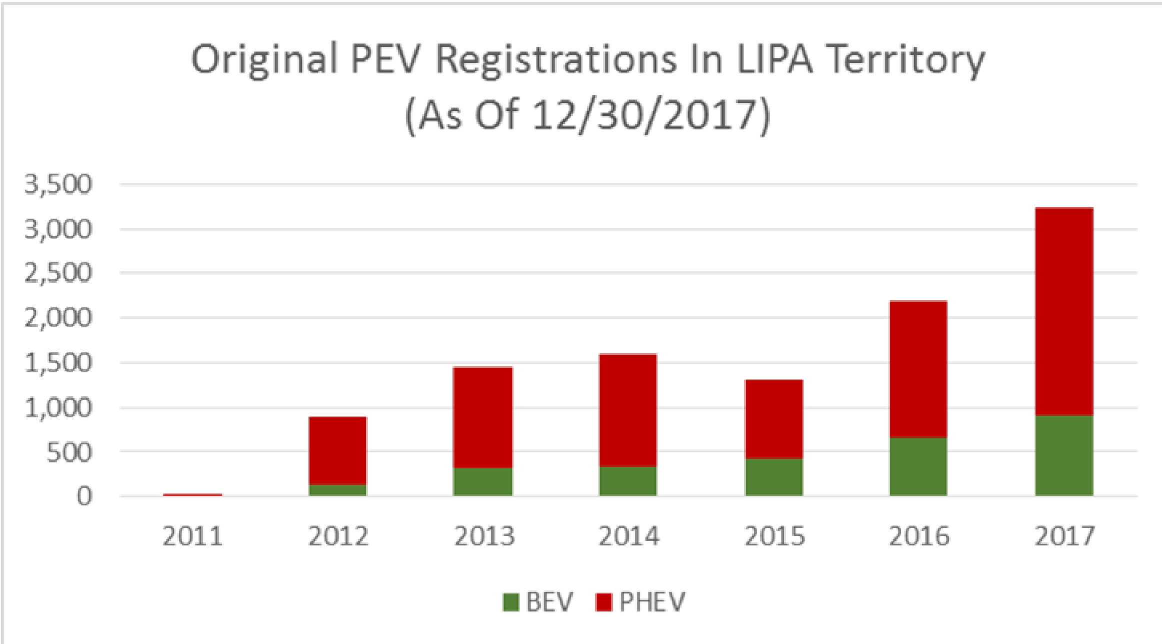
- **NYSERDA:** New York State has a unique advantage for energy market development and innovation – the New York State Energy Research and Development Authority (NYSERDA). In support of the formal state goals outlined above, NYSERDA has implemented, and continues to implement, a variety of programs related to the EV market, including data collection and reporting, a variety of incentives for vehicle purchase and charging infrastructure development, and the overall "Charge NY" initiative[17].

3.2.2 Historical Sales Results

Based on vehicle registration data collected and analyzed by NYSERDA, the graph in Figure 3.2.2 - 1 summarizes original PEV registrations[g] in the LIPA territory since 2011. This data captures only road-certified plug-in vehicles.

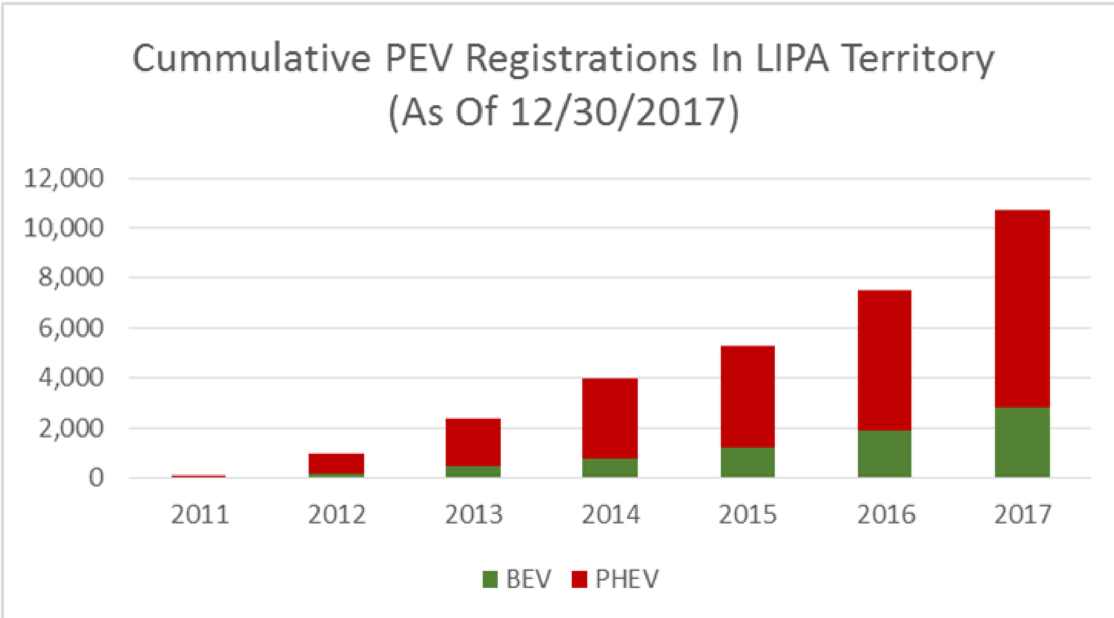
Figure 3.2.2 – 1: Original PEV Registrations In LIPA Territory

[g] "Original Registration" reflects the first time a new vehicle is registered. This metric tracks the sale of new PEVs.



The following chart summarizes the cumulative sales over time. Note that this statistic is not the same as "vehicle on the road", since it does not reflect vehicle retirements. When taking rolling retirements into account, approximately 70% of cumulative sales are "on the road" at any point in time. As of the end of 2017, NYSERDA reports that 6,568 PEVs are "on the road" in the LIPA territory, of which 1,764 are BEVs, and 4,804 are PHEVs. This represents a small (<1%) fraction of the approximately 2.1M light duty vehicles on the road on Long Island.

Figure 3.2.2 – 2: Cumulative PEV Registrations In LIPA Territory



After several years of modest growth (from 2013-2015), sales increased sharply in 2016 and showed continued strength in 2017: 2016 sales increased 68% over 2015, and 2017 sales were 48% over 2016, almost twice the national sales growth rate in 2017 of 26%[18]. Vehicle owners in the LIPA territory buy about 22% of the light duty vehicles sold in New York State, but buy 30-35% of the PEVs in the state. Long Island vehicle owners are adopting PEVs at a higher rate than New York State residents overall, indicating an especially strong PEV growth opportunity for Long Island.

Based on the federal U.S. Department of Energy (USDOE) national database, as of November 2017, the state of public charging infrastructure on Long Island is mixed[19]. Public charging is especially important since it is a key factor for many consumers to overcome range anxiety issues – i.e. the concern that they may become stranded on the road due to lack of public facilities for charging the vehicle conveniently (similar to the role gas stations play for conventional vehicles, although the usage patterns are very different). To understand the current state of the charging infrastructure on Long Island, it is helpful to compare the territory to other jurisdictions where strong PEV adoption has been demonstrated. There are two metrics that help characterize relative position, but which address different aspects of market need:

- **Public Charger Plugs per Capita:** This factor speaks to the general availability of public charging (regardless of actual use), and it affects the perceptions of *potential* PEV drivers regarding availability of public charging stations. In general, regions with higher public charging plug density per capita also have higher overall EV adoption rates, since stronger public charger visibility helps assuage the range anxiety concerns of potential PEV owners.

- **Public Charger Plugs per PEV:** As PEV population increases, the number of public chargers needed increases. The public charger plug count per 1000 therefore provides a benchmark that indicates the extent to which the *existing* based of PEV drivers are being well served (i.e. wait times at charging stations, etc).

The following two charts summarize the number of public charging plugs per 1M people, and per 1000 PEVs. In both cases, Long Island lags other leading states in infrastructure density, especially regarding infrastructure density compared with PEV population level.

Figure 3.2.2 – 3: Public Charger Plugs Per 1M People (In LIPA Territory)

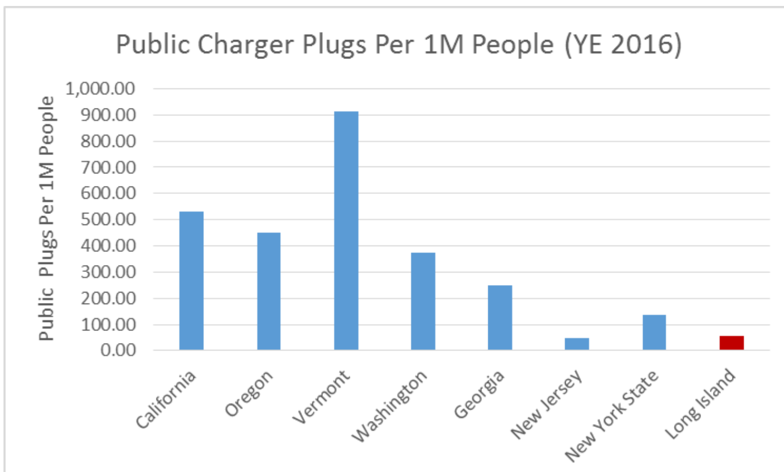
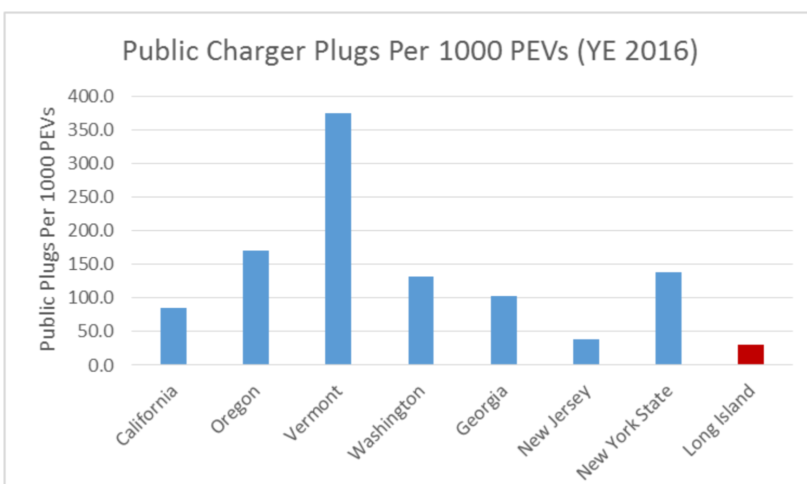


Figure 3.2.2 – 3: Public Charger Plugs Per 1000 PEVs (In LIPA Territory)



As detailed more completely in Section 3.3, these figures may over-state the current status of public charger infrastructure on Long Island, since not all stations/plugs are available at all times, nor do all stations support the full range of technical standards that current PEVs require. Given these conditions, it is highly likely that an EV driver in Long Island would be unable to use one of these stations for either commercial or technical reasons. Enhanced availability of vehicle charging infrastructure of all types is a particular unmet need in the LIPA territory.

3.3 Opportunities for Growth

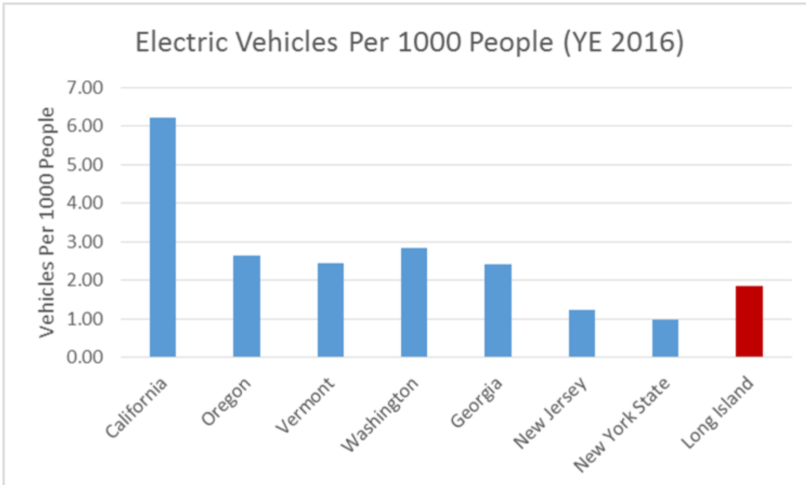
While New York State has taken initial steps to develop the EV market statewide (including Long Island), and recent sales have become more robust, there are indicators that there is opportunity for increased PEV adoption in the state. As summarized in Section 3.2.1, key programs are already in place, and Long Island consumers have demonstrated strong interest in EV adoption.

Despite this strong start, however, benchmarks suggest that there is untapped opportunity for higher levels of EV adoption in the State. Compared with other leading EV-adoption states, New York State lags slightly in vehicle penetration on a per capita basis[h]. This metric suggests that higher vehicle sales rates are possible. The state is currently running about 62% of the adoption rate demonstrated by leading states such as Oregon, Vermont, Washington State, and Georgia (but not including California)[i]. A variety of factors are likely to account for this EV-uptake difference. Based on a qualitative comparison between regions, the factors that appear to affect PEV uptake most strongly are a) vehicle purchase incentives, b) strong charging infrastructure development, especially for home, work, and public charging, and c) consumer awareness programs. As summarized in Figure 3.3 - 1 below, New York State has lower per capital EV penetration than market leaders, but Long Island is achieving almost twice the adoption rate as the rest of New York State.

[h] These statistics compare metrics for the territory of Long Island to other states. These are market characterizations that are valid whether the basis is a territory or a state, especially since they are provided on a per-capita basis.

[i] Unlike some of the other states shown, Georgia is not a ZEV state. It became a national leader in EV sales, however, after implementing a strong vehicle purchase rebate program combined with public charging infrastructure development. Conversely, after the rebate program was suspended, PEV sales dropped by nearly 90%, which demonstrates the strong impact these programs have on early stage adoption.

Figure 3.3 - 1: PEVs Per 1000 People



A strong growth foundation is in place for EV adoption in New York State, and on Long Island. But with additional market development support – especially regarding charging infrastructure development and better consumer awareness – an increase in EV adoption rate is likely possible. Many of these market developments operate at the state level, as led by statewide entities (especially NYSERDA), and will impact Long Island as well. Given the essential role of charging infrastructure, however, there is a particularly strong opportunity for utility support, combined with the action of others, that will contribute to stronger overall market growth.

4 Impact Model: Scope and Methodology

The primary objective of this study is to rigorously quantify the impacts of PEV adoption under a variety of scenarios, including consideration of economic, environmental, and other strategic implications, as well as to provide an estimate of impacts on electricity markets and utility infrastructure. This assessment is based on developing a set of reference adoption scenarios informed by a variety of demographic, travel, and vehicle statistics, and modeling the impacts of those PEV adoption levels on the electric energy system. Since many of the impacts of PEV adoption are realized through the associated impacts on electricity markets and infrastructure, the focus of modeling is on energy and related implications. This section describes the model used to develop the key findings summarized in Section 5, and critical assumptions and scope boundaries. These models have been tuned to specifically reflect vehicle, travel, energy market, and utility conditions on Long Island.

4.1 ZEV Framework

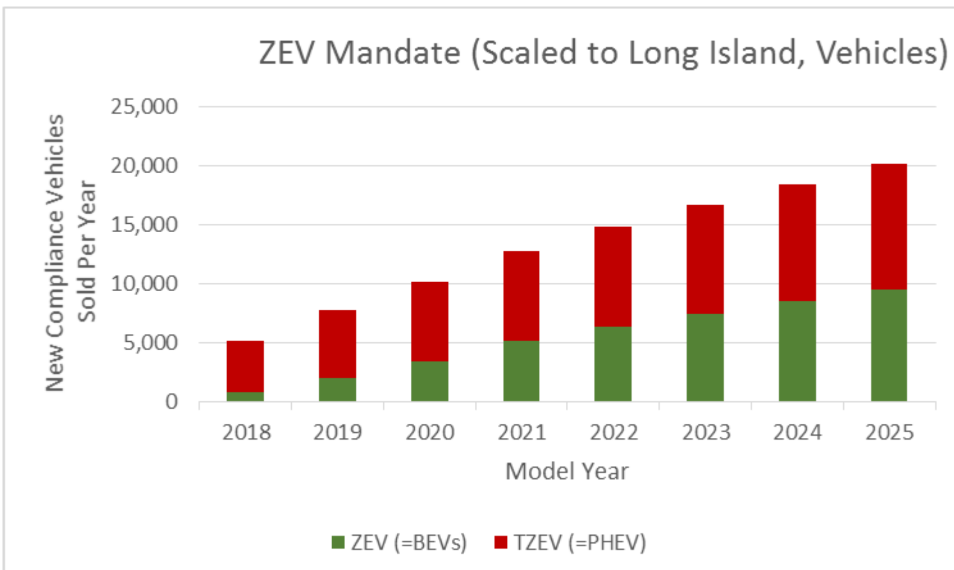
As noted in Section 3.2.1, New York has opted-in to the California Section 177 Waiver, creating a “ZEV Mandate” for the state. This mandate is defined through 2025, and requires that a specified fraction of new light duty vehicle sales each year must be zero emission vehicles as defined under the California ZEV program. The percentage of ZEVs required increases each year, and is allocated against large volume automobile OEMs. Compliance is managed through a “credit system”, with different types of vehicles “earning” credits at different rates. The ZEV framework is therefore focused on ZEV credits, not actual vehicle sales directly.

Note: The USDOE and U.S. Environmental Protection Agency (EPA), and therefore the ZEV framework, use the terms “Zero Emission Vehicle” (ZEV), and “Transition Zero Emission Vehicle” (TZEV). For purposes of this study, ZEVs are assumed to be equivalent to Battery Electric Vehicles only (BEVs, cars with an electric motor only, and no on-board fueled engine) and TZEVs are assumed to be equivalent to Plug-In Hybrid Electric Vehicles (PHEVs, which use both an electric motor powered by stored electricity from an external source along with an on-board fueled engine). This is a simplification, however, since under the EPA program other vehicle types (like fuel cell vehicles) would qualify at ZEVs. This study makes the clarifying assumption that all ZEVs required by the framework are fulfilled by BEVs, and TZEVs are fulfilled by PHEVs, since the focus of this analysis is electric vehicles charged from the grid.

To understand market impacts, however, the adoption of actual physical vehicles must be quantified. As part of the study, an estimate of the ZEV requirements – if converted to vehicles – was developed. A variety of assumptions are required to make this conversion, particularly regarding the ZEV vs TZEV mix. Only EVs were assumed (no other ZEV vehicle types, such as hydrogen), and the minimum levels of ZEV sales (as established in the framework) were assumed to set the vehicle type mix. Vehicle requirements were projected past 2025 using the clear percentage-growth trend evident in the requirement through 2025 on a percentage basis. This vehicle requirement profile is not a hard compliance baseline. It is one sales outcome that, if achieved, would fully satisfy the ZEV requirements for the state for each year, and which is considered reasonable given current market conditions.

This ZEV baseline is a key foundation for the study, and although it should not be accepted as a projection of actual sales, it is used as a well-vetted trajectory for minimum ZEV adoption levels in the state. These adoption profiles were developed through an extensive public policy process in California over a multi-year period, which included exhaustive public and industry input, review by federal authorities, and detailed studies related to feasibility. Therefore, the study team considers the ZEV requirement as the "best available" estimate for potential ZEV sales in the short term, under conditions that are considered aggressive but achievable. The following graph summarizes the ZEV requirement on a vehicle basis.

Figure 4.1 - 1: ZEV Mandate (scaled to Long Island, in vehicles)



These projected ZEV requirements are similar to, but slightly lower than the Long Island fraction of the statewide goals for 2025 when extrapolated based on population, but significantly lower when extrapolated based on vehicle ownership (~116K vehicles required by the ZEV framework, but ~176K vehicles required by state goals).

4.2 The PEV Adoption Scenarios

The study translates various levels of PEV adoption into energy impacts, and therefore is inherently driven by assumptions about PEVs sold each year and associated Long Island light duty fleet composition. Four scenarios have been defined, including a baseline consistent with existing PSEG-LI long range planning assumptions, and three adoption scenarios representing basic ZEV compliance (as defined in Section 4.1), medium growth, and high growth adoption trajectories from 2018 to 2035[j].

[j] The model simulation was run through 2050 to allow comparison with long term state goals. The majority of the analysis, however, and all the results presented in this study are through 2035.

These profiles are the foundation of the model, and all results tie back directly to these vehicle adoption scenarios.

It is important to note that these four cases are not projections of what will happen in the market. Instead, they are a set of reference trajectories for which impacts can be computed, the results of which can be used to assess impacts at varying levels of adoption. Extrapolation of recent sales suggest that the Long Island EV market is currently tracking slightly below the Scenario One trajectory, but the market may naturally increase adoption rates slightly due to the introduction of new longer range, lower priced vehicles in 2018. Early evidence is that the New York State vehicle purchase incentive has already increased adoption over prior levels, contributing to the "upshift" expected.

The baseline, plus three adoption scenarios, were developed as follows:

- **Baseline**: PSEG Long Island previously developed an EV adoption planning assumption based on sales rates available at that time, and included those assumptions in its long range plan (the Integrated Resource Plan, or "IRP"). Since those adoption levels are already integrated into the existing plan, these adoption levels were used as the baseline against which higher levels of PEV adoption can be compared. The IRP Baseline projects 11,324 PEVs in the Long Island territory by the end of 2018, growing to 70,612 (base case) by the end of 2025 (note: there had been 10,726 cumulative "original registrations" on Long Island by the end of 2017, of which approximately 6,568 were estimated to be "on the road" by the end of the year[k]).

- **Scenario One – ZEV Only:** The ZEV mandate, when translated to vehicles and extrapolated, as summarized in Section 4.1 above. This adoption scenario is consistent with basic compliance requirements already in place, and is approximately consistent with overall statewide goals (when scaled based on population).

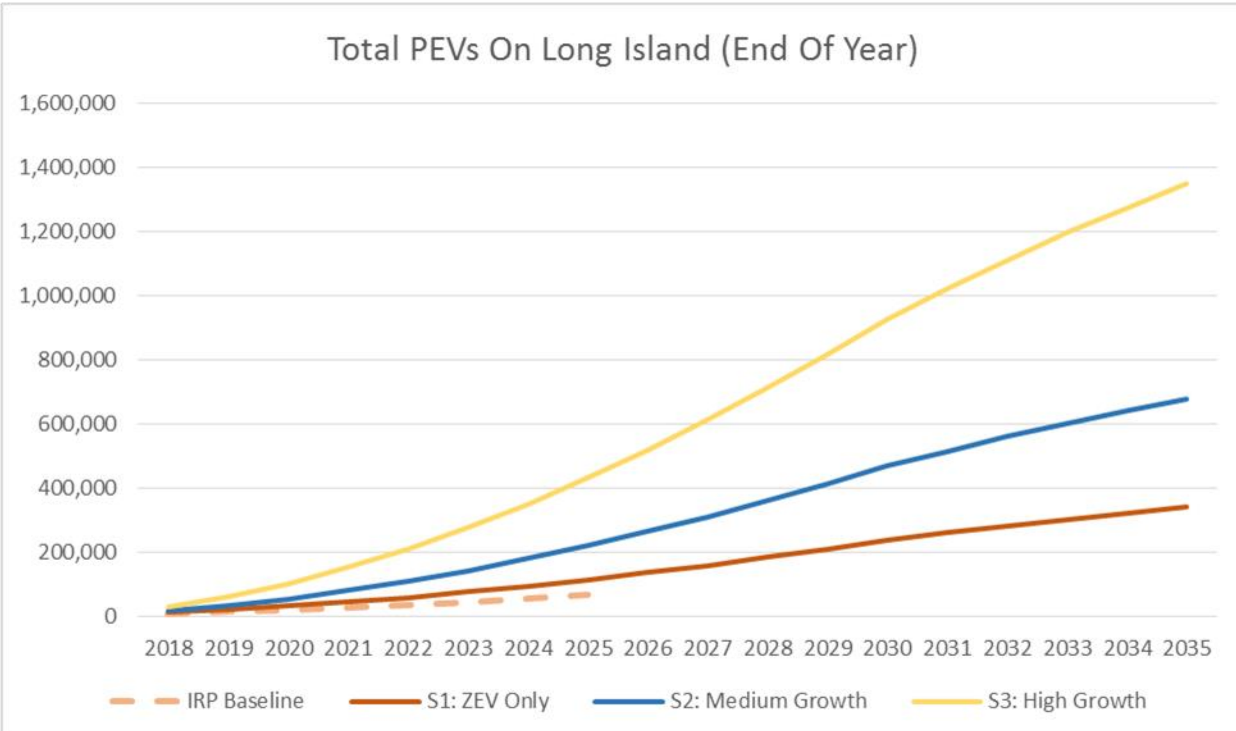
- **Scenario Two – Medium Growth:** A mid-range level of adoption that is consistent with what leading PEV adoption states have accomplished, and approximately twice the adoption rate of Scenario One. This scenario represents a significant increase over existing PEV sales in the state, but this trajectory is considered achievable given what other leading states have realized. This scenario is considered the "nominal case" for the study, with the other two scenarios considered "lower" and "higher" growth rate sensitivities.

- **Scenario Three – High Growth:** The high adoption trajectory is consistent with the level of light duty vehicle electrification necessary to achieve the 80% CO_2 reduction goals established by the Governor, which is approximately twice the adoption rate of Scenario Two. This trajectory represents nearly complete displacement of traditional gasoline vehicles by PEVs consistent with long range goals established by the state.

[k] The number of PEVs "on the road" is always lower than the cumulative PEVs sold due to normal retirement of older vehicles. PEVs tend to "turn over" at a slightly higher rate than traditional vehicles, since the technology is changing quickly and many consumers are leasing their vehicles (typically for about three years). That is why the "vehicles on the road" statistics is typically about 70% of the cumulative vehicles sold.

The following chart summarizes the three adoption scenarios, in terms of new PEV vehicles sold per year on Long Island.

Figure 4.2 - 1: PEV Adoption Scenarios (For Long Island)



Most of the results presented in the following sections are computed as the difference between a given scenario and the baseline. For example, "savings" for Scenario Two are computed as the difference between the full costs computed in Scenario Two and full costs computed in the Baseline case. As noted in the definition above, the baseline assumes a historical projection of likely PEV adoption as already integrated into PSEG-LI long range planning.

In addition to the three adoption scenarios and a IRP baseline, two variations were developed that describe "natural" and "managed" residential charging schedules. "Natural Charging" reflects the default charge pattern that results when most people plug-in when they get home from work, versus a "Managed Charging" scenario when charging is moved to a more optimal time *and spread out over multiple hours*. Within this study, "managed charging" is an intentionally broad practice that include consideration of when charging happens, what power levels are involved (including throttling), how charging transactions are spread out over time (staggered starts), how transactions are managed within a site, and a wide variety of more sophisticated actions often classified as "smart charging". The common thread is that "managed charging" transactions influence when charging happens and is used to create a more optimal aggregate load curve. These two scenarios apply time-of-day variations only to charging that happens in the residential sector, and all other forms of charging (public charging, workplace, etc) are consistent with measured practice in the field for those charging segments. The following graphs show an illustrative PEV charging load for a peak day in 2025, for both the natural and managed cases on Long Island.

Figure 4.2 - 2: Representative Load Curve (Natural)

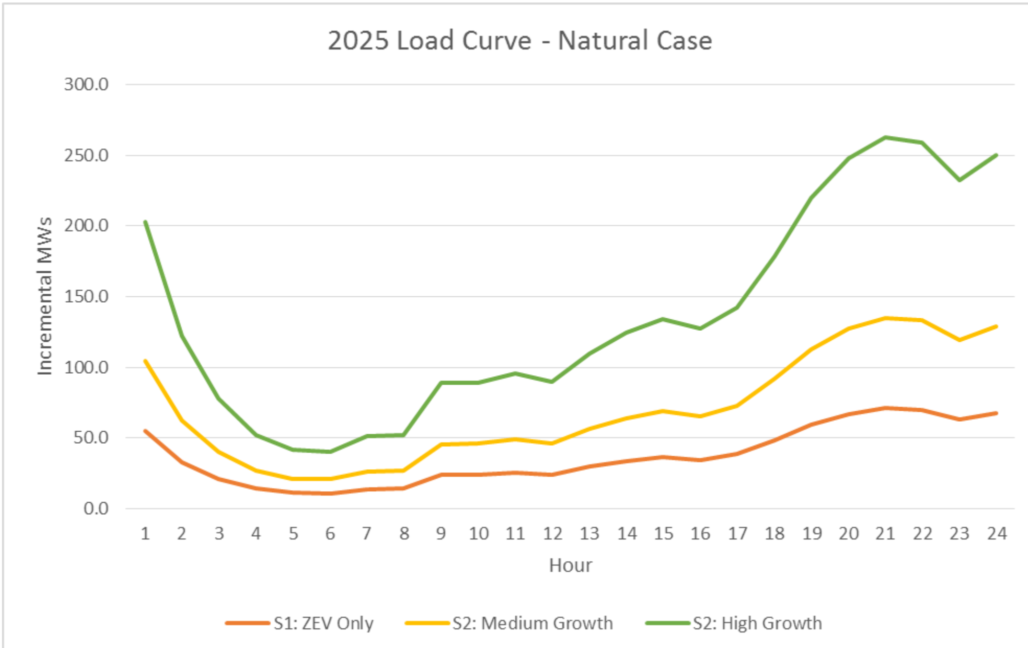
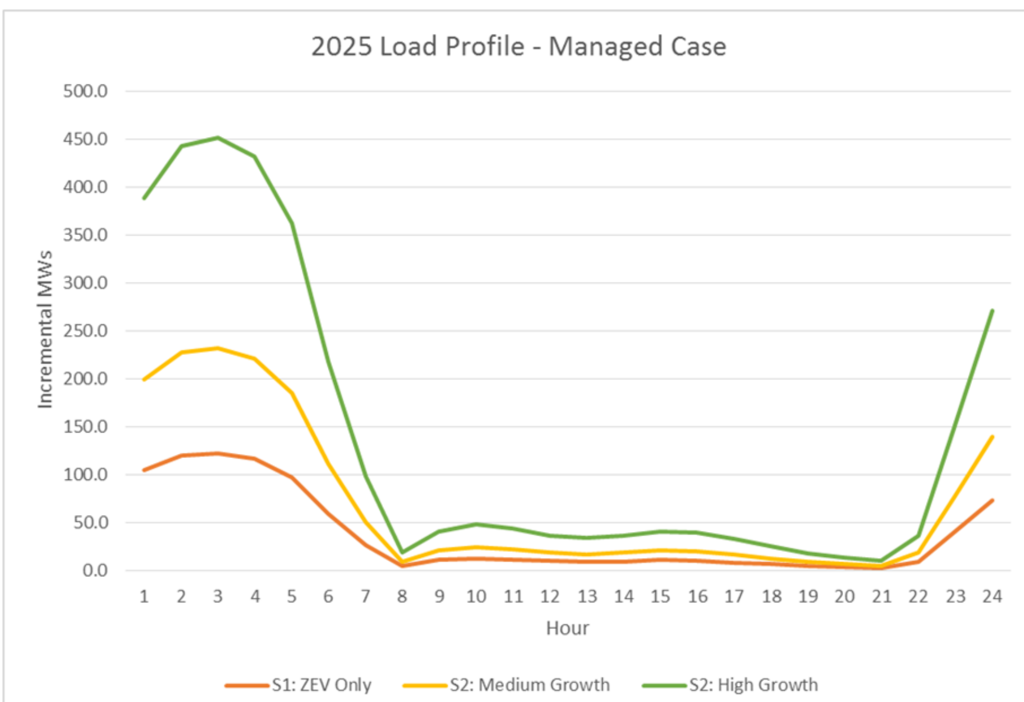


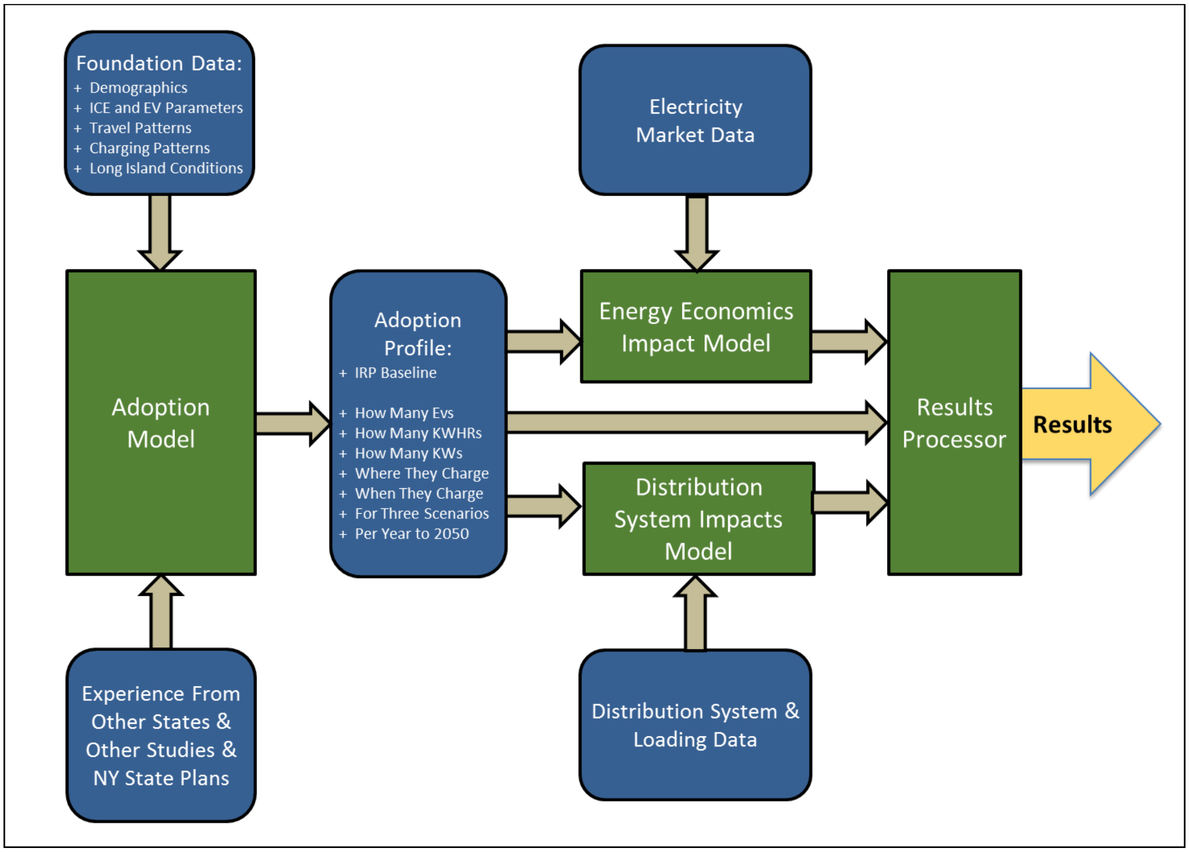
Figure 4.2 - 3: Representative Load Curve (Managed)



4.3 The Impact Model

The core model is based on four connected sub-models as summarized in the Figure 4.1 – 1:

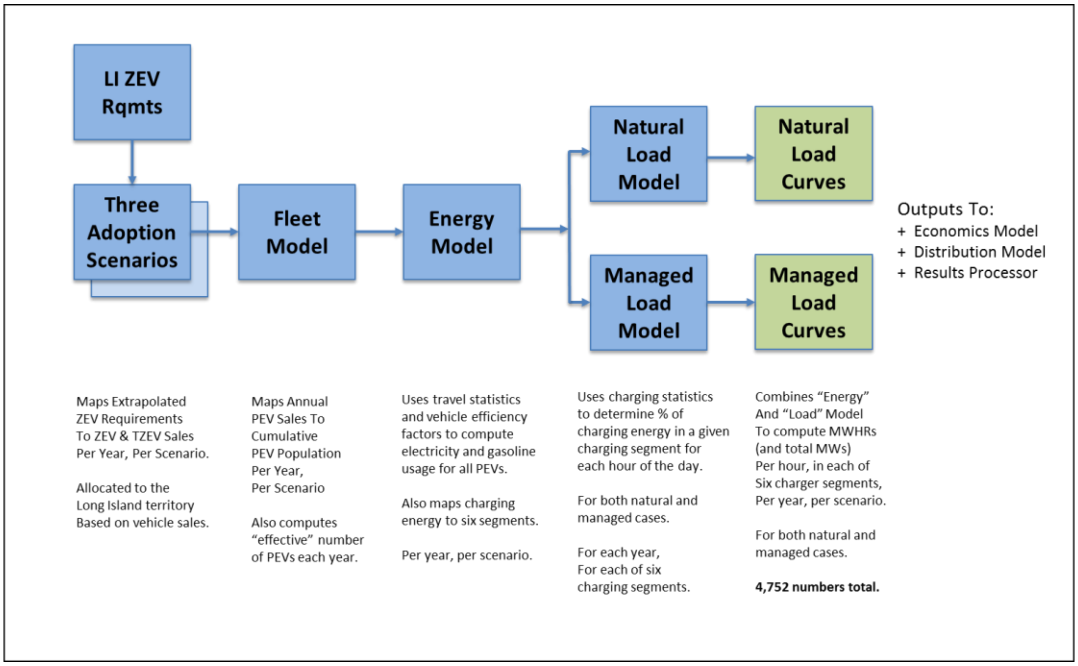
Figure 4.3 - 1: The Impact Model



The purpose and function of each of these sub-modules is as follows:

- **Adoption Model:** The Adoption Model applies the adoption scenarios and translates demographic, transportation, and vehicle statistics into electricity load curves. These load curves are then used to estimate energy market and system impacts. Key data used within the Adoption Model are population, Long Island light duty fleet parameters (size, sales rates, etc.), driving pattern statistics (especially Vehicle Miles Travelled), vehicle charging information (based on real charging statistics obtained from industry sources and a synthesis of numerous market trials and studies), and a variety of other vehicle statistics. The Adoption Model characterizes various PEV Adoption Scenarios, as described in Section 4.2 above, and quantifies charging requirements (energy, power, time of day) through six different charging segments (see Section 5.3). The Adoption Model includes several internal layers that translate vehicle statistics into energy profiles and loading curves, as summarized in Figure 4.3 - 2 below.

Figure 4.3 - 2: Internal Layers Of The Adoption Model



The following Figure 4.3 - 4 summarizes key data resulting from the Adoption Model.

Figure 4.3 - 3: Summary Of Impact Statistics From Adoption Model

	2018	2019	2020	2021	2022	2023	2024	2025
Number Of PEVs (on the road, by Year End)								
Scenario One (ZEV Only)	15,669	23,414	33,579	46,358	61,148	77,801	96,237	116,377
Scenario Two (Medium Growth)	20,769	36,258	56,589	82,147	111,727	145,033	181,904	222,184
Scenario Three (High Growth)	30,967	61,947	102,607	153,723	212,884	279,496	353,238	433,798
EFFECTIVE Number Of PEVs								
Scenario One (ZEV Only)	13,120	19,542	28,497	39,969	53,753	69,475	87,019	106,307
Scenario Two (Medium Growth)	15,669	28,513	46,423	69,368	96,937	128,380	163,468	202,044
Scenario Three (High Growth)	20,769	46,457	82,277	128,165	183,303	246,190	316,367	393,518
Electricity Required For Charging (MWhrs/YR)								
Scenario One (ZEV Only)	35,925	54,276	80,532	114,741	156,457	204,673	259,161	323,972
Scenario Two (Medium Growth)	42,824	79,101	131,178	199,187	282,205	378,215	486,761	615,528
Scenario Three (High Growth)	56,620	128,750	232,469	368,080	533,702	725,298	941,960	1,198,640
Incremental Peak Associated With Charging (MW, coincident with NYISO peak)								
Natural Charging Schedule								
Scenario One (ZEV Only)	4.7	7.1	10.4	14.6	19.7	25.5	31.8	38.4
Scenario Two (Medium Growth)	5.6	10.3	16.9	25.4	35.6	47.2	59.8	73.0
Scenario Three (High Growth)	7.5	16.8	29.9	46.9	67.3	90.5	115.7	142.1
Managed Charging Schedule								
Scenario One (ZEV Only)	2.2	3.1	4.3	5.7	7.2	8.7	10.2	11.1
Scenario Two (Medium Growth)	2.6	4.5	7.0	9.9	13.0	16.1	19.2	21.1
Scenario Three (High Growth)	3.4	7.3	12.3	18.2	24.6	31.0	37.2	41.1

- **Energy Market Impacts:** A detailed market simulation of NYISO dispatch of generation assets for both baseline loading, and incremental loading imposed by PEV charging as characterized by the Adoption Model. This simulation is based on the AURORAxmp® modeling platform (a fundamental market-based dispatch and simulation model that calculates forward market energy prices and emissions), and benefits from a variety of proprietary datasets developed by Gabel Associates for accurate modeling of energy market response to changes in loading. The Energy Model outputs the overall wholesale cost of power for each scenario and vehicle charging schedule, physical emission rates for CO_2, NOx, and SO_2, and projected wholesale capacity-build requirements over time. As a result, the Energy Model simulates hour by hour dispatch conditions for the known and projected NYISO assets for all seven scenarios (one baseline, plus natural and managed variations of the three adoption scenarios) from 2018 through 2050.

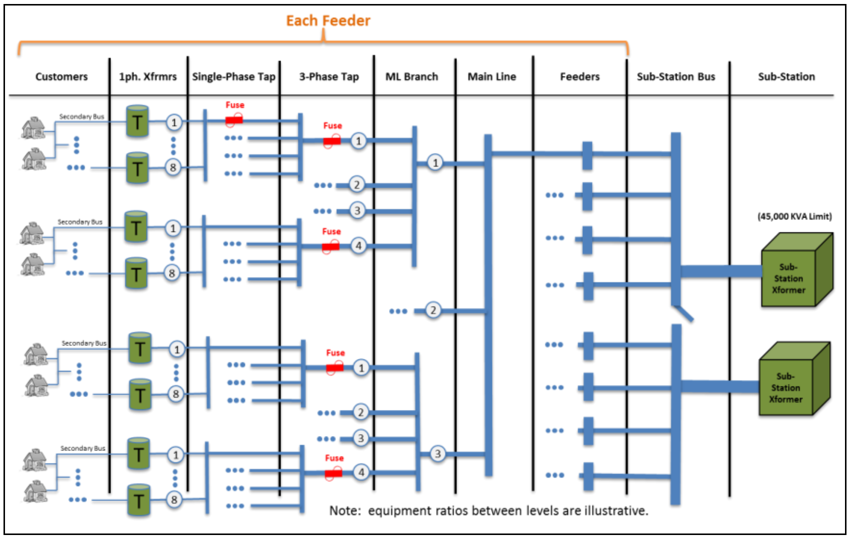
  In some studies on EV impact, economic benefits are quantified simply as increased utility revenue. Since EVs increase electricity usage, and utility revenues grow as a result, that incremental revenue is used as a measure of rate payer benefit. This study does not take that approach. Instead, **all references to energy-related "economic benefits" in this study refer to real reductions in energy costs, as would ultimately be visible in a utility customer's bill.** These energy cost reductions are computed based on detailed market simulations through AURORAxmp®and PSEG Long Island utility tariff analysis. General utility revenue increases are quantified, but not represented as a benefit. The economic benefit approach taken in this study is based on comprehensive NYISO/New York/Long Island specific energy market modeling, and translates ultimately to real cash impacts for electric utility customers.

  The economic impact for utility customers is based on two dynamics: changes in wholesale energy costs due to charging-related adjustment in the aggregate load curve, and dilution of fixed costs through a higher delivered energy volume (kwhrs). The wholesale analysis estimates overall changes in load-weighted average pricing, across all times and locations (within NYISO) in response to aggregate load curves that are influenced by vehicle charging. Similar to the way Demand Response programs are expected to have a market-wide impact on wholesale pricing through more optimal aggregate load profile, vehicle charging induces a pricing affect that changes average market pricing as well. This Charging Induced Price Effect (ChIPE) is what is estimated by the Energy Model. While this indicator is a realistic estimate for overall wholesale market costs, it is difficult to translate that into the rates or pricing an individual customer, customer class, or tariff may realize as a result of this induced market efficiency, since there are numerous other factors that affect how actual wholesale market costs translate into rates. But consistent with estimates used for predicting impact of demand response programs, this ChIPE factor is expected to result in real consumer savings for two reasons: a) in a competitive market like wholesale energy, wholesale cost efficiencies are eventually translated into changes in customer rates, although it is difficult to say exactly how individual tariffs might be affected in advance, and b) consumers on fixed-price tariffs (like residential customers) will see real changes in their load profile that track strongly with the aggregate load profile changes associated with vehicle charging, and the ChIPE impacts should be a strong predictor for wholesale costs passed through to those customers.

- **Environmental Impacts:** Electric vehicle impacts on the environment are examined primarily through changes in air emissions. All reported emission impacts are based on the summation of all NYISO-wide emissions as allocated to Long Island based on its share of NYISO consumption on an annual MWh basis, regardless of where all the generation assets are located. This is a classic "scope two" allocation method based on induced emissions. Two different accounting methods were used in the analysis, which accounted differently for the impact of where assets were located, but given the state-specific scope of NYISO the results were very similar and the more conservative method described above was used as the basis for all reported results. To provide context for the potential impact of vehicle electrification: based on the New York State GHG inventory, air emissions from the combination of all NYISO electricity generation resources are significantly lower than emissions from the use of gasoline in light duty vehicles[20].

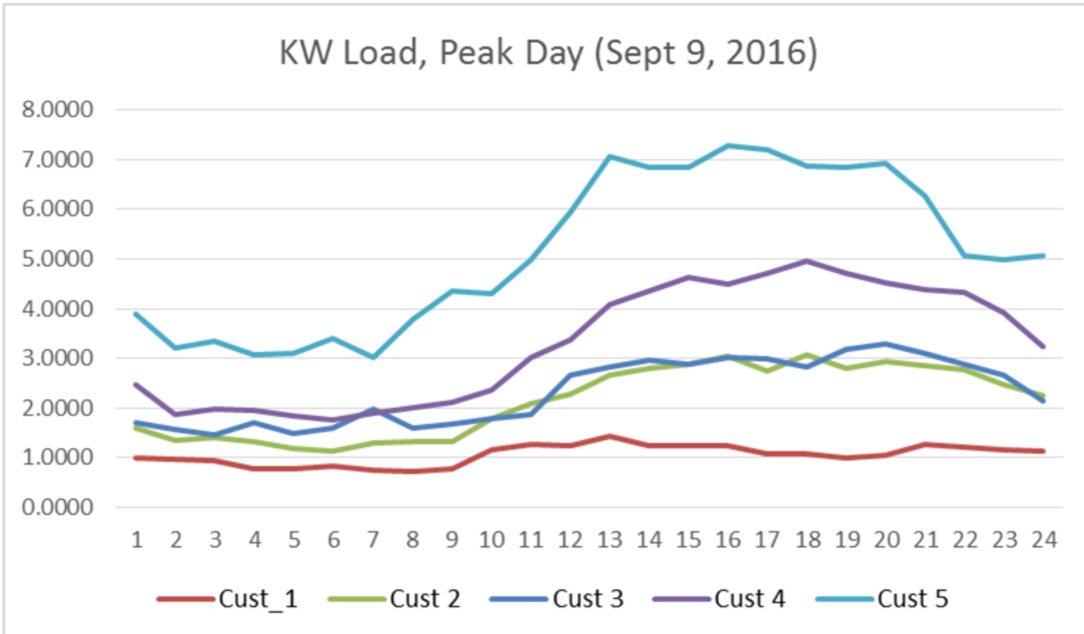
- **Distribution System Impacts:** Based on very detailed physical system data provided by PSEG Long Island, this model characterizes the loading impacts of EV adoption on the distribution system. The model is based on an idealized feeder model that aggregates EV charging impact from individual homes, through single phase distribution transformers, up through the feeder network to the sub-station. The model predicts how many PEVs can be adopted in the residential sector before an overload condition is triggered, and where (in the physical system) that overload condition occurs. In this case, "overload" represents scenarios where power draw by a particular "neighborhood" of consumers exceeds the design parameters of the infrastructure serving that neighborhood, e.g. 30KW of load on a 25KW transformer. The model considers a wide variety of sensitivity scenarios that combine various customers per transformer, transformer sizes, baseline loading conditions, and consumer PEV charger choices. These results are very specific to the PSEG – Long Island distribution system, but also accounts for a range of EV-specific factors as defined in more detail below. The following *representative* diagram (Figure 4.3 – 4) illustrates the idealized feeder model used to determine distribution system impacts, with actual numbers modified to protect confidential system configuration information provided by the utility.

Figure 4.3 - 4: Idealized Feeder Model



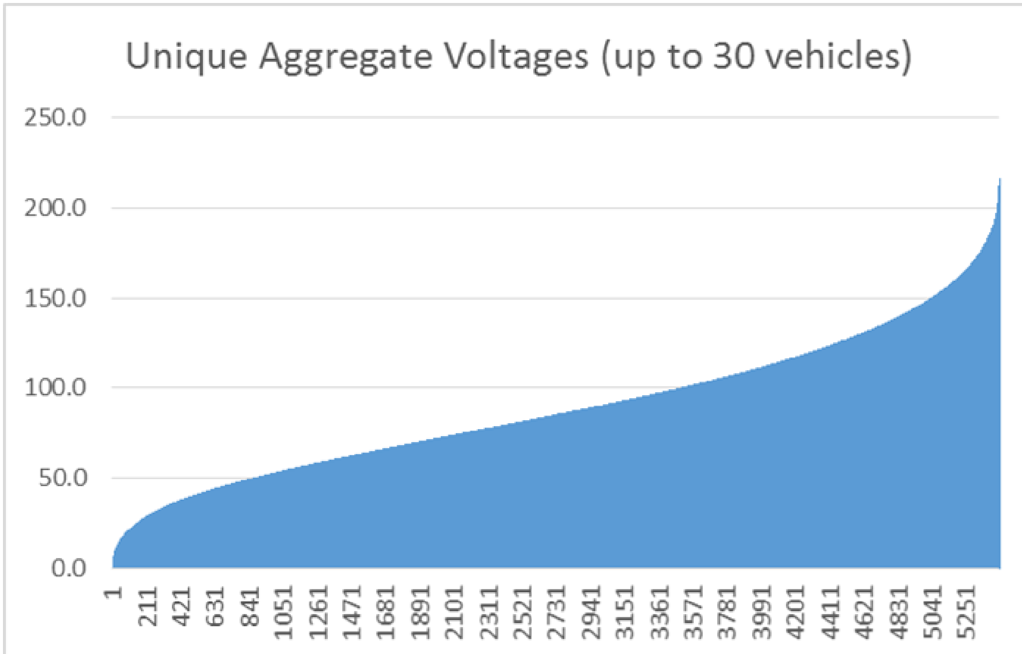
The distribution load results are very sensitive to: a) the number of homes connected to each single phase distribution transformer, b) the baseline loading (before EVs are added) for the homes on that transformer, c) the type of chargers used (ranging from a 1.3 kilowatt (KW) Level One, to a 7.2KW Level Two) and the permutation of chargers that aggregate to impact a given transformer, d) whether the charging is natural or managed (which affects how the charging load is distributed over time), and e) the amount of charging energy required for each charging transaction. Transformer configuration and baseline loading characteristics were based on data provided by the utility. The following chart provides an illustrative sample (for a single day) of the baseline loading provided by the utility for five representative residential customers.

Figure 4.3 - 5: Residential Load Curves



The charger configurations can vary widely, and are a function of consumer choices, not any design characteristics of the distribution system itself. As an extreme example, if all homes on a transformer elected to use low power Level 1 chargers, that would have a very different impact than if those same customers had elected for high power 7.2KW L2 chargers instead. So the PERMUATION of chargers, and the aggregate load resulting from that charger configuration, has a large impact on the analysis results. To understand the full space of possible impacts, the study identified all possible charger combinations: for a scenario in which up to 30 PEVs are charging on a single phase distribution transformer, there are 5,456 unique permutations of the three common charger types (1.3 KW L1, 3.3 KW L2, and 7.2 KW L2). The range of charging loads that results from this spread of consumer choices is demonstrated in the chart below. Based on this exhaustive sample space analysis, the model takes a representative configuration consistent with the average power load for each customer-group size. The following chart (Figure 4.3 – 6) demonstrates the aggregate voltage, as seen by a local single phase transformer, induced by various vehicle charger permutations.

Figure 4.3 - 6: Aggregate Voltage Of Vehicle Charger Permutations



- **Post Processor:** The outputs from the Adoption Model, Energy Model, and Distribution Model are combined to create net results. Many of the computed outcomes depend on calculations that combine several elements. For example, net emission impact is based on considering the increase in power plant emissions (from the Energy Model) combined with the reduction in tailpipe emissions from mobile sources (from the Adoption Model). All the economic, emission, and distribution system impacts flow out of the integrating post processor, which also generates the charts and graphs needed for visualization and documentation. Note that many of the results are represented as the difference between gross impact (MWhs, tons CO_2, etc.) of a given scenario minus the reference IRP baseline. As a result, the results are relatively insensitive to many of the baseline assumptions since they are constant across all the scenarios and net-out (i.e. cancel each other out) for most result calculations.

The Energy Model is inherently an "aggregate tops-down" assessment useful for understanding consequences on the wholesale fleet (especially regarding market pricing) and the resulting physical emissions. The Distribution Model explores "bottoms-up" system impacts at the neighborhood level as required to understand implications on real physical systems locally. Therefore, the model combines tops-down and bottoms-up elements to characterize loading characteristics that apply in aggregate, or at the local physical equipment level.

4.4 Key Assumptions and Boundary Conditions

Within the model structure and key concepts outlined above, there are a variety of key assumptions and boundary conditions that determine the scope of the model and its results, as summarized below:

1. The demographic, vehicle, and travel statistics are based on Long Island conditions.

2. The study considers only on-road light duty vehicles, which in general represent all two-axel/four-wheeled vehicles, typically fueled by gasoline (a very small fraction of this class of vehicle is fueled by diesel). This includes passenger cars of all types (sedans, hatchbacks, etc.), and passenger trucks (cross-overs, SUVs, mini-vans, pick-up trucks). The study does not consider motorcycles and medium or heavy-duty vehicles typically fueled by diesel.

3. The study assumes that driver travel patterns do not change as the result of using a PEV rather than a traditional gasoline fueled vehicle. In particular, annual vehicle miles traveled remain the same between traditional vehicles and PEVs, although that factor changes slightly over time consistent with recent trends.

4. To make the scenario space manageable, all days are assumed to be equal. The study does not account for EV travel seasonality or day-of-week differences, although the baseline electricity loads are based on historical data for a full year.

5. The electric energy market simulation is based on a detailed hour-by-hour simulation of dispatch for the NYISO wholesale generation fleet, using known run-prioritization rules, heat factors, marginal costs, emission rates, etc. The simulation considered all seven scenarios (baseline, plus natural and managed variations of each of the three adoption cases), for the years from 2018 to 2050 (i.e. 231 full year 24X7 simulations, two emission methods each). Outputs include wholesale energy costs, physical emission rates, and wholesale generation capacity build requirements. Where new capacity was required, "business as usual" construction was assumed consistent with the most economical options (combined cycle natural gas), typically with plant sizes of 400MW or above. The simulation matches EV loading against baseline loading conditions in full consideration of baseline peak loading conditions. All "incremental" peak load estimates are coincident with NYISO peak loading.

6. The calculation of electricity cost impacts is based on a detailed analysis of PSEG-LI electricity tariffs. The analysis broke out billing determinants across rate classes and by billing element (flat fee, per KWhr, etc.), and assessed impacts to supply rates based on wholesale cost changes and dilution of relatively fixed capacity, transmission, and distribution costs. To keep cost impact estimates as conservative as possible, the following approach was utilized: a) current rate class allocations were assumed to continue proportionally over time unchanged, and b) only those cost changes that impact per-KWhr charges (under current tariffs) were included. This approach probably under-estimates how actual cost efficiencies might be allocated, although there are numerous factors that could affect those outcomes. As noted above, this analysis estimates overall cost impacts (typically efficiencies) that are realized by incremental EV

loading, but how those benefits are realized in end-consumer rates could vary depending on cost allocation decisions by the utility and approvals by the NY Public Service Commission. All electricity cost calculations include the impact of the Renewable Portfolio Standard (RPS), all delivery charges including known current riders, energy/capacity/transmission costs, and ancillary charges.

7. Electricity cost calculations that impact the EV driver reflect the typical RESIDENTIAL tariff (not average electricity costs), which were also increased to include a per-KWhr payment by EV drivers to compensate for lost revenues from the New York gasoline tax[l].

8. Gasoline costs over time are based on U.S. Energy Information Administration (EIA) projections for gasoline costs through 2050, BUT increases were moderated by approximately half to reflect the softening of demand that would result from widespread PEV adoption consistent with these scenarios. Note the combination of assumed HIGHER electricity costs (due to gasoline tax replacement) and LOWER gasoline prices (due to softening demand) combine to mostly likely under-estimate savings for EV drivers.

9. Mobile emission rates for NOx and SO_2 were based on emission factors supplied by the New York Department Of Environmental Conservation.

10. Energy characteristics of BEVs, PHEVs, and traditionally fueled vehicles are modeled separately and combined based on projected vehicle mix to assess the aggregate impact.

11. As detailed in Section 5.3, all vehicle charging is modeled through six different charging segments, each of which has its own time-of-day charging profile per vehicle type. These time-of-day profiles were developed based on actual field data supplied by industry sources for the NY/NJ area, combined with research from the University of California – Davis (UC-Davis) on charging behaviors and a variety of other studies (the DOE EV project, the Atlanta Travel Survey, etc.).

12. Much of the detailed data about vehicle usage was compiled based on first generation vehicles, which have relatively short range. A significant portion of market data is also based on experience in California. The study recalibrated market data to account for second generation vehicles becoming predominant, and for applications outside the relatively mature California market. Changes in vehicle range, in particular, significantly alter vehicle travel patterns and charging behaviors.

[l] Although this study added a cents/kwhr premium to the cost of electricity to ensure that EV owners pay their fair share for transportation infrastructure funding, that was a modeling expediency and is not intended to endorse that particular approach. There are a variety of ways that contribution could be structured besides per-kwhr surcharges. The premium used in the study is equivalent to the current gasoline tax (on an average per mile basis), and any other funding mechanism is expected to be similar economically.

5 Key Findings

Fueling vehicles with electricity rather than petroleum represents a profound systemic change with an exceptionally wide range of impacts. As justified by the net benefits quantified below, taking action to expand and accelerate EV adoption on Long Island has positive bearing on energy costs, environmental impact including GHG emissions, consumer safety and public health, the operation of the public electricity grid, among numerous other strategic considerations. **Vehicle electrification is unique in its breadth of impact and predominantly positive implications.** EV adoption is just beginning to grow in Long Island so impacts are currently small – but adoption is growing quickly, and the transition is clearly a long term trend in which impacts accumulate over time. At even modest levels of adoption, economic, environmental, and other strategic impacts will be much larger than are evident today. Based on the in-depth, territory-specific model described in Section 4, the following sections summarize the key impacts of Plug-In Vehicles on Long Island over time.

5.1 Findings: How Drivers Charge Their Vehicles

Vehicle charging is the lynchpin between the transportation domain and the energy world, and many EV adoption benefits emerge from the impact charging has on energy markets and infrastructure. The "charging transaction" itself has evolved significantly, and it is progress in this technology, combined with changes in the vehicles themselves, that have made EVs an alternative that is viable for mainstream consumers. Vehicle charging is a safe "do it yourself at home" transaction that most consumers will find manageable, similar to behaviors for mobile phone charging that have been widely adopted. For those relatively rare occasions (for most drivers) when a public charge is needed, that technology is also evolving quickly, with expectations that in the short term quick charge transactions can be almost as short as a gas station visit today.

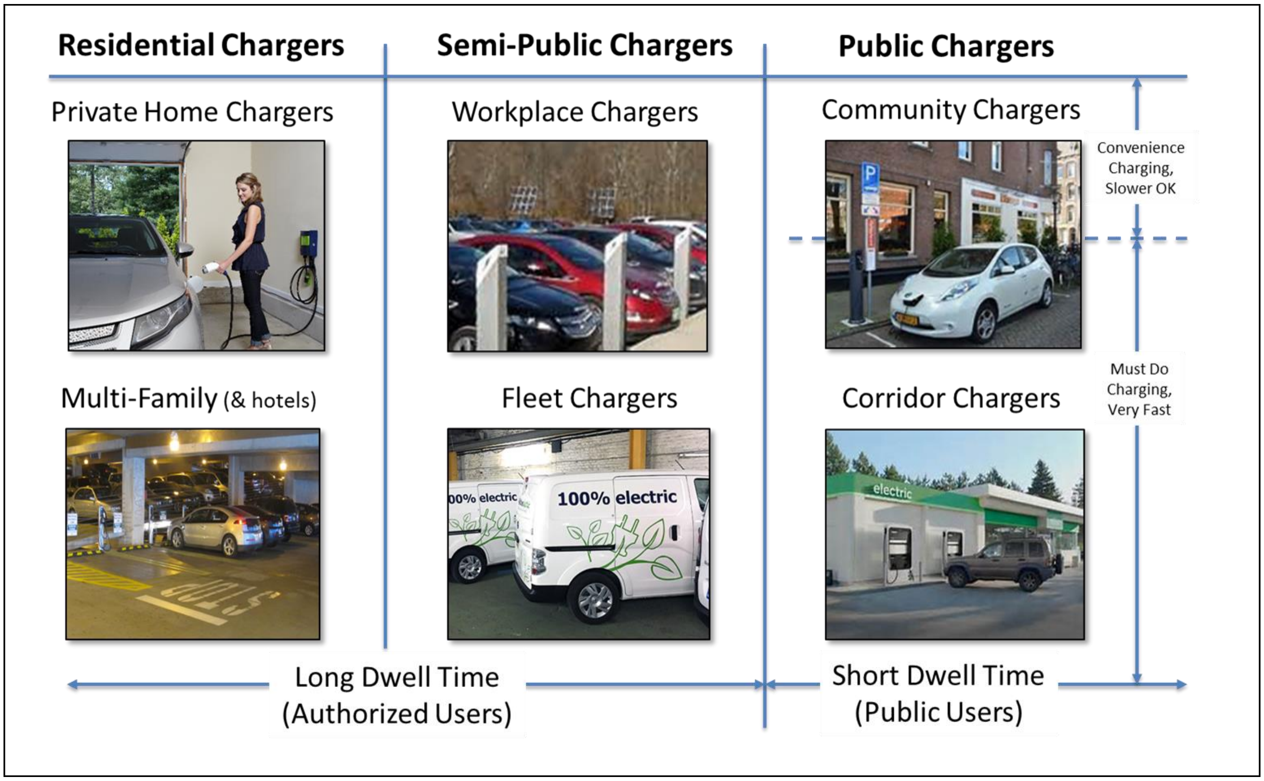
Figure 5.1 -1

A Residential EV Charger From The Early 1900's

As part of developing the impact model, the study team assimilated data about vehicle charging from industry data, numerous studies, and information from industry sources (especially charging companies). This information was synthesized to develop a charging model that describes how EV users charge their vehicles and when.

The diagram below summarizes the vehicle charging segmentation used in this study.

Figure 5.1 – 2: Vehicle Charging Segments



As annotated along the horizontal axis at the bottom, vehicle charging can be conceptualized as long dwell time events, or short dwell time events. Most charging happens where vehicles spend most of their time not moving: parked at home or (to a lesser extent) at work. This convenient fact makes frequent long duration (and lower power) charging of EVs possible. Public chargers support relatively short transactions (by comparison), when the vehicle is away from home or work. These public chargers vary (along the horizontal axis) by whether the public charge is a "must do" charging transaction (i.e. the battery is nearly exhausted, and a quick charge is needed), to more optional charging when it is convenient but not necessarily needed. The six segments capture different vehicle charger settings, each of which has a unique role in the vehicle charging ecosystem, including distinctive user, ownership, business model, and usage profiles, as summarized below:

1) **Privately Owned Home Chargers (with integrated parking):** Located in single family homes, or any residential unit with adjacent and accessible parking where a charger can be easily installed and conveniently used on a daily basis. These chargers are typically Level One or Level Two equipment, and typically owned by the person that owns the car and/or home. In general, the users of the charging equipment are limited to the vehicle/home owners. These chargers are simply a load within the building and the energy delivered to the EV is part of the monthly

electricity bill. The charge transaction can take place at any time of the day, but typically EVs will be charged overnight.

2) **Multi-Family Residential (with separated parking):** A residential property with less convenient parking arrangements, especially in lease/rent scenarios where charger availability is determined by a building owner or manager that is different from the EV owner. Typical examples include condominium and apartment buildings with common lots or parking garages, buildings with "street-side" parking, or rental/lease free-standing homes or duplexes where the landlord makes charger installation decisions. The usage profile for chargers located at multi-family dwellings is similar to that of the private residential segment (mostly overnight), but there are significant differences in the equipment ownership, vehicle access rights and scheduling, and payment arrangements. In general, the charging equipment must be approved by, and will typically be owned by[m], the residential property owner or homeowner association, and the resident will pay for charging services in some form. A key aspect of this segment is that the Level One or Level Two chargers are typically neither assigned to a single vehicle/user, nor available for general public use – they are available for use by *authorized users.* The multi-family segment is significant in communities where a substantial portion of building stock is multi-family, or where many families rent or lease their homes. Overnight lodging (hotels, etc.) are also modeled as multi-family residential properties since their characteristics are nearly identical. In a hotel setting, most charging will still be done overnight, but the owner of the equipment is different than the owner of the vehicle, and therefore only *authorized users* (registered guests) may use the charging facilities. Vehicle charging privileges will be offered similar to the way WIFI access is offered to guests today.

3) **Workplace Charging:** EV chargers at a non-residential property for use by employees[n]. These chargers are typically Level One or Level Two equipment and are provided as an employee benefit and/or in support of corporate sustainability or CO_2 reduction goals. These workplace chargers are especially useful for two usage profiles: those employees that don't have a charging option at home (if they live in an apartment, for example) and for whom charging at work is their primary routine charging option, or as a "back-up" for employees that are able to charge at home but need redundant charging options (to cover extended travel during the day, forgot to charge at home the night before, etc.). In some cases, employees may be using a workplace charger to extend their daily driving range, and if they own a PHEV, to minimize fuel use. Workplace chargers are therefore part of the charging ecosystem that supports EV owners

[m] Even in cases where the tenant pays for and owns the charging equipment, the landlord, management company, or homeowner's association retains significant decision-making authority about its installation and its use.

[n] To be more precise, workplace chargers should really be thought of as "chargers used by EV drivers while they are at work". For some employees, this may not be at the workplace itself. In urban settings, in particular, some employees park in a public lot and work in a nearby office. Similarly, an employee may drive to a commuter lot, and park their car there all day while taking the train or bus to and from work. Both of these situations benefit from typical Level Two charging similar to what would be found at the workplace, but in what would normally be considered a more typical "public charging" setting.

living in a multi-family environment, while also providing greater confidence in charging away from home for all drivers. It should be noted that workplace chargers are often effective awareness building mechanisms, and there are examples of workplace chargers stimulating EV purchases, even if many of those employees end up charging at home. Similar to multi-family settings, the chargers are not owned by the vehicle owners, and equipment usage is by authorized users only. These chargers are usually "behind the meter" of the commercial building and the EV charging load is part of the overall building load. Precautions must be taken to avoid EV charging having a negative impact on commercial demand charges. Employers may provide EV charging at no cost, but increasingly, the electricity and/or charging service will be paid for by the employee.

4) **Fleet Chargers:** Chargers at non-residential properties focused on supporting light duty EVs owned by the hosting entity. Functionally, these chargers operate the same as a residential unit, with charging typically happening overnight to support vehicle use during the day – but that can vary depending on the vehicle usage profile. As with workplace chargers, there is only a loose coupling between vehicles and chargers, and only authorized users/vehicles may use the charging facilities. Unlike workplace chargers for employees, the owner of the vehicle and the owner of the charger are typically the same entity, which may simplify (or eliminate) the need for the vehicle driver to pay for charging services.

5) **Public Charger – Corridor Locations:** Chargers, typically with higher power levels that allow open public access to faster charging, located on or near heavily used travel arteries. On Long Island, these corridor locations can serve BOTH long distance travelers and local travelers. In either case, these chargers are most frequently used under "must charge" conditions where the battery is nearly exhausted. The recent rapid advancement of DC Fast Chargers (DCFC), which within a few years will be able to charge vehicles to within 80% of full capacity in 15 minutes or less, are ideal applications for corridor public chargers. These charging facilities will typically be owned by an operator that is providing charging as a service available to the public, and charging will be a purchased service. The property owner may own the charger (at a coffee shop or gas station, for example) or the site host may enter into an agreement for a third party to own and operate the asset.

6) **Public Charger – Community Locations:** Chargers for public use, but located away from travel corridors. They will typically be located at public parking areas (sponsored by the municipality), destination locations (entertainment or park facilities), or retail locations – community locations near where drivers live or work, or may visit frequently as part of daily routine. Like corridor chargers, they will be owned and operated for use by the public for a wide variety of reasons. Community chargers will benefit from fast charging equipment similar to corridor chargers, but there may be applications for lower power Level Two chargers as well in some properly matched locations.

These six segments create an ecosystem of charging solutions that cover the majority of charging settings and use cases. Recent research has identified several important modes of interplay and distinction between the segments:

- Most charging energy is delivered through the residential, and to a much lesser extent, the workplace settings. Therefore, ensuring availability of these routine charging solutions is critical to market adoption – **most consumers will not transition to a PEV unless they have access to convenient charging at home and/or work**. Current market statistics indicate that as much as 70% of all EV charging energy is delivered at home and work, and this is expected to increase (due to increasing battery capacity) to at least 90% over time. This is an important fundamental fact about EV charging – most of the energy is delivered at home at night, and there is some flexibility about the scheduling of that charging transaction as long as the vehicle is fully charged by morning.

- The amount of energy needed for each overnight charge is, on average, NOT a function of the capacity of the battery. It is related to the number of miles driven each day. For most drivers on Long Island, the overnight charge will average slightly under 10 KWhr a day.

- This residential charging dynamic represents a fundamental departure from the way traditional vehicles are fueled today. **EV drivers will charge their cars similar to the way they charge their cell phones.** Unlike traditional gasoline fueled vehicles – which for most drivers MUST be fueled at a commercial gas station – charging an EV at home is a viable, usually more cost effective, and frequently a preferred option[o]. The role of public chargers is therefore very different than the role of gas stations. While gas stations provide routine fueling of a traditional vehicle, public EV charging transactions happen relatively rarely – only on a long distance trip, or when the driver is outside their normal travel pattern. Comparisons between gas station density and public EV charging requirements are irrelevant, since they support fundamentally different "fueling transactions".

- Although they do not deliver much charging energy on a MWh basis, Public Chargers are absolutely critical for market adoption since they address consumer concerns about range anxiety.[21] The amount of energy delivered is not an appropriate metric for the success of a public charging station, since the intended effect is reduced consumer concerns about range anxiety and an associated increase in EV adoption.

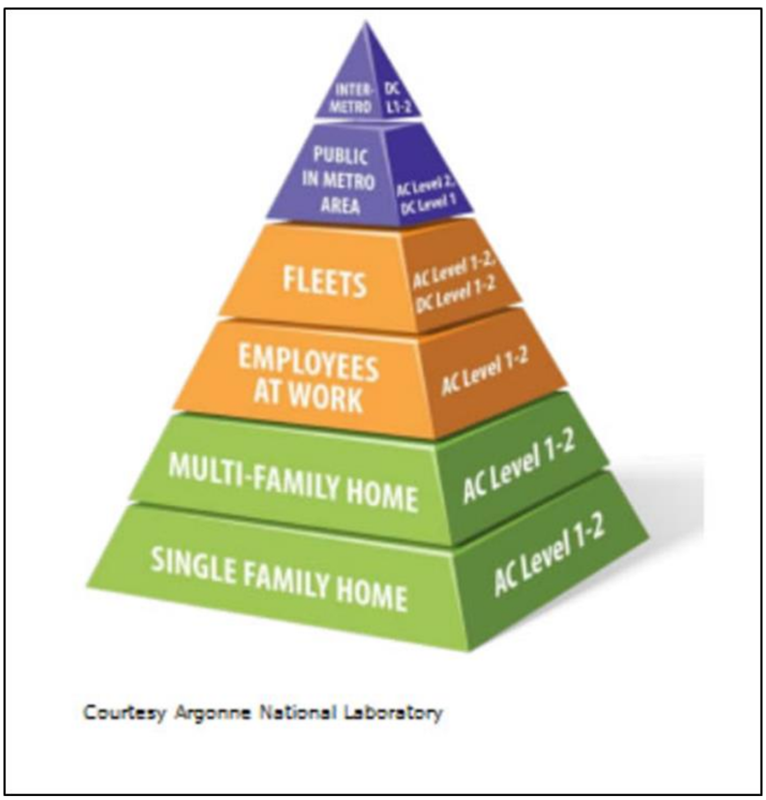
- In the early stages of market development, affordable but longer range EVs (which are now becoming available), geographic density of public charging (especially fast chargers), and public awareness of public charging availability, are key factors in reducing consumer range anxiety.

[o] For this reason, especially in the early years of market development when EV ownership is still small, utilization of public charging stations can be relatively low. This naturally stresses the economics of public charging stations, especially the higher power stations preferred by consumers due to the demand rates inherent in typical tariffs.

The need for sufficient geographic coverage of public chargers (especially DCFC), BEFORE the EV population is large enough to ensure economically viable asset utilization, is a particularly challenging aspect of EV market development. In short, sufficient geographic density is needed BEFORE they can be economically viable on a stand-alone basis, but this effect declines as the size of the EV population grows and utilization of charging infrastructure naturally increases. The essential challenge for addressing range anxiety is therefore supporting public charging economics (especially for DCFC) during the early years when economics are challenging.

- Both the private and multi-family residential, and the workplace employee and fleet chargers, are long dwell time solutions – typically measured in hours. Public chargers tend to be much shorter transactions, and with corridor chargers (and long-distance travelers) especially, the consumer need is for the shortest possible charge time. Matching dwell time characteristics with the location usage profile is critical to application success. In general, the first four segments (residential and commercial for employees and fleets) are Level One or Level Two equipment, while public chargers are best served by DC fast chargers that are capable of faster, high power charge transactions. The following Figure 5.1 - 3 summarizes the "EV Charging Ecosystem" and, as characterized by their respective sizes at each level, illustrates the fraction of energy delivered in each charging segment.

Figure 5.1 – 3: Vehicle Charging Usage Hierarchy



- Pricing of delivered electricity for both workplace and public chargers has a large impact on how they are used. Recent research at UC-Davis suggests that if workplace or public charging is FREE, it is used by EV drivers that actually do not need the charge. Their research suggests that free workplace charging creates a need for approximately 80 chargers for every 100 EVs on the lot. In instances where the electricity is priced similar to residential costs, that coverage factor reduces to about 60 chargers per 100 EVs. If the workplace charger is double the cost of home charging, only 20 chargers per 100 EVs are needed. Free charging can therefore induce unnecessary demand, force the need for more infrastructure investment, create parking spot usage conflicts, and increase less preferable daytime (on-peak) charging.

5.2 Findings: Impact of EVs on Achievement of State Goals

As noted in Section 3.2.1, New York State has formally adopted a variety of goals and strategies that can be realized by widespread EV adoption. In particular, key GHG reduction objectives **can only** be realized with significant decarbonization of the transportation sector, and widespread PEV adoption by mainstream customers is a highly impactful approach for achieving that result. Based on the New York State GHG Inventory[22], combined with new research as part of this study, several key trends and conclusions are evident:

- **GHG emission reductions required by formal state mandates can be effectively achieved through widespread vehicle electrification.** New York State's GHG reduction goal calls for an 80% reduction in CO_2 emissions by 2050, compared with a baseline in 1990.[23] Transportation was the single largest CO_2 emissions segment in 2014, representing 34% of CO_2 emissions, and the use of gasoline by light duty vehicles (as would be displaced through vehicle electrification) accounts 25% of all CO2 emissions. **An overall 80% reduction is not possible without massive reductions in transportation emissions, especially in the predominant light duty vehicle segment**[24].

- **Fueling vehicles with electricity on Long Island is much cleaner than using gasoline, so vehicle electrification makes extraordinary reductions in CO_2 emissions possible.** EVs replaces emissions at the tailpipe with emissions from a smokestack at the point of electricity generation. Given that power plants are generally more efficient and cleaner than the internal combustion engine in a car, that emission displacement delivers a significant net improvement. On Long Island, where the generation fleet is relatively clean (and becoming cleaner over time), every electrically fueled mile is between 82% lower in CO_2 emissions than a gasoline fueled mile in 2018. Vehicle electrification therefore tackles one of the largest sources of GHG through an alternative that is substantially cleaner with each electrically fueled mile. See Section 5.6 for more details.

- **Vehicle electrification will also support state goals for compliance attainment on other regulated air quality emissions, especially NOx.** Vehicle electrification produces significant reductions in NO_x, similar to the reductions identified for CO_2. Similar trends are estimated to be realized for other criteria pollutants (VOCs, etc.), but those emissions have not been modeled in this study. See Section 5.6 for more details.

- **There is a strong synergy between renewable energy growth and vehicle electrification.** How this "clean-up affect" scales with increased EV adoption depends heavily on the carbon intensity of new generation assets deployed over the next 30 years. There is a profound synergy between EV adoption and the use of de-carbonized electricity generation: when a lot of electric vehicles are on the road, solar or wind generation displaces not just coal or natural gas use in electricity generation, but also the use of gasoline in inefficient car engines[p]. Increased EV adoption therefore makes zero-carbon renewable energy more valuable, and increased renewable energy use makes the "clean-up effect" inherent in vehicle electrification stronger.

- **Reducing overall electricity costs is a key strategic goal for the state, and widespread vehicle electrification contributes to achieving this objective.** The cost of electricity is highly dependent on when electricity is used, with consumption at off-peak times being less expensive. The majority of EV charging will happen at night, during off-peak times, especially if managed charging programs are implemented to encourage that outcome. As a result, a larger fraction of total consumption is during lower-cost periods, and the overall unit cost ($-per-KWh) of electricity declines. There are similar impacts related to diluting relatively fixed costs (for infrastructure) through higher electricity volume, and these impacts are significant. Vehicle electrification therefore contributes to goals for reducing electricity costs for utility customers, as quantified in more detail in section 5.3.1.

5.3 Findings: Economic Benefits

Vehicle electrification brings a variety of economic impacts, particularly to electric utility customers, but also to society at large and to owners of electric vehicles. The following sections summarize study results on gross benefits realized in all three areas, potential costs that may be incurred to help increase EV adoption rates, and the associated NET benefit as realized directly by utility customers.

NOTE: The economic benefits represented in Section 5.3.1 through 5.3.4 represent gross benefits (typically savings) that accrue to impacted populations, without consideration of potential costs. Section 5.3.5 addresses potential costs, and provides a NET benefit perspective that reflects benefits AFTER potential costs are accounted for. Note that the benefits covered in Sections 5.3.1 through 5.3.4 may apply to different impacted populations, ranging from utility rate payers (through changes in electricity costs), to society at large through induced externalities.

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[p] In early years, when RE and EV penetration are both relatively small, the degree of coincidence between EV consumption and RE generation is not relevant. At higher levels of both RE and EV penetration, this coincidence becomes more important, but benefits from the fact that solar and wind tend to have relatively complementary generation profiles. If managed charging is the prevailing charging pattern, EV charging will happen mostly at night when wind is more dominant. Longer term, the higher RE penetration will support EV charging REGARDLESS of the coincidence between EV charging and RE generation, since there is likely to be significant storage online as well.

NOTE: In all summaries of economic benefits below, "total savings" refers to the nominal sum of annual savings from 2018 to 2035 without discount. All references to "Present Value" (PV) are based on the present value of annual savings from 2018 to 2035 at a discount rate of 5.5%.

5.3.1 Economic Benefits Due to Reduced Electricity Costs

The average unit cost of electricity is likely to go down as EV use increases, and this results in an aggregate cost reduction that flows to electric utility customers overall. This reduction results from two affects happening simultaneously: a) lower average cost due to changes in wholesale load profile, and b) dilution of fixed costs through increase MWh volume. Both of those dynamics are described in more detail blow:

- The average $/MWH cost of wholesale electricity – which has a large impact on rates experienced by many customers, especially residential, that buy on a fixed rate – depends on the shape of the load curve. It is widely accepted, for example, that when more electricity is consumed at peak times, average costs go up. For that reason, demand response programs that reduce peak loading are considered to have a beneficial impact on overall costs. There is a similar affect when more electricity is consumed during off-peak times when wholesale electricity pricing is low. As the FRACTION of annual usage in lower-priced times increases, overall load-average costs typically decline. This Charging Induced Price Effect (ChIPE) is evident as EV usage increases, and results from the fact that most vehicle charging will happen during off-peak periods when costs are lower. The ChIPE analysis accounts for how average wholesale costs change when a larger fraction of annual electricity use occurs during off-peak time due to residential vehicle charging. The study simulated detailed hour-by-hour dispatch of NYISO assets as needed to support the EV adoption scenarios under consideration, and estimated the impact on wholesale electricity costs that result (as described in Section 4.3). Note: this analysis creates an overall wholesale average that can be used as an index to compare overall costs. Additional factors affect how those costs are allocated to individual customer classes or tariff rates: this analysis characterizes basic costs, but cannot quantify individual rate or tariff impacts[q].

- In addition to wholesale impacts, average unit costs decline due to increased utilization of existing assets (power plant capacity as well as and the transmission and distribution infrastructure), especially under the managed charging scenarios that shift EV charging to off-peak times. The study estimated how relatively fixed costs are diluted through increased electricity usage. To be conservative and minimize the impact of uncertainty about how overall cost reductions translate to individual tariffs, only fixed-cost changes

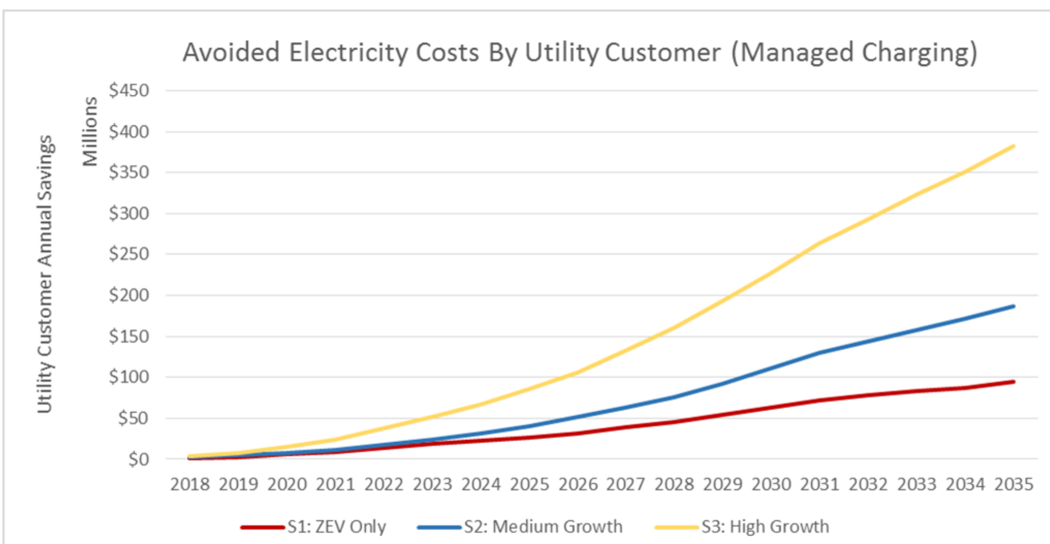
[q] This analysis quantifies basic cost efficiencies that affect aggregate electricity unit costs, load-weighted across all times and load points. A variety of factors affect how those impacts translate into particular rates for customer classes or individual tariffs. ***Short term, existing energy purchase contracts or similar commercial or regulatory commitments may influence how or when those benefits are passed through to consumers.*** This analysis focuses on basic costs, with the expectation that in a competitive market any cost efficiencies eventually flow through to customers through rates, approximately consistent with current tariff structures, especially longer term.

that flow to consumers through KWh-based charges were included in the savings assessment.

The combination of these effects were estimated for both the baseline case and all EV adoption scenarios, reflecting changes in loading that result from EV charging. Savings were computed based on the total costs for scenario under consideration compared with baseline costs, as applied primarily against non-EV charging loads. All the following savings estimates noted in this section are gross savings, without consideration of any costs that may apply.

- **Electric utility customers could benefit from a total of $1.3B in electricity cost reductions through 2035 (PV of $198M)** for the medium adoption case (Scenario Two, managed charging) relative to the IRP baseline. These savings result from structural changes in the market, and grow as EV adoption continues to increase. These benefits will accrue to electric utility customers overall, not just the EV owners, and reflect only the savings on non-vehicle charging consumption**.** **In the medium adoption case (Scenario Two) when managed charging is common, electric utility customers could average $77M in savings each year, reaching as much as $186M in annual savings in 2035.** Electricity cost reductions are proportionally lower (Scenario One) and higher (Scenario Three) in nearly linear lockstep with PEV adoption. The chart below summarizes annual utility customer savings as a function of PEV adoption under all three scenarios over time.

Figure 5.3.1 – 1: Avoided Electricity Costs By Utility Customers



- **The cost efficiencies realized are very sensitive to WHEN vehicle charging takes place**. Under natural charging scenarios, where vehicle charging begins in the early evening, there is still savings but it is more modest. Electric utility customer increase if programs and policies are implemented that encourage more optimal managed charging profiles. Through 2035 for the medium adoption case (Scenario Two), this impact averages approximately 37% more savings annually, totaling approximately $225M in incremental benefit.

- **All components of utility costs are likely to be reduced.** Savings are likely to be realized in all four components of utility rates as EV use increases, including ChIPE impacts on wholesale costs (as defined above), and dilution of relatively fixed capacity, transmission, and distribution costs. Longer term, the dilution impacts become the dominant factor, shifting from 45% of the savings in 2018 to 86% in 2035 (Scenario Two, managed charging).

In summary: even when considering only impacts on electricity costs, EV adoption will likely create significant savings that accrue to electric utility customers overall, and those benefits grow with EV usage, affect all components of the utility bill, and are amplified significantly if policies and programs that encourage managed charging are implemented.

5.3.2 Economic Benefits for Electric Vehicle Owners

EV owners will realize real cash-flow savings due to reduced maintenance costs and "fueling" with electricity rather than gasoline when compared with use of a traditional gasoline-fueled vehicle. These benefits accrue to the owners of electric vehicles, as summarized below:

a) **EV owners could realize as much as $3.5B in total savings on vehicle operating expenses[r] through 2035 (with a PV of $1.7B)** for the medium adoption case (Scenario Two, managed charging)[s]. Operating savings could average $192M annually over the period, with annual impact scaling linearly with PEV adoption level. Fueling with electricity rather than gasoline, combined with the lower maintenance associated with EVs, delivers substantial cash savings for Long Island EV drivers, and this benefit results in a direct cash benefit that improves disposable income.

[r] This savings represents only the reduction in operating expense for EV owners, reflecting both reduced "fueling costs" (through electricity rather than gasoline), and projected lower costs for maintenance. This does not account for possible premium's paid for the EV (compared with a traditional vehicle purchase), since at a transaction level a) the electric vehicle premium is declining quickly, and is not expected to be significant after 2025, and b) through that period, incentives cover the vehicle purchase premium (if any), especially in New York State where a rebate is available in addition to the federal tax incentive. Total Cost Of Ownership analysis has been conducted by others, but may not accurately reflect the impact of incentives or practical considerations evident in the vehicle purchase transaction.

[s] This savings calculation assumes that a sur-charge is added to EV charging KWhrs equivalent to the current New York State gasoline tax to fund transportation infrastructure, and that gasoline costs grow at reduced rates (compared with EIA projections) due to softening petroleum demand.

b) **Fueling costs represent the majority of these savings, representing approximately 85% of these benefits across all scenarios.** **In 2018, each electrically fueled mile will average 7.68 cents/mile (for a BEV), compared with an estimated 11.17 cents/mile for average gasoline vehicles. "Fueling" with electricity rather than gasoline cuts that expense by about half on average.** This study used extremely conservative assumptions about future gasoline prices, much lower than EIA projections due to an assumed softening in prices expected to result from the reductions of gasoline demand induced by widespread EV use. This results in the estimated fuel savings noted above being conservative. In the event that gasoline price increases in line with more bullish EIA projections, the savings for EV drivers "fueling" with electricity will be significantly higher than the savings represented in this study.

5.3.3 Economic Benefits Due to Avoided Environmental Impacts

There has been growing recognition that the emission of greenhouse gases (GHGs) results in a wide variety of adverse systemic impacts, leading to economic losses from extreme weather, changing agricultural patterns, economic disruptions, displacement of populations, impacts on fresh water, numerous public health implications, and other negative outcomes. These broader impacts have been quantified in the U.S. by the federal Inter-Agency Working Group on the Social Cost of Carbon. This group, which convened a wide array of government agencies and stakeholders, set a "Social Cost of Carbon" factor to be used as a standard in policy analysis. This study applied those parameters, as updated by the Working Group in August of 2016, against the CO_2 emissions projected by this study.[25] **The resulting savings represent the benefit that would accrue to society at large** (i.e. all electric utility customers, tax payers, and citizens) from reduced emissions of CO_2 and associated mitigation of negative impacts such as extreme weather, public health impacts, etc, as summarized below:

- Summed through 2035, the medium adoption case (Scenario Two) could avoid approximately $1.7B in costs due to reductions in CO_2 emissions, with a savings PV of $268M.

- CO_2 impact scales strongly with EV adoption level, with closely coupled impact on avoided CO2 related costs. This savings could be as low as $920M ($144M PV) in the low adoption case (Scenario One), and up to as high as $3.5B (PV of $516M) in total savings for the high adoption case (Scenario Three). The savings that result from reduced CO_2 emissions vary minimally between natural and managed charging scenarios.

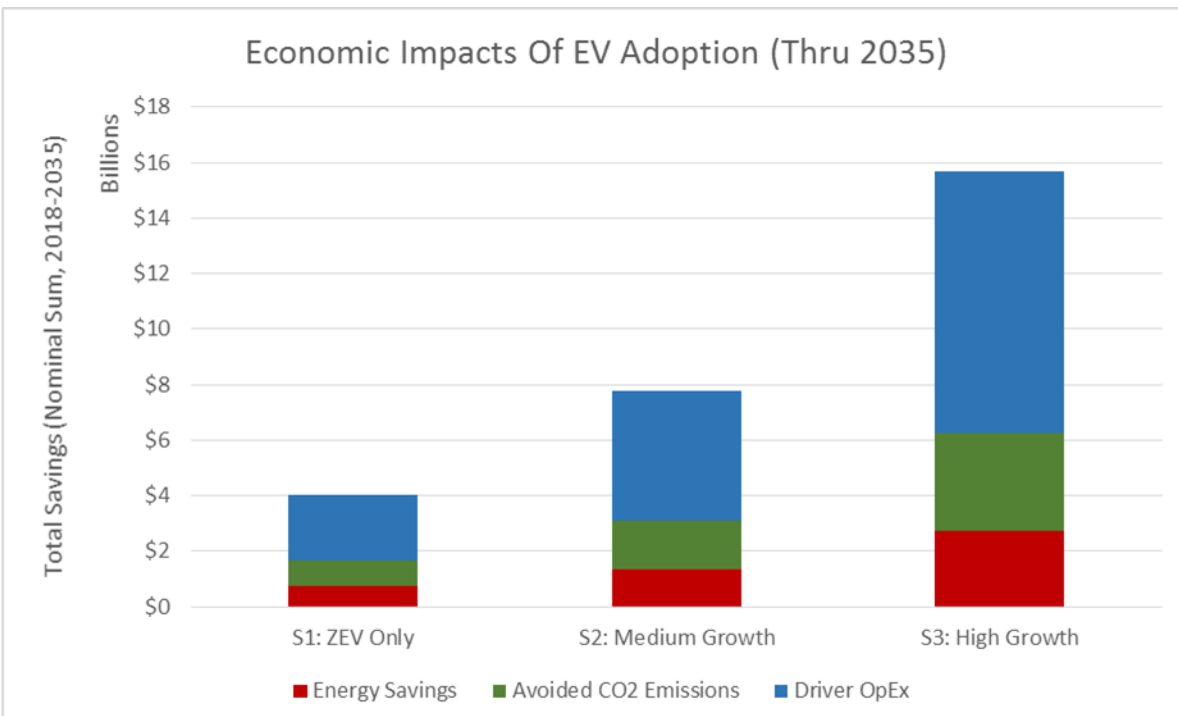
- Note that these estimates of the economic value of environmental impact consider only CO_2 emissions – the largest pollutant (by mass) impacted by vehicle electrification. Similar reductions apply for other pollutants (such as NOx, particulates, VOCs, etc), but those were not fully quantified in this study, and therefore not included in the environmental impact calculation. Adding those emissions reductions, as allowed under the federal protocol, would increase the projected economic benefit substantially.

5.3.4 Combined Economic Benefits

This study quantifies the economic impacts of increased EV use across three primary dimensions: (1) savings that accrue from reduced electricity costs (for electric utility customers overall), (2) reduced vehicle operating expenses (for EV owners), and (3) avoided costs based on reduced CO2 emissions (for society at large). Taken together, these three economic streams combine to provide significant economic value associated with increased EV use as summarized below:

- In the medium adoption case (Scenario Two, managed), total savings from all three benefit domains could be as much as $7.8B, delivering a PV of $1.2B, through 2035. These combined benefits scale in direct proportion with aggregate EV adoption. The following chart summarizes total gross savings for all three domains through 2035.

Figure 5.3.4 – 1: Economic Benefits Of EV Adoption



- **There may be broader economic uplift from these savings, which increases economic activity on Long Island.** As noted in more detail above, EV owners will spend less on vehicle operation. Similarly, electric utility customers will spend less on electricity (on a unit basis). Those savings represent enhanced disposable income that will have a multiplier effect on the economy when spent on other goods and services.

- A wide variety of other factors will likely contribute to additional savings, but where not quantified directly in this study or were modeled conservatively. Key examples include:

  a) The value of reduced emissions is based on CO_2 impacts only -- full consideration of all GHG emission reductions and other pollutants, as allowed under the federal protocol, would increase those benefits substantially.
  b) Managed charging only captures trough fill (i.e. adding additional load to underutilized periods at night, through one-way charging), not peak shaving (i.e. using electricity stored in vehicles to offset peak generation through two-way charging). If those impacts are included, cost efficiencies increase and electricity costs could decline further due to the "demand reduction" impact of EV use.
  c) Economic impacts of public health implications are probably significantly under-represented. The Social Cost of Carbon method only partially accounts for public health impacts.
  d) Since widespread EV adoption will reduce demand for gasoline, the cost of gasoline will likely decline even for owners of traditional gasoline powered vehicles. That benefit is not captured in this analysis.
  e) The model assumes no increase in existing capacity and transmission costs associated with the no-EV baseline. In the natural charging case, where EV charging increases the existing peak load conditions, those costs are in fact likely to increase. That means that the "no-EV baseline" costs could be much higher than captured in the existing benefit numbers, at least in the natural charging scenarios. That means that projected cost savings (relative to the no-EV baseline) may be under-estimated.

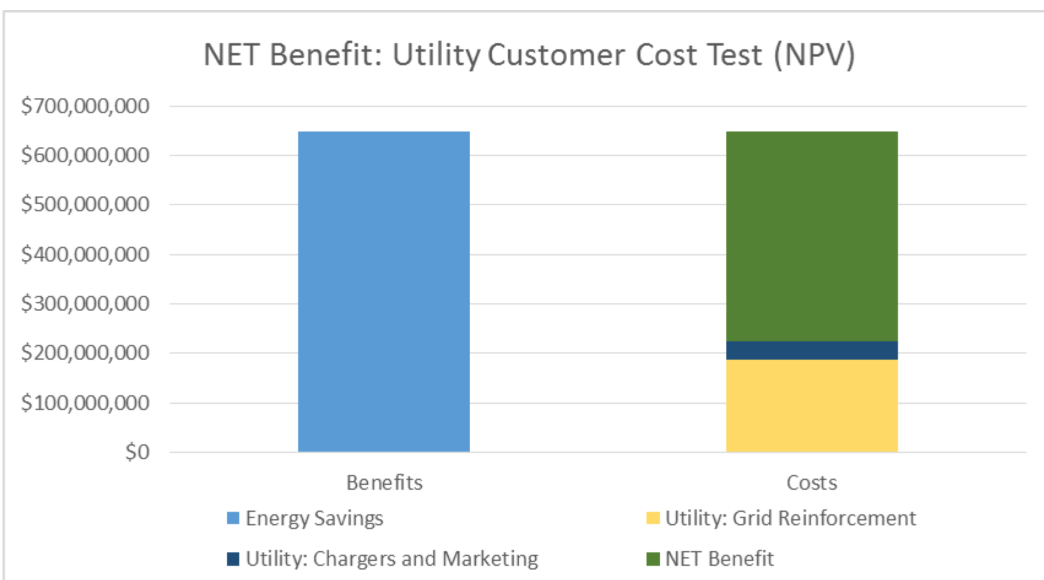
5.3.5 NET Economic Benefits

As detailed in the sections above, widespread adoption of PEVs will result in a variety of economic benefits, including reduced electricity costs, savings in operating costs for EV drivers, and avoided costs through reductions in CO_2 emissions. Achieving these high levels of adoption will require investments, however, including funding to implement the market development initiatives needed to stimulate growth, and reinforcement of the public grid due to additional EV-induced loading. To allow for determination of NET benefit – after applicable costs and investments as further defined below – the study estimated potential expenses associated with EV adoption. The study assumes utility implementation of a $25M market development program over the next five years, with larger scale investments (especially for grid reinforcement) through 2035. See Section 6 for details on the potential costs assumed for the NET benefit analysis.

As noted in the benefit sections above, the economic benefits impact different populations, including rate payers through reduced electricity costs, EV owners through reduced operating expense, and society at large through reduced emissions. The COSTS associated with market development and grid reinforcement also impact these populations differently – but utility related investments impact rate payers. Given this complexity, NET benefits are considered from two perspectives: a simple NET benefit test that balances potential costs recovered from utility customers through rates against savings realized by utility customers through reduced electricity costs, and a second test that more broadly considers the wider variety of benefits that also apply. In both cases, a discount rate of 5.5% was used for the Net Present Value calculation.

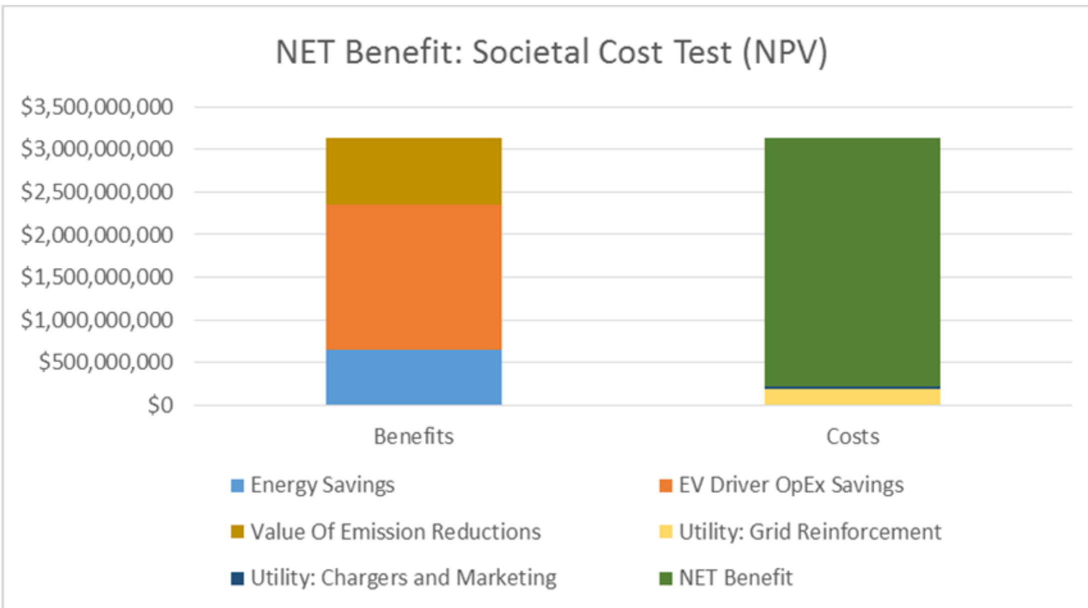
- **Utility Customer NET Benefit:** Given that some of the potential costs may be recovered from utility customers through rates, it is important to understand how benefits will accrue specifically to that population. A simple Net Benefit test was performed that sharply aligns potential rate payer costs with projected rate payer benefits as realized through lower electricity costs. Other potential benefits, such as savings realized by EV drivers or environmental benefits, are not included since they accrue to other populations. For the medium adoption case (Scenario Two), and assuming managed charging (which is an expected outcome from the market development programs), the savings realized by electric utility customers through reduced utility bills are sufficient to fully recover potential costs, with significant additional economic benefit remaining. **NET benefit is estimated to total $916M through 2035 (nominal sum), with an NPV of $422M, representing a B/C ratio of 2.87 (NPV basis). This represents This NET benefit will be realized by utility customers overall, not just the EV drivers. Investing in faster and more extensive EV adoption is an initiative that pays for itself even when only reduced utility rates are considered as a benefit.** The following chart summarizes the NET benefit realized when considering utility costs relative to rate payer benefits.

Figure 5.3.5 – 1: NET Benefits Based On Utility Customer Cost Test



- **NET Benefit For All Impacted Consumers:** As detailed in the sections above, widespread adoption of PEVs will realize a diverse range of benefits across a variety of beneficiary groups. A broader NET benefit test was developed, which compares potential utility costs compared with the full portfolio of EV-induced impacts as defined in Section 5.3.4 (including electricity cost savings, vehicle operating expense reductions, and the economic value of reduced emissions). **NET benefit for all impacted consumers is estimated to total \$6.0B through 2035 (nominal sum), with an NPV of \$2.9B[t].** The following chart summarizes NET benefit under this broader Societal Cost Test, but based only on consideration of utility based investments.

Figure 5.3.5 – 1: NET Benefits Based On Utility Customer Cost Test



5.4 Findings: Environmental Benefits

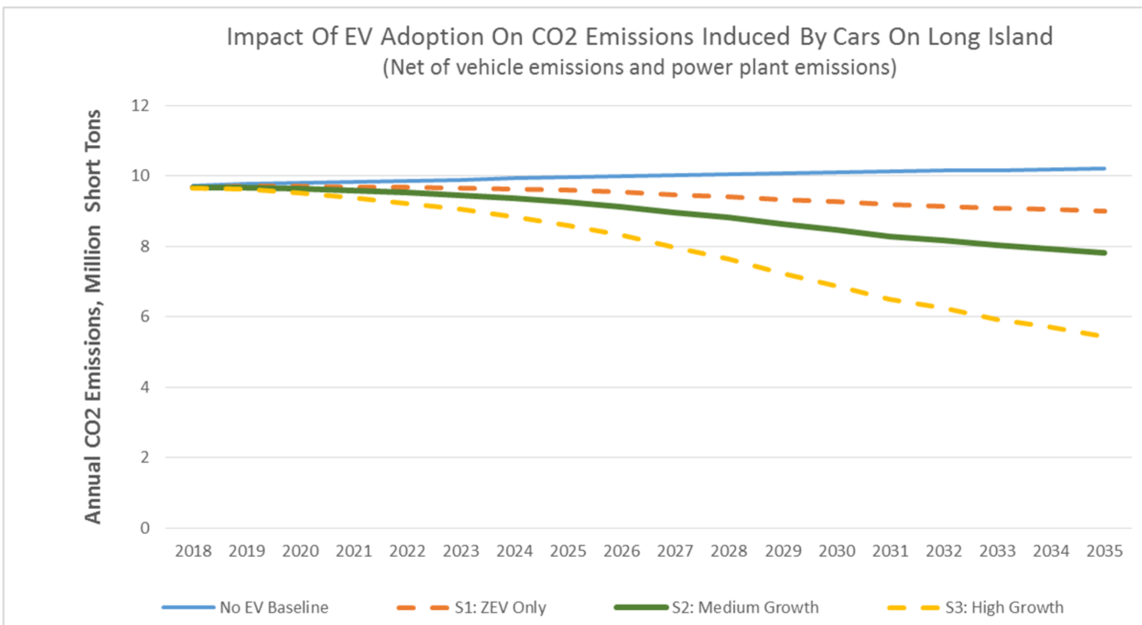
Powering a vehicle with electricity rather than gasoline means that tailpipe emissions go down (or disappear entirely), but power plant emissions go up. The net impact is beneficial, however, due to the use of relatively clean (especially carbon-free) generation on Long Island (and within NYISO), and the fact that power plants are more efficient than internal combustion car engines. Electricity generation also benefits from a much more diversified range of primary energy supplies (including nuclear, renewable energy, and fossil fuels) compared with the sole form of energy (petroleum) used in

[t] A broader Societal Cost Test would usually include a wide array of potential costs incurred by society at large as part of widespread EV adoption, which would increase the cost portfolio considered in this test. The scope of this analysis, however, was on a single utility and utility-related investments. In this case, this NET benefit is based the broader portfolio of benefits (experienced by Long Island residents) compared exclusively with utility investment. This comparison is included to demonstrate the comprehensive range of benefits utility investment could leverage.

traditional vehicles. The study estimated the NET impact on emissions at varying levels of EV adoption through highly detailed market dispatch simulation, and quantified the reduction in CO_2 emissions and other air pollutants.

- **Widespread EV adoption reduces transportation related NET CO_2 emissions dramatically, and this benefit scales strongly with growing EV use. Scenario Two (Medium growth) could decrease transportation related CO_2 emissions by 22% in 2035, and as much as 40% by 2050 (compared with emissions in 2018 in both cases). Achieving the highest levels of electrification (Scenario Three – High) could reduce CO2 emissions by as much as 57% by 2050 (compared with 2018). The following chart illustrates the reduction of NET CO_2 emissions for each scenario through 2035.**

Figure 5.4 – 1: CO_2 Emissions Impact Due To EV Adoption

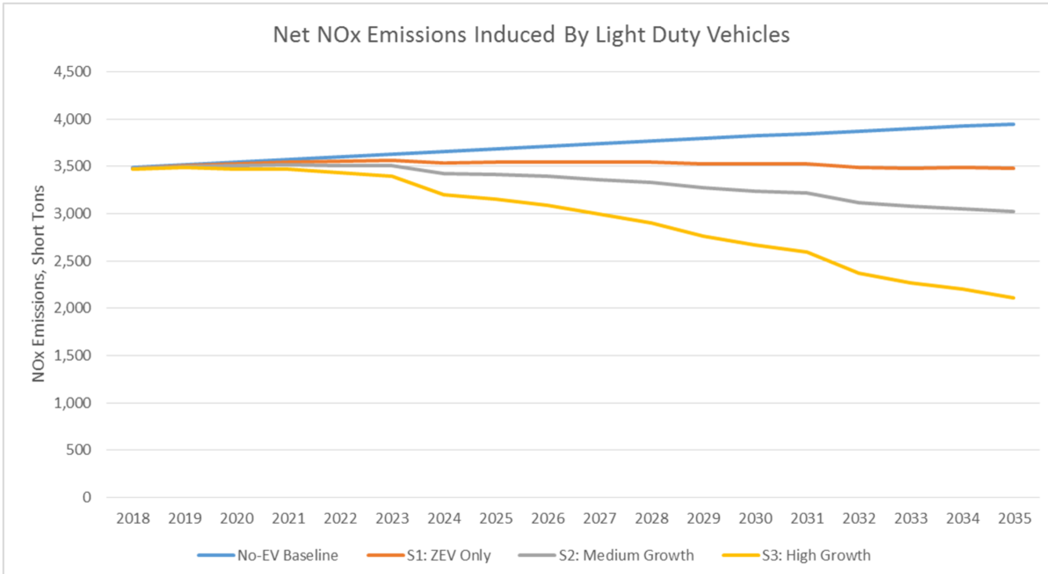


Emissions for the IRP-baseline track strongly with the Scenario One (low) adoption case.

- **CO_2 emission impacts are similar regardless of whether charging is scheduled naturally, or managed to be scheduled more optimally.** Although there is little impact on emissions, there are significant differences on economic benefit and grid loading impacts depending on whether charging is natural or managed. Longer term, under conditions where renewable energy generation has achieved high penetration and there is more renewable power available than load during the day, there may be emission benefits to expand the definition of “managed charging” to include coincidence with preferred energy sources.

- **Increased EV use also results in reduced NOx emissions on Long Island.** Scenario Two (medium adoption) could result in a 16% reduction in NOx emissions by 2035, increasing to as much as a 37% by 2050. If the highest levels of electrification are achieved (Scenario Three, high adoption), NOx could reduce by 44% by 2035, and as much as 68% by 2050. All reported reductions are relative to transportation-related NOx emissions in 2018. The following chart summarizes NOx impacts for various scenarios through 2035.

Figure 5.4 – 2: Nitrous Oxide Reductions Due To EV Adoption



- **SOx (mostly sulfur dioxide) emissions rise as a result of vehicle electrification, and this is one area where increased EV use is not positive.** SOx emissions from the combustion of gasoline is negligible, but there are SOx emissions from fuel combustion in power plants. Displacing mobile gasoline use with electricity therefore results in a net increase in SOx emissions. SOx calculations are considerably more complicated for a variety of reasons, but preliminary estimates from this study suggest that Scenario Two (medium adoption) will add approximately 236 tons of SOx emissions per year in 2035, and that incremental SOx emission generally rise with EV adoption levels. Note that the magnitude of emission for this pollutant is approximately 3,000 times smaller (in absolute mass) than CO_2 emissions. Further study on this issue is needed, including synchronization with New York DEC measurement and reporting methods. The negative implications of SO_2 increases wanes as generation becomes more renewable.

5.5 Findings: Impacts on the Utilities – Opportunities and Challenges

Although EVs are usually thought of as a transportation innovation, widespread adoption will also have a profound impact on our electricity systems, including the wholesale market, the transmission and distribution infrastructure, the operating profile (and optimization potential) of the grid, and the utilities themselves. Those impacts are a double-edged sword, including both opportunities and challenges. The study looked specifically at many of these impacts and was able to characterize a variety of significant implications. The opportunities arise from the positive impact that EV use could have on increased electricity use and the opportunity to use vehicle charging as a mechanism for overall load optimization. A utility may also face challenges due to increase EV use, due to the need to ensure responsible grid integration of vehicle charging infrastructure, and distribution system reinforcement that will probably be required long term.

This section explores both the opportunities and challenges faced by a utility associated with increase EV use. As noted in Section 4.3, many of the following conclusions are based on a detailed model of the distribution system that uses an idealized feeder profile that reflects the physical architecture of the distribution infrastructure on Long Island based on information provided by PSEG Long Island.

- **EV impacts on the electricity infrastructure will be minimal (but not zero!) in the short term, but significant impacts will begin to emerge at modest levels of adoption.** At the current time, the number of EVs is so small, and the electric infrastructure is so large, that EV charging implications are small and within normal utility system maintenance boundaries. EV charging is a relatively high power transaction within the residential setting, however, and at the "neighborhood level" where impacts will first be felt, stress conditions can materialize based on only a few clustered vehicles. These conditions become more likely once there is more than one EV per single phase distribution transformer (typically residential), which is assured to happen at about 6% EV penetration of the light duty population (between 2022 and 2026, depending on the adoption scenario). As noted in more detail below, these impacts can be predicted and moderated significantly through proactive policies. Although impact is modest and easily managed short term, those impacts will increase *quickly* and become more widespread after key aggregate adoption thresholds are reached (somewhere between 5% and 10%).

- **Vehicle charging will increase average residential electricity consumption (KWhrs) by at least a quarter for each vehicle in the home.** As noted in Section 5.3, most vehicle charging will be delivered at home, mostly overnight. This is a new residential energy use that will significantly change KWhr-energy consumption for that sector, especially at higher levels of adoption. Based on data developed in the study, an average EV will use approximately 2,700 KWhrs per year short term, increasing to 3,750 KWhrs per year by 2035 as a wider range of vehicles become available. Typical homes on Long Island range from approximately 4,900 KWhrs/year to 19,500 KWhrs/year, with an average around 11,000 KWhrs/year. Annual residential KWhr-consumption will therefore increase 25% - 34% for each EV charged at home, with that number doubled for a typical Long Island household with two vehicles. **This outcome implies that widespread adoption, when two EVs per home (or more) become common, is similar to increasing the number of homes on a residential circuit by about half from an energy consumption (kwhr) perspective.**

- **Unit costs for providing electricity will decline as a result of EV adoption.** Wholesale unit costs will go down since a greater fraction of total energy generated (MWhs) is during lower cost, off-peak times (i.e. the ChIPE factor described in Section 4.3). Meanwhile, relatively fixed capacity, transmission, and distribution costs are diluted over a larger MWh volume. For Scenario Two (medium), assuming optimal scheduling of vehicle charging, **electricity unit costs could decline by as much as 12% by 2035 compared with the existing IRP baseline[u], and this impact scales strongly in proportion to EV adoption level.**

[u] Note that these wholesale impacts from EV charging are relative to the IRP-baseline, which already includes substantial EV charging. This wholesale cost improvement should therefore not be interpreted as the economic

- **EV adoption will increase utility revenues, even though unit costs are declining.** If Scenario Two (medium) levels of EV adoption are achieved, **total revenues for the utility and electricity suppliers will be $763.7M higher through 2035** (in nominal dollars, compared with the IRP baseline) resulting from increased electricity use.

- **Daily charging requirements will require a relatively modest amount of energy on average, typically less than 10 KWhrs.** Although longer range EVs have 40-100KWhr battery packs, it will be rare for the vehicle to require a full charge in a single session. Instead, most drivers will only need to replenish the KWhrs required by the daily travel pattern (commute, errands, etc). With average daily driving in 2018 estimated to be 29.2 miles, and EVs currently achieving 3.5 miles/KWhr, daily charging requirements will average just over 8.3 KWhrs in the short term, growing slightly as larger EVs become common and consumers with longer drive patterns begin driving EVs.

- **Vehicle charging will change residential KW-load profiles dramatically, potentially increasing the peak loading of an average home by a factor of two to four.** EV chargers, especially the higher power units becoming popular (7.2KW Level 2), are relatively high-power devices compared to most household equipment. Average peak loading for a typical Long Island home is 3-5KW. Adding a single 7.2KW charger to a home that normally peaks at 4KW is therefore a significant change in load, with aggregate impacts on distribution infrastructure overall.

- **Loading impacts aggregate through the distribution system, with primary impact on the secondary transformers, many of which will need to be upgraded or re-configured eventually as EV adoption increases.** As outlined in Section 4.3, the study included development of an idealized feeder model based on actual configuration and baseline loading parameters from PSEG Long Island. Unlike the economic and emissions analysis, which depends on aggregate EV loading impacts, the feeder model characterizes physical conditions within a neighborhood and upward through the substation. A wide variety of transformer sizes, baseline loading, and charger configurations were evaluated, leading to identification of EV adoption thresholds that create stress conditions, and where in the feeder (from single phase distribution transformer up to the sub-station) those overload conditions emerge. Across all baseline load and neighborhood configurations (i.e. home to transformer ratios), the primary point of EV charging induced stress was the single phase distribution transformer – often at relatively low levels of adoption. In some neighborhoods, even a single EV would exceed capacity of the local transformer. More typically, adoption between 10% and 30% created stress conditions. This analysis suggests that significant upgrades will be required to single phase distribution transformers throughout the system, although when those upgrades are required varies significantly depending on whether natural or managed charging profiles emerge.

- **Managed charging may also help defer the point when charging-induced upgrades are needed.** As noted above, as EVs cluster on a given single phase distribution transformer, at

benefit of EVs, but the INCREMENTAL impact of EVs if Scenario Two levels are adoption are achieved about the EV adoption assumptions already built into the IRP-baseline.

some point an equipment upgrade or transformer/feeder re-configuration will be needed. The timing of that impact – and the number of EVs that can be handled within a given neighborhood – is very sensitive to natural vs managed charging. In most cases, managed charging essentially doubles the number of EVs that can be accommodated on a given configuration before stress conditions emerge. This dynamic doesn't eliminate the need for reinforcement eventually, but it can defer the timing of that upgrade significantly and spread it out over time.

- **These system reinforcements may be forced by EV loading conditions, but they are also motivated by other factors and can potentially bring other benefits.** Utilities are upgrading and re-configuring distribution transformers (and feeders) all the time, and many of them are in need of attention as part of routine maintenance, repair, and load matching and balancing. The EV loading noted above becomes an additional, but significant factor that should (eventually) influence reinforcement plans for the distribution system. In addition, the upgrades required can help address other needs, especially enhancements related to better instrumentation and controls, and architecture upgrades related to resiliency. The system reinforcement motivated by EV charging requirements are best considered as part of overall distribution system evolution, with upgrade investments targeted to deliver multiple benefits.

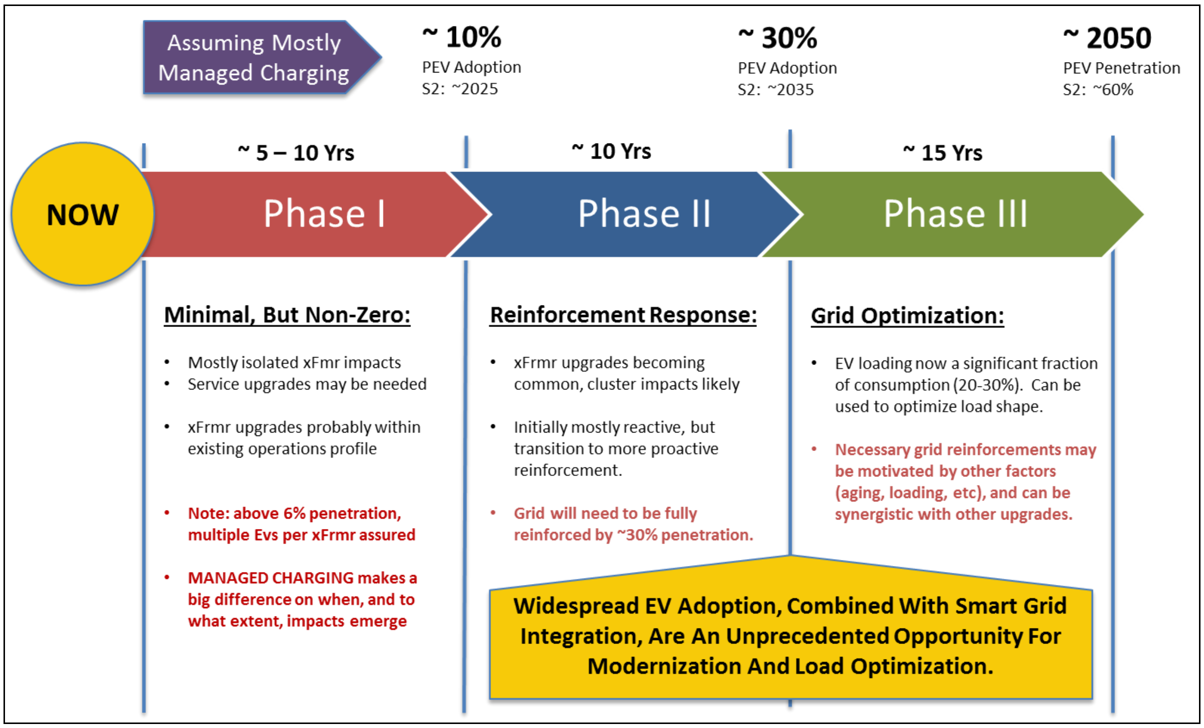
- **Because the average residential charge duration is relatively short, and there is some flexibility on exactly when (or how fast) charging takes place overnight, managed charging can be used to reduce loading impacts significantly.** Residential EV charging is both a RISK and an OPPORTUNITY. As noted above, if left to natural charging patterns under which most drivers plug-in when getting home from work, KW-loading impacts could be severe – at a time of day that is already a peak load on the system (6:00-8:00 PM). However, most residential charge transactions will average 2 hours (or less) each night. **This creates a large opportunity for Managed Charging, since it is feasible to scatter or spread those charge transactions over an 8-hour period overnight, thereby reducing the KW-load impact by approximately a factor of four.** Natural charging therefore compounds existing peak conditions, whereas managed charging programs can not only avoid incremental peak load, but can also shift most EV charging consumption to off-peak times to maximize economic advantages. The study modeled loading impact differences under both Natural and Managed conditions, and quantified the significant benefit of proactively ensuring Managed charging conditions. Section 5.5.1 quantified the economic differences between Natural and Managed charging.

- **Treating vehicle charging as a partially dispatchable load represents an unprecedented opportunity for load profile optimization.** Beyond avoidance of incremental peak induced by residential EV charging, managed charging programs represent significant opportunities for actively shaping the overall load profile to achieve optimum outcomes, either in physical loading or in economics. Since EV charging is a relatively large amount of electricity (~16% of overall electricity consumption under Scenario Three by 2035), and most of that consumption is naturally biased during off-peak times (at home, at night), and there is some flexibility in when those typically short charge transactions take place, sophisticated managed charging programs can actively shape off-peak load to achieve optimum profiles. These opportunities are most mature after the market achieves high levels of EV adoption, and would benefit from parallel advancements in EV-charging related billing features and potentially AMI infrastructure as well (potentially, in addition to interfaces with charging infrastructure, as noted below).

- **Simple managed charging solutions can evolve to more sophisticated Vehicle-To-Grid systems in the medium term, and the beneficial impact of those systems could increase the beneficial impacts already quantified.** The benefits of managed charging noted above assumed simple one-way charging technology, such that only the start time of charging, and potentially staggering of charge-starts and throttling of charging power, is used to achieve the optimum aggregate power impact overnight. Emerging Vehicle-To-Grid (V2G) technology takes this solution one step further by allowing TWO WAY transactions – energy can flow into the battery from the grid, or into the grid from the battery. While there may be some benefit of this technology during the day (mostly at commercial locations), the primary opportunity is in residential settings at peak time. A majority of vehicles arrive home and plug-in between 6:00 and 8:00 PM, a time period which overlaps with the typical system peak. As noted above, most of those vehicles will have partially charged batteries – in a vehicle with 60KWhrs of storage, using 10 KWhrs for the daily commute, it will plug-in during peak time with 50KWhrs (minus some reserve) available. If half the light duty fleet on Long Island (~ 1 million vehicles) was plugged in during peak time, and most vehicles had 20KWhrs of "spare" energy it could share with the grid through a V2G transaction, that would represent around **20GWHRs of dispatchable storage available during peak time through residentially connected vehicles.** That is enough to completely support Long Island's peak load (of ~5.2GW) for over three full hours, or to support half the load for approximately 6 hours. While standards to implement V2G technology are still emerging, and it will be at least a decade before there are enough EVs in the market to make a difference, the potential for peak time residential V2G applications are substantial enough to merit strategic priority. Simple managed programs developed in the short term can be evolved to support more advanced V2G solutions in the medium term. As that opportunity matures, EVs can be used not just to "fill the trough" during off-peak times, but to "shave the peak" as well.

- **There is no single "utility response" to the EV opportunity, since impacts and needs will evolve over time.** The key conclusions outlined above, when taken together, suggest three distinct phases of utility impact and potential engagement. The transition between these phases depends on when critical "impact thresholds" are crossed as determine by aggregate EV adoption. In the first phase, which EV adoption is below 5%-10%, impact is relatively minimal and probably within normal operating profiles for maintenance. Past that point, as the number of EVs exceeds the number of single phase transformers (in Long Island, around 5% aggregate EV penetration), broader systemic impacts will emerge quickly. During this second phase, more proactive reinforcement programs are probably required, up to approximately 30% EV penetration. By that point, most reinforcement will need to have been completed, and attention can focus on the large EV load that is now present on the system and the use of that "dispatchable load" to optimize grid loading and maximize benefits. The following diagram summarizes these three phases of EV impact from a utility perspective. This is not intended to be a complete strategy for any given EV market or utility, since overall utility response to the EV opportunity will vary by territory, strategic goals, regulatory influences, investment priorities, infrastructure condition, etc. Instead, this three-phase framework outlines typical focus areas expected to emerge based on the impact-results of the study, and how those priorities shift over time as a function of aggregate EV adoption.

Figure 5.5 – 1: Phases Of Utility Impact Due To EV Adoption



- **Implications For Commercial Circuits:** Although the economic and emissions analysis considered the aggregate impact of all types of charging (residential, DC fast charging, commercial Level Two, etc.), the distribution system analysis focused on characterizing implications for residential charging. This focus was motivated in part by the fact that a relatively small fraction of charging energy is delivered through non-residential segments. In addition, based on discussions with utility representatives, public charging installations are typically either behind larger scale commercial meters, or (especially for DCFC) on new dedicated service that has been engineered to meet service requirements. As a result, implications for commercial circuits are not expected to be significant short term. This aspect of EV charging merits further consideration, however, especially regarding commercial Level Two (such as workplace) and multi-family applications within existing service settings, or support for more demanding fleet applications (such as delivery trucks or buses). Certain charging applications – such as "charging barns" for taxis or car sharing services, electric buses (either at the depot or en-route), long range truck charging (which may require MW+ charging units), or very high power public DCFC – may require specialized support on commercial circuits. See section 5.6 for further details about the potential impacts of advanced mobility solutions.

5.6 Findings: Potential Impact Of Advanced Mobility Innovations On Findings

The PEV adoption scenarios and associated impact assessments assumed a continuation of existing vehicle ownership and usage paradigms. The study specifically assumes that consumers switching from an existing gasoline fueled vehicle to an EV don't change the way they drive materially, particularly regarding average number of miles driven per year. All the grid impact and economic implications are based on current EV usage statistics. These results are likely to be fairly representative through 2025.

In parallel with vehicle electrification, however, there are a variety of other trends that are dramatically changing private vehicle ownership. Advanced mobility solutions including ride hailing, car sharing, vehicle subscription services, and autonomous vehicles have the potential to completely change the way consumers meet their mobility needs, with particular impacts on vehicle ownership paradigms. The study explored how these trends might intersect with vehicle electrification, and how the impacts reported above might change as a result.

Some key trends – like ride hailing or autonomous driving – might change WHO is doing the driving, but not how much driving is being done. There is some opportunity for consumers that own vehicles today, especially if they live and work in an urban area, to abandon private vehicle ownership and depend exclusively on either of these options instead. In that case, their previous travel pattern is likely retained, but with a different driver. The significance of that trend, however, is unclear at the current time, at least through the 2025 timeframe. This is especially true since much of Long Island is either sub-urban or rural.

The bigger potential impact comes from car sharing, or similar innovations like ownership subscriptions. Two potential impacts were considered: CONVERSION scenarios, in which existing vehicle owners abandon vehicle ownership and rely on a shared vehicle instead, or GROWTH scenarios in which consumers that do not have mobility options today increase their travel due to the availability of shared vehicles. Based on available statistics about vehicle sharing, the conversion scenario does not appear to change the miles traveled significantly. The number of vehicles required to provide a given amount of mobility goes down, but the utilization of each shared vehicle is much higher. Widespread adoption of shared vehicles, under the conversation scenario, does not appear to change the number of miles driven, and therefore has little impact on the energy implications due to electrification.

Under the growth scenario, however, the number of miles driven could increase. A variation of Scenario Two was developed that assumed that half of the households that currently don't own a vehicle began using a shared vehicle with average travel patterns. That scenario has minimal impact on the results, since vehicle ownership on Long Island is already very high.

Based on this initial examination of a variety of advanced mobility options, there appears to be minimal impact on the energy implications. This outcome is primarily a result of the fact that although these new paradigms may profoundly affect how vehicles are owned or who does the driving, they do not change the fundamental amount of travel being supported, and that is the primary influence on transportation energy requirements (electrified or not).

HOWEVER, these innovations may have a profound impact on how vehicle charging is accomplished. The primary model assumed a continuation of existing ownership structures, with the majority of private vehicles being charged at home in the evening. A dramatic increase in ride hailing, or car sharing, could potentially result in vehicles being charged in more commercial settings, including during the day. This could result in increased need for high power fast charging, dedicated “community charging” lots or “car barns”, and increased charging on commercial circuits (rather than residential). These aspects of emerging advanced mobility trends merit deeper consideration.

6 Potential Utility Programs And Anticipated Costs

As part of the study, the team considered a wide variety of utility programs and/or investments that could be implemented to achieve more widespread PEV adoption and to ensure responsible grid integration of vehicle charging infrastructure. In the case of Long Island, the actions of both the state (through formal goal setting and related efforts) and NYSERDA (especially vehicle purchase rebates and infrastructure charging development programs) already have a positive impact on PEV adoption within the territory. As summarized in Section 3.3, these conditions have resulted in PEV sales on Long Island that are relatively strong, but the experience from other states suggests that additional market development investment could increase PEV uptake by further reducing consumer adoption barriers. The primary opportunity for utility contribution (short term) to enhanced EV adoption is by addressing charging infrastructure needs and consumer awareness building, since that is so closely related to existing utility functions and recognized responsibility, along with the longer term need to ensure sound grid integration.

The team focused on achieving Scenario Two levels of uptake, consistent with what other leading states have achieved. Given the context of other market development measures already in place, especially expectations that NYSERDA would address the need for additional public charging, the top priorities for utility support were a) development of programs to encourage managed charging so as to maximize economic benefit and avoid adverse grid integration issues, b) continuation and potential growth of other “routine charging” applications such as workplace charging, and c) utility sponsored consumer awareness programs. These actions were expected to align strongly with existing utility roles and to leverage utility strengths.

Long term, as PEV penetration becomes more significant, managed charging creates an opportunity to a) minimize potential harmful loading impacts from vehicle charging, and b) use vehicle charging as a “dispatchable load” that can be used to optimize overall wholesale market and distribution system loading profile. The platform by which these goals can be realized will likely change over time as the technology and markets evolve, but there are two elements of managed charging that are expected to remain important over time: a) a flow of usage and control information between the charging infrastructure and the utility, and b) incentives that encourage vehicle owners to charge their vehicles at optimal times. Strategies that have been used in other jurisdictions to allow relatively quick implementation of residential managed charging programs, with an eye toward establishing a long term program, include:

- Leveraging use of networked Level two charging equipment and services from competitive solution providers. Identify a “certified” set of solutions for use in the utility offer.
- In addition to promotion directly to utility customers, partner with other stakeholders and market participants, especially automobile retailers.
- Establishing a basic integration point for participating residential charging installations, potentially through an outsourced services contract. Long term, direct integration with an intelligent device that meters/controls the charging transaction will be required.
- Provide off-bill incentives to encourage consumer charging at optimal times.
- Use outsourced integration services and off-bill incentives for early implementation and learning, then migrate to more tightly integrated systems and rate design as appropriate longer term.

The team defined an initial five year utility program focused on EV market development, operating from 2018 to 2022. This program builds on the workplace charging program already offered by PSEG Long Island, as follows:

- **2018: Early programs and foundation building ($800K)**
    - Develop detailed implementation plan for 5-year program, including offer designs, operational plans, budgets, and regulatory filings as needed.
    - Design residential managed charging offer for launch in 2019. Primary focus will be on establishing managed charging platform, and development of financial incentives to encourage charging at optimal times.
    - Continue workplace charger program as currently implemented.
    - Develop and implement consumer awareness programs to increase consumer understanding of EV availability and benefits.
    - Establish coalitions and partnerships to a) create synergy with consumer awareness building efforts, and b) ensure strong public DCFC availability through others (especially NYSERDA).
    - Continue to develop EV-focused tracking and planning processes, especially for system loading impacts, combining access to external data sources (like vehicle registrations and NYSERDA data) and using expanded AMI infrastructure.
    - Purchase 8 fleet PEVs for learning and awareness building.

- **2019: New Program Launch ($2.375M)**
    - Launch residential managed charging solution.
    - Expand consumer awareness programs.
    - Expand other private charging offers as appropriate, with most likely focus area being solutions for multi-family housing.
    - Begin detailed impact tracking and assessment.

- **2020: Program Scaling ($4.425M)**
    - Assess program successes, identify further needs, make beneficial adjustments.
    - Expand program availability as results dictate.
    - Ensure readiness for system impact tracking and response.

- Build updated EV assumption into revised IRP – make EV-trends part of detailed planning.

- **2021: Focus On System Impacts ($8.2M)**
  - Continue availability and expansion of successful programs.
  - Significant increase of transformer impacts expected, ensure appropriate response.

- **2022: Assessment And Future Expansion ($9.2M)**
  - Sustain momentum during final year of initial 5-yr plan, especially managed charging.
  - Plan second 5-year program as market needs and results dictate.

The estimated costs for this five year utility program is $25M, with a primary focus being on laying the foundation for managed residential charging, workplace charging, and consumer awareness building. An additional $25M program was assumed as a program-continuation placeholder from 2023 through 2035, with focus expected to be on consumer awareness building, expansion of managed residential charging infrastructure, and other targeted low power (L2) charging segments as dictated by future market needs.

As summarized in Section 5.5 above, the study completed an evaluation of grid integration issues related to EV charging infrastructure, and especially the need for upgrades to support EV charging loads. Those results suggest that while the infrastructure impact is minimal (within routine maintenance parameters) in the short term, loading impacts will become significant medium term, with primary stress conditions especially on single phase distribution transformers. The cost program assumes replacement of approximately half the existing single-phase distribution transformers (about 70,000 units), at a pace determined by EV adoption, by 2035. That represents an estimated $353M in upgrade costs (spread over 10 to 20 years) for the medium adoption case (Scenario Two) with managed charging. No grid reinforcement, beyond isolated impacts that can be handled within routine maintenance programs, is assumed through 2022.

The market development and infrastructure costs are assumed to be planned programs that could potentially be recovered from utility customers through rates and both those recovered costs are assumed in the cost model. The following table summarizes the high level budget assumptions for this analysis.

Figure 6.0 – 1: Utility Program Annual Budget

Budget Line	2018	2019	2020	2021	2022	Total
Market Development						
Customer EVSE Incentives (L2)						
a) Original "100 port" Workplace Program ($4000/port)	$195,000	$137,500	$50,000	$17,500	$0	$400,000
b) Expanded Multi-Year Workplace Program ($4000/port)	$0	$400,000	$1,600,000	$3,200,000	$1,600,000	$6,800,000
c) New Residential Smart Charging Program ($500/port)	$0	$484,053	$762,384	$1,677,244	$2,958,020	$5,881,701
Sub-Total: EVSE Incentives	$195,000	$1,021,553	$2,412,384	$4,894,744	$4,558,020	$13,081,701
Smart Charging Platform Costs (rounded up)	$24,000	$1,230,000	$1,600,000	$2,750,000	$3,700,000	$9,304,000
Cost Of Off-Bill TOU Incentive (2 cents/kwhr in window)	$0	$56,537	$145,584	$341,486	$686,983	$1,230,590
Marketing, Outreach, Awareness Building	$50,000	$50,000	$125,000	$200,000	$200,000	$625,000
Utility Fleet Vehicles	$375,000	$0	$0	$0	$0	$375,000
Other Program Costs (contingency)	$156,000	$16,910	$142,032	$13,770	$54,997	$383,709
Sub-Total: Development	$800,000	$2,375,000	$4,425,000	$8,200,000	$9,200,000	$25,000,000
Grid Reinforcement	$0	$0	$0	$0	$0	$0
Total Investment:	$800,000	$2,375,000	$4,425,000	$8,200,000	$9,200,000	$25,000,000

In summary: the NET benefits summarized in Section 5.2.5 included the initial $25M market development program from 2018 through 2022, an additional $25M placeholder for a continuation of market development programs though 2035, and grid reinforcement (upgrading about half of existing single phase transformers) through 2035. Grid reinforcement expenses are not expected to be required until after 2022, with EV loading issues (if any) up to that point handled as part of routine maintenance.

This high level program represents short term priorities for utility offerings, with considerable flexibility for evolving and responding to market needs and results. The initial prioritization is strongly shaped by current market needs and the expected actions by other market participants, with a focus on making sure utility efforts are not duplicative. Medium term, there are a variety of additional opportunities that may be considered for utility support as market needs dictate:

- Support public DC Fast Charging as needed and appropriate
- Scaling up managing charging of all types, active load optimization
- Explore Vehicle-To-Grid opportunities
- Supporting infrastructure needs for underserved segments
- Support specialized charging infrastructure where needed (car barns, buses, etc), especially as new vehicle use and ownership paradigms emerge
- Support medium-duty and heavy-duty electrification infrastructure

7 Conclusions and Recommendations

This study characterized current EV market conditions in Long Island, and explored the potential for expanded EV adoption within the territory. Strategic opportunities for the utility to support this emerging market were identified, as well as potential challenges that result from the impact of vehicle charging on energy markets and utility infrastructure. Costs and benefits have been quantified under a variety of EV growth scenarios. Expanded EV adoption has a variety of highly beneficial impacts, and this portfolio of benefits is robust across a range of adoption scenarios and cost assumptions. Key conclusions include:

1. PSEG Long Island has taken some initial steps to support the growth of the EV market within its territory, in parallel with actions by others including formal goal setting and ZEV framework participation by the state, a vehicle purchase rebate, and infrastructure development incentives. Sales are already beginning to grow based on those incentives and the availability of second generation vehicles that offer longer range and lower prices. But as demonstrated by other jurisdictions with higher levels of adoption, there is an opportunity to further increase uptake over the sales rate emerging naturally. Achieving the medium growth adoption path (Scenario Two) identified in this study would result in approximately 34% of new sales being fueled through a plug, and conversion of about 22% of the fleet, by 2035.

2. EV adoption brings both economic and environmental benefits. Even after accounting for the estimated costs of market development programs and potential grid upgrades that may be required, there are NET economic benefits that accrue to utility customers through lower electricity costs. Additional economic benefits are realized by EV drivers through reduced operating costs. EV adoption also improves air quality, especially through CO_2 and NO_x reductions. Under the medium growth case (Scenario Two), benefits exceed costs and deliver substantial NET benefits. The state's existing goals for CO_2 reduction can be effectively realized through high levels of EV adoption.

3. Physical impacts on the grid are relatively modest in the short term, and well within existing operating profiles. However, loading conditions will become evident at relatively low levels of adoption (aggregate 6%), and will emerge quickly past that point. There will likely be the need for significant reinforcement, especially of single-phase distribution transformers, by the time the market achieves ~30% adoption. Managed charging, which encourages residential charging to happen at more optimal times, can help amplify economic benefit, and both defer and reduce impacts on generation, transmission, and distribution assets.

4. Given actions already being taken by others (especially the state, NYSERDA, and the competitive market), the primary opportunity for utility involvement (short term) is through low power (level two) charging infrastructure for routine "fueling" of EVs with electricity. This focus aligns with natural utility strengths and responsibilities, and is consistent with the need to ensure appropriate integration of charging infrastructure with the grid. The primary focus area is on managed residential charging, which helps grow EV adoption by addressing consumer needs for a home charging solution, but also a) minimizes the loading impact on the grid short term, and

b) creates an opportunity to use vehicle charging as a dispatchable load that enables loading optimization.

5. A preliminary five year plan has been identified for initial utility program focus, which leverages utility strengths and complements the efforts of other market participants. That $25M program focuses on managed residential charging, a continuation of the workplace charging program, and a strong consumer awareness building campaign. Other potential opportunities for utility program support have also been identified medium term, depending on market conditions.

Given these results, the study team concludes that EV adoption can be expanded and accelerated on Long Island, and that there are strong NET economic benefits (after accounting for costs), as well as environmental benefits, that justify those market development efforts and grid reinforcement costs.

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