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Electric Vehicles In New Jersey
Costs And Benefits

The Opportunities, Impacts, and Market Barriers To Widespread Vehicle Electrification In New Jersey

Prepared For ChargEVC By Gabel Associates, Inc.
& Energy Initiatives Group, LLC.

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1 Executive Summary

Personal mobility is at the heart of modern life in New Jersey. While the last century has seen an explosion in private vehicle use, and society has reaped the benefits of that mobility, the costs and consequences of burning fossil fuels in our cars has become clear. Fortunately, an alternative is now available: electric vehicles that are "fueled" by electricity rather than gasoline.

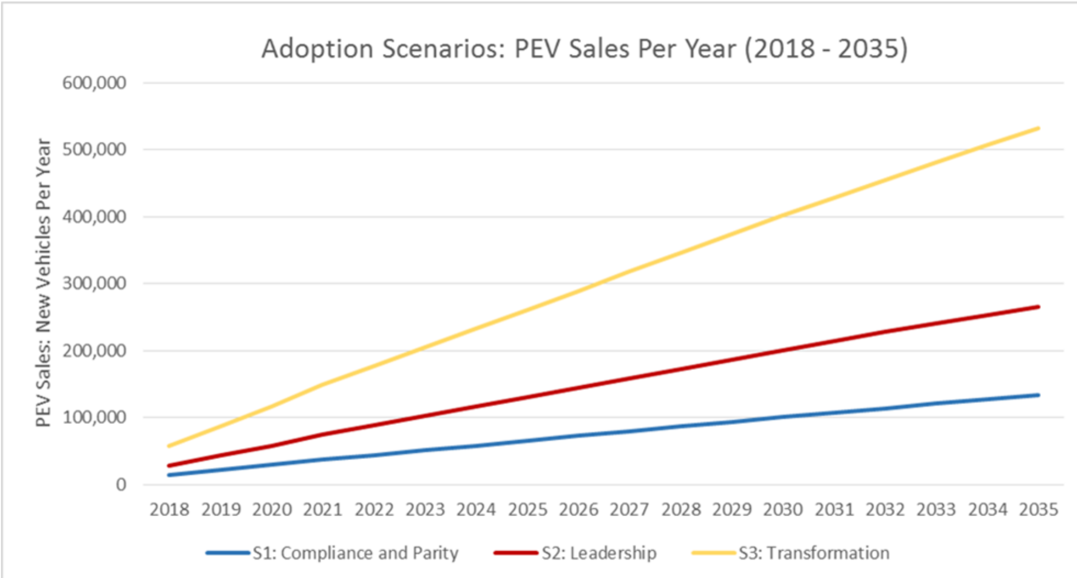
Electric Vehicles (EVs) have been around since the advent of the horseless carriage, but only recently have they become a viable alternative for mainstream consumers. A new generation of vehicles are now available that have longer range and lower prices – and consumer acceptance for "vehicles with a plug" is beginning to emerge. This technology innovation is being reinforced by a growing focus within the automotive industry on vehicle electrification, and further encouraged by strong supporting policies around the globe. New Jersey has taken initial steps to develop the state's EV market, and sales have recently begun to grow. However, New Jersey currently lags leading states in per capita penetration and other benchmarks, suggesting that there is significant untapped opportunity for additional EV market growth in the State.

Market conditions are in place for a strong increase in EV adoption in New Jersey, especially if investments are made to eliminate market barriers and encourage accelerated acceptance by mainstream consumers. These investments could be based on a combination of utility support, state-enabled programs, and leveraging of private capital. But are those investments worthwhile? What are the costs and benefits related to stimulating EV adoption in New Jersey beyond the modest growth already underway? This study was commissioned by ChargEVC, a coalition of diverse stakeholders united in their support for accelerating and expanding the use of EVs in New Jersey, to answer these important questions. Please see Appendix A for a list of ChargEVC members.

The study provides a comprehensive assessment of current EV market conditions in New Jersey, 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 conditions in NJ.

Analysis is based on three adoption scenarios: low, medium, and high trajectories that span basic compliance with existing New Jersey policies (the Zero Emission Vehicle mandate), up to maximum electrification as required to achieve the Carbon Dioxide (CO_2) emission reductions associated with New Jersey's Global Warming Response Act (GWRA), i.e. the "Transformation Scenario". The middle growth path, which is approximately halfway between these two extremes, represents the "Leadership Scenario", and is consistent with the higher rates of EV penetration achieved by other leading states. The study determined the feasibility of achieving this Leadership trajectory, and identified specific costs and benefits associated with that level of EV adoption along with lower and higher adoption rate sensitivities through 2035 and 2050.

The following chart summarizes the three EV adoption scenarios that were the basis of the study:



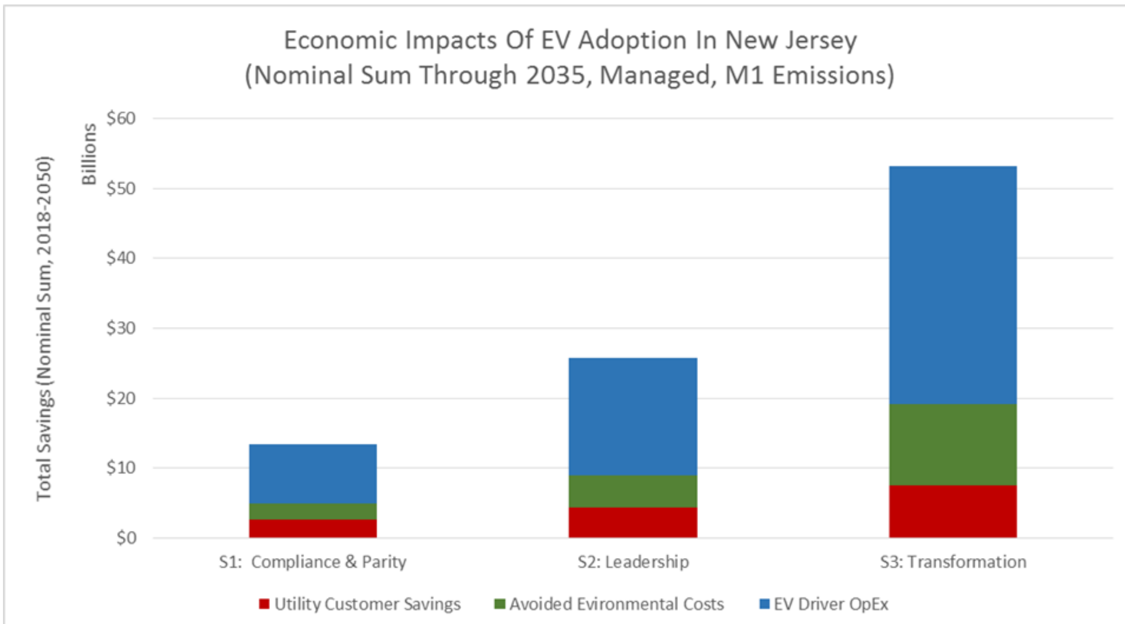
The study concludes that there are significant benefits associated with increasing EV use, and it quantifies the opportunity for increasing the pace and scale of EV adoption so that those benefits are realized faster, to a greater degree, and more equitably. An outline of key findings is summarized below:

- **Untapped Opportunity and Potential for Growth:** The New Jersey EV market has untapped adoption potential and with additional support, the state could increase adoption levels significantly. Based on a comparison of New Jersey to leading states that have achieved higher per-capita PEV penetration**, investment in additional market development could reinforce natural growth by at least a factor of two**.

- **Net Savings for Utility Customers:** Vehicle charging, especially if done at off peak times, creates cost efficiencies that deliver substantial economic savings for utility customers, even after accounting for potential investments in market development and infrastructure reinforcement. **Utility customer savings exceed costs by a factor of 1.99 through 2035, with savings averaging $156.7M annually. NET savings total over $2.9B by 2035 (NPV of $976M), and grow to a total of over $17.1B by 2050 (NPV of $3.8B) if Leadership Levels of EV adoption are achieved**. These net benefits potentially impact all New Jersey utility customers (not just EV owners), reflect only benefits delivered through lower electricity costs, and increase at higher levels of EV adoption.

- **Other Significant Benefits:** Beyond the direct impact realized by utility customers through lower electricity costs, widespread EV adoption brings a variety of additional economic benefits. EV owners realize reduced operating expense, especially due to the lower costs of fueling their vehicles with electricity rather than gasoline. For EV owners in particular, the economic value is significant: putting two EVs into the garage of an average New Jersey household will create **$1,440 of additional disposable income in 2018, and these savings will average $1,983/year through 2035**. Net savings on operating expense totals $8.4B through 2035, growing to $34.8B by 2050 under the leadership scenario. There is also economic benefit to reduced environmental emissions, and even in the case where only CO_2 reductions are valued, those savings total $2.3B through 2035, and $13.0B through 2050.

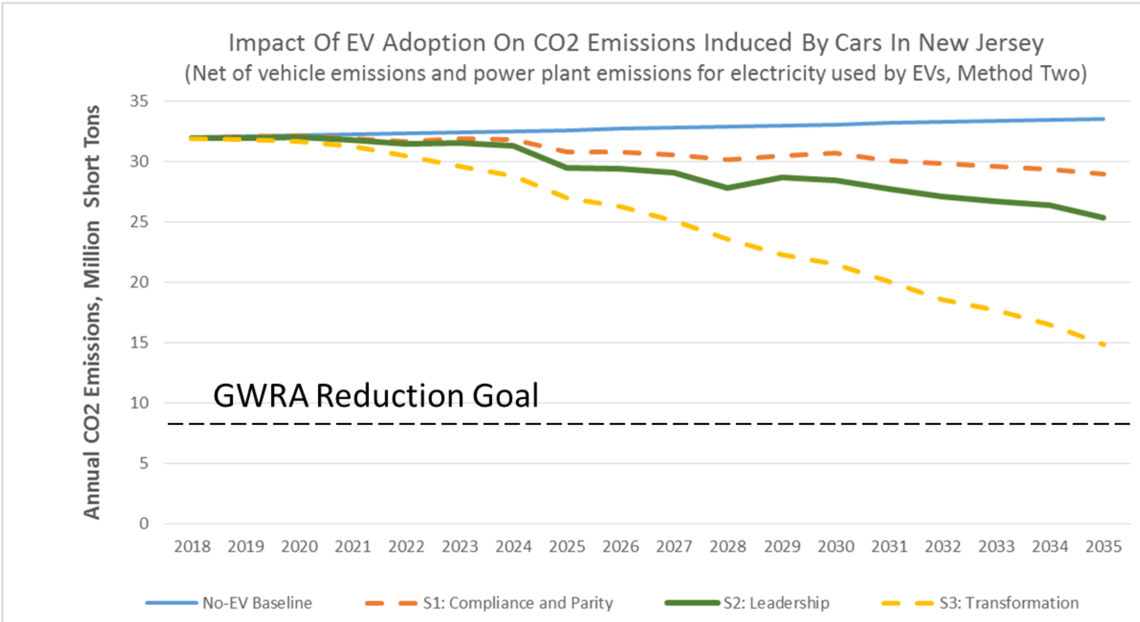
- **Broad Portfolio of Societal Benefit:** As noted above, EV adoption enables a comprehensive portfolio of economic benefits realized by multiple beneficiaries. EVs are unique in the broad and diverse range of beneficial impacts they induce. Combining utility savings, reduced vehicle operating costs, and the value of lower emissions, these benefits (without consideration of potential costs) accrue to **$25.7B by 2035 (PV of $11.5B) for the Leadership case, and as high as $53.2B (PV of $23.7N) by 2035 for the maximum electrification case**. The following chart summarizes these three economic benefit streams, for each adoption scenario, through 2035.



- **Total Societal Benefits Far Exceed Potential Costs:** A formal Societal Cost Test (SCT) analysis indicates that overall societal benefits far exceed potential costs over a broad range of impacted populations. In the case where Leadership levels of EV adoption are achieved and vehicles charge at optimal times, overall societal benefit exceeds costs by a factor of 2.19 through 2035, delivering an average net benefit of $942.6M annually. **Society-wide benefits, net of all incurred costs, total over $24.0B by 2035 (NPV of $11.3B), and grow to a total of over $98.7B by 2050 (NPV of $50.6B)**.

- **Environmental Benefits:** EVs deliver widespread environmental benefits, especially regarding the CO_2 emissions that drive climate change and nitrogen oxide (NO_x) emissions that directly affect public health. Air quality improves with EV use since tailpipe emissions are displaced by reduced emissions at power plants. **The study found that in 2018, every electrically "fueled" mile in New Jersey emits 69% to 79% less CO_2 than an average gasoline fueled mile**. Widespread PEV adoption delivers the deep reductions in vehicle related CO_2 emissions needed to achieve New Jersey's greenhouse gas reduction goals. Without electrification, CO_2 emissions from light duty vehicles will rise from 31.9 million tons in 2018 to an estimated 35.4 million tons in 2050. Instead, **with approximately 82% of the fleet electrified under the transformation scenario, emissions from light duty vehicles (net of both tailpipe and induced power plant emissions) will decline**

by 22.3 million tons. These air quality improvements, especially NO_x, will have their largest impacts in the urban core and along high volume travel corridors, which means that those benefits will accrue in higher proportion to disadvantaged and environmental justice communities. The following chart summarizes CO_2 emission reductions for each of the three adoption scenarios through 2035:



- **Utility and Energy Market Implications:** Widespread EV use will create deep systemic changes in electricity use, especially if EV charging can be encouraged to happen mostly at off-peak times. This change has profound implications for the electric utilities and the customers they serve.

  - Because EV charging is a large incremental load, and since scheduling of that load can be flexible and mostly occur off-peak, **EVs represent an unprecedented opportunity to optimize overall grid loading and introduce significant cost efficiencies**.

  - Wholesale unit costs will go down since a greater fraction of total energy generated (MWhrs) is during lower cost, off-peak times. Meanwhile, relatively fixed capacity, transmission, and distribution costs are diluted over a larger MWhr volume. At Leadership levels of EV adoption, assuming optimal scheduling of vehicle charging, **electricity costs could decline by 9.6% by 2035, and 13.1% by 2050**.

  - If Leadership levels of EV adoption are achieved, **total revenues for utilities and electricity suppliers statewide will be $2.8B higher through 2035 and $16.7B higher by 2050** (in nominal dollars, compared with the no-EV baseline) resulting from increased electricity use.

  - Detailed modeling of physical impacts of EV adoption on the distribution infrastructure indicates that the system will be able to tolerate modest impacts in the short term, within existing operating parameters for maintenance and repair. As statewide adoption exceeds 5-10%, however, the system will begin to experience more widespread impacts. By approximately 30% fleet penetration, significant distribution system reinforcement will be required. Most of these impacts occur at the single phase distribution transformer level, and **by approximately 2035 (depending on the adoption rate), most of these transformers may need to be upgraded or reconfigured.** Those upgrades will increase grid capacity and potentially resiliency as well, and can deliver additional modernization benefits that are funded by increased electricity sales. The estimated costs associated with these reinforcements are included in the NET economic benefit noted above, and **even with high levels of reinforcement, utility customer savings significantly exceed estimated costs**.

- The study demonstrates significant differences in NET benefits between EV drivers charging any time they please (i.e. the "natural" case in which drivers begin charging when they get home from work), and managed charging programs that encourage vehicle charging at times that are more optimal for the grid. Managed charging can push load increases past peak periods and thereby avoid incremental transmission and wholesale power plant capacity requirements that would likely otherwise be imposed by widespread EV adoption. Economic benefit to electricity customers is also increased by shifting more load to off peak times. **In the Leadership case, managed charging delivers an additional $1.2B in total savings compared with natural charging through 2035 ($4.3B by 2050). If implemented early and effectively, managed charging would defer utility system impacts significantly.**

This study provides a rigorous quantification of both the costs and the benefits associated with expanded and accelerated EV adoption in New Jersey, including net savings (after accounting for estimated costs), lower emission rates, progress toward key state goals, and other strategic benefits. The Roadmap developed separately by ChargEVC and released in September 2017 (http://www.chargevc.org/wp-content/uploads/2017/09/ChargEVC_Roadmap.pdf), recommends a variety of market development programs that are intended to address current market barriers, accelerate growth, and achieve these benefits for New Jersey residents.

2 Introduction

Like most of the developed world, mobility is the foundation of New Jersey's economy and the lifestyle of its people. Whether it is commuting to work, moving goods and materials, or visiting the Jersey Shore, transportation is an essential feature of modern life in the Garden State. However, along with the enormous positive impacts delivered by fossil fueled vehicles over the last century, there have been significant costs and consequences.

Now there is a better way. Due to the rapid development of Electric Vehicles (EVs), New Jersey drivers can 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. The market for EVs in New Jersey is in its early stages, and there are unprecedented opportunities to expand and accelerate the adoption of EVs and their associated benefits.

This study was commissioned by ChargEVC, a not-for-profit coalition of automotive retailers, utilities, technology companies, original equipment manufacturers (OEMs), local governments, environmental, community, labor advocates and others working to accelerate the transition to electrically fueled transportation in New Jersey. Please see Appendix A for list of ChargEVC members. The study explores the opportunity for EV adoption in New Jersey and quantifies the wide range of costs and benefits that apply statewide. It is intended to provide a rigorous and independent analysis to support policy development and market improvements in New Jersey.

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. This study report is a companion to the New Jersey Market Development Roadmap published by ChargEVC in September 2017.

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 in New Jersey

The use of EVs is exploding globally, and due to its dense geography and demographics New Jersey provides fertile conditions for realizing the benefits that widespread use of these new vehicles will bring. At the current time, however, New Jersey lags other leading states in developing the early stage EV market. This section explores the current state of the New Jersey EV market and quantifies the potential for expanded and accelerated adoption of EVs.

3.1 Why Now: New Market Developments

The Electric Vehicle is not new. In fact, many of the first automobiles were electric, and by 1900, a third of all vehicles on U.S. roads were driven by electric motors[1]. Thomas Edison, working in his New Jersey laboratory, partnered with Henry Ford to develop a competitive vehicle powered by electricity. 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. Electric cars saw a resurgence in the 1970s after the oil embargo, and again in the 1990's with GM's innovative EV1. Nonetheless, despite their enduring potential, EVs have not been attractive alternatives to well established fossil fueled vehicles for mainstream consumers.

Thomas Edison With An Electric Vehicle At His New Jersey Laboratory

The automotive industry faces a new inflection point, however, and electrification has recently become a primary theme of transportation innovation. Motivated by the desire to diminish dependence on fossil fuels, a renewed focus on reducing Greenhouse Gas (GHG) emissions, and the positive consumer experience provided by a new generation of innovative vehicles, EV adoption is now growing at an unprecedented rate, both globally and in the U.S. 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.

The EV market now mirrors the early days of the automobile market itself: the earliest automobiles had limited range, drivers suffered from "range anxiety" due to limited fuel availability, and their high costs made them an extravagance for the rich. But in 1908, Henry Ford introduced a vehicle that was reliable, practical, and priced at a level that almost any family could afford. Within just two decades, the Model T and other similar vehicles fully displaced horses (especially in urban settings).

Similarly, EVs over the last 10 years have suffered from limited range, high costs, and acceptance by a small segment of affluent early adopters. Within the last year, however, that has changed: a "second generation" of EVs has become available that – similar to the Model T - combines practical design, longer range, and lower cost. These vehicles are offered by leading automotive companies, and were designed as mass market vehicles with the potential for large scale production. Aggressive new market entrants, such as Tesla and BYD, have made vehicle electrification a competitive necessity globally. EVs are at their "Model T Moment," and the market is beginning to grow at unprecedented levels.

Several factors suggest that EVs are 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. These vehicles offer over 200 miles of range[a], at a price between $30-$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[2]. 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.

  These three vehicles are available now, but nearly every major automobile manufacturer has announced similar vehicles for sale over the next several years.

- **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 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

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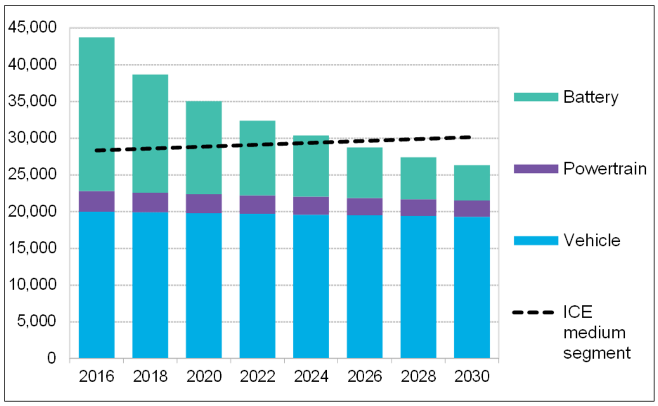
[a] The 2018 Nissan Leaf offers 150 miles of range, available in the U.S. beginning in the first quarter of 2018, with an upgraded version capable of 225 miles of range available in the third quarter of 2018.

will be competitive with traditional internal combustion vehicles across all vehicle types. The cost impact of reduced battery costs is being augmented by increased industrial scale and growing global competition. There is emerging consensus from both auto makers and industry analysts that EVs will achieve price parity by 2025, possibly sooner for some vehicles. The chart below, from Bloomberg New Energy Finance[3], illustrates the projected cost of EVs compared with traditional Internal Combustion Engine (ICE) vehicles.

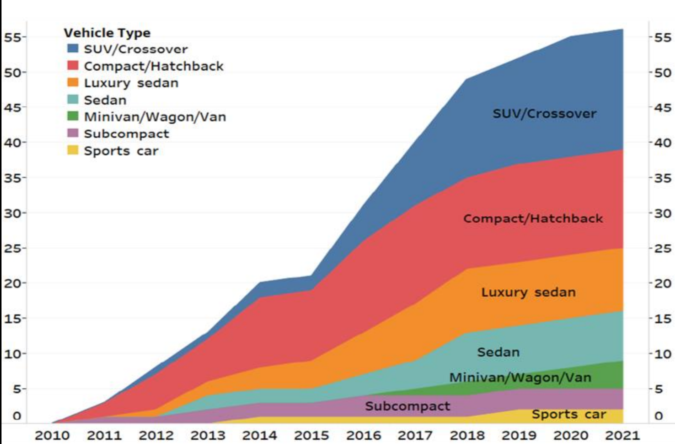
Average Price Of Electric Vehicles
(Vehicle Purchase Price, Nominal US $)



Source: Bloomberg New Energy Finance

- **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 any automaker. Most global OEMs have announced significant commitments to overall vehicle electrification, and 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 that point in time[4]. As summarized in the chart below, 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.[5]

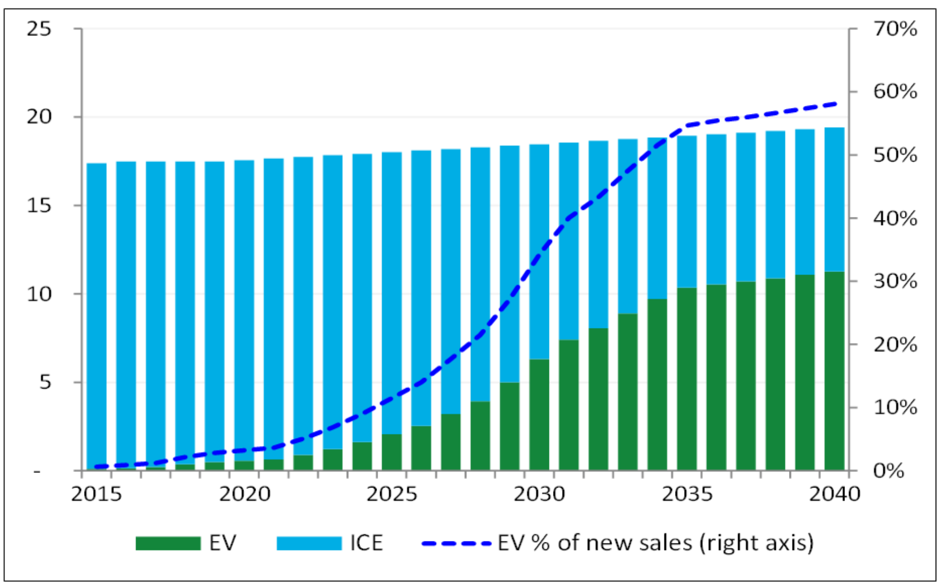
Number of electric vehicles (EV) by type



Source: EPRI

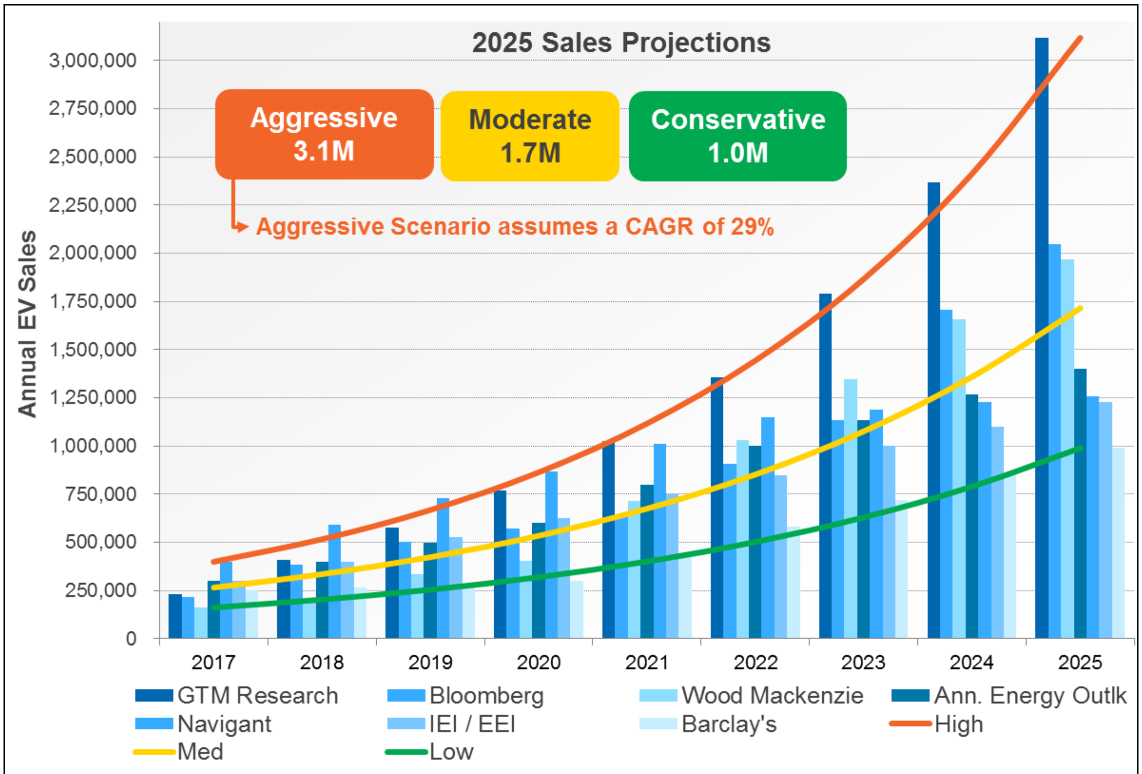
- **Global Policy Drivers:** New vehicle innovations and industry focus have been reinforced by extraordinary levels of policy commitments intended to ensure widespread EV adoption, especially in Asia and Europe. A tipping point has been reached in 2017, with several countries now committing to mandates that will eliminate the sale of new petroleum fueled vehicles by 2025 – 2040, including Norway[6], the Netherlands[7], France[8], India[9], and the UK[10]. China[11] (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. Similar forecasts have been provided by a variety of typically conservative analysts, including Morgan Stanley and the Boston Consulting Group. The chart below shows projected PEV adoption as a fraction of overall light duty vehicle sales in the U.S (left axis), and the associated percentage fraction of sales (right axis), recently released by Bloomberg New Energy Finance.

Annual U.S. Light Duty Vehicle Sales
(million vehicles)



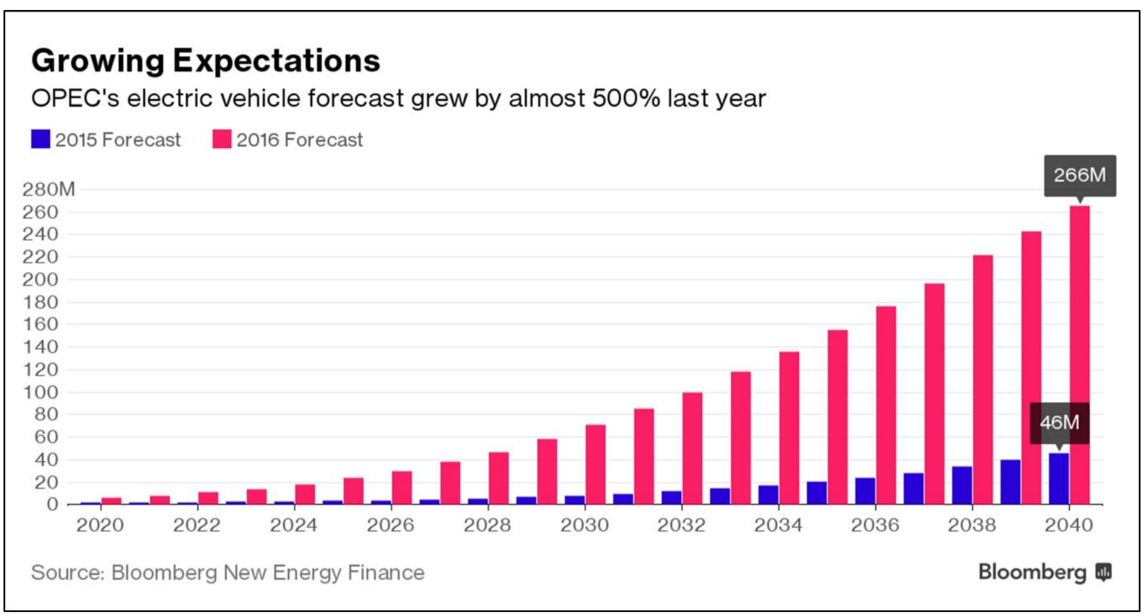
Source: Bloomberg New Energy Finance

- **EV Growth Forecasts:** In response to automotive industry focus and global policy drivers, market analysts are projecting significant growth for the EV market in the US (and globally). The following chart summarizes a range of industry projections, spanning conservative to aggressive outlooks. Even the most conservative trends project at least a million plug-in vehicles on the road over the next seven years. Note that recent US sales growth has been consistent with the CAGR noted for the aggressive case.

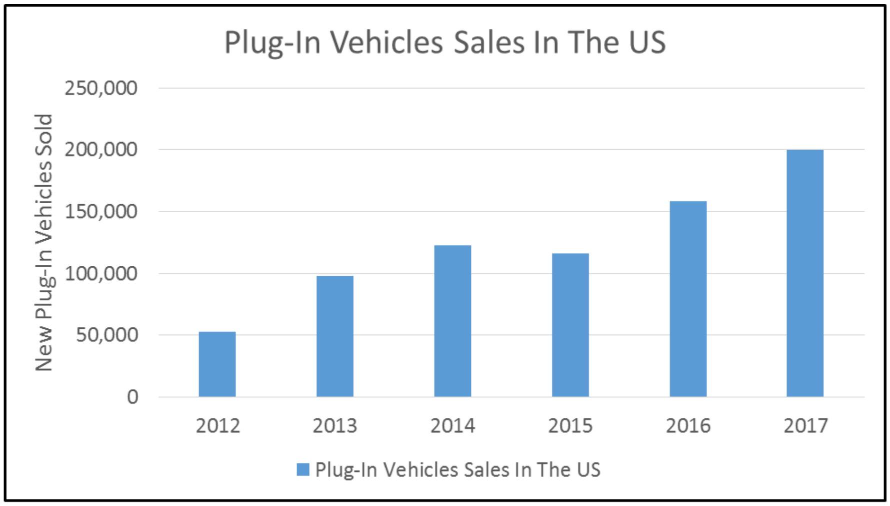


Based on analysis by Atlantic City Electric. Sources embedded in chart.

These industry projections have become incrementally more bullish on EVs and their adoption rates over the last three years. 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[12]. The following chart summarizes how OPEC projections have changed from 2015 to 2016.

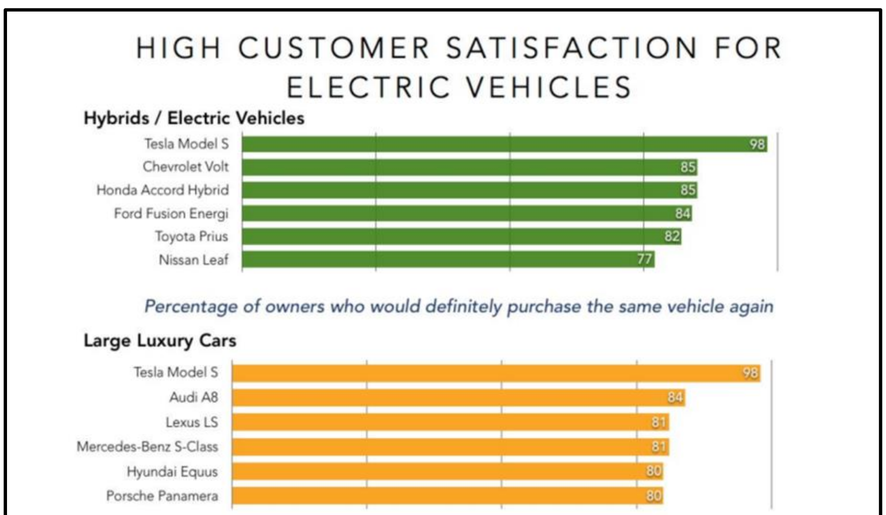


- **US Market Results:** The dynamics outlined above – including the availability of second generation vehicles with longer range and lower price, increased industry focus, and strong policy drivers that affect all global automakers – have combined to encourage strong plug-in sales in the U.S. over the 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.[13]



Source: InsideEVs.com

- **High Levels of Consumer Satisfaction:** As of the end of 2017, nearly 800,000 PEVs have been sold in the U.S[14]. Many of those vehicles have been on the road for at least three years, and consumer surveys have consistently demonstrated high levels of consumer satisfaction – on par with luxury class vehicles at much higher price-points.



Source: InsideEVs, based on Consumer Reports

In summary: the availability of second generation vehicles with longer range, 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. 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 in New Jersey.

3.2 New Jersey Market Conditions

EVs have been selling in New Jersey since the introduction of first generation vehicles in 2010, and based on the market drivers noted in Section 3.1, sales have started to accelerate. Compared with other leading states, however, New Jersey has so far implemented few policies, programs, or market development initiatives to achieve the higher level of sales that are likely possible. This section outlines New Jersey's market conditions, recent EV sales results, and opportunities for further growth.

3.2.1 Existing Market Policies and Programs

New Jersey has implemented a small number of measures intended to encourage PEV adoption, as summarized below:

- **Sales Tax Exemption:** The New Jersey legislature implemented a state sales tax exemption for Zero Emission Vehicles (ZEVs, N.J.S.A. 54:32B-8.55) as defined under the California Zero Emission Vehicle program. The incentive applies to any ZEV that is purchased, leased, or rented after May 1, 2004. This is a significant incentive that eliminates what would otherwise be several thousand dollars in tax for a purchased vehicle. The value of this incentive is captured at the point of sale if the customer supplies a "sales tax exemption waiver" (ST-4) form. The New Jersey Department of Environmental Protection (NJDEP) maintains a list of vehicles that are eligible for earning the Sales Tax Exemption.

- **Section 177 Waiver (ZEV Compliance Program):** As allowed under the federal Clean Air Act, New Jersey opted-in to the California Zero Emission Vehicle compliance program. New Jersey 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. The NJDEP is responsible for tracking credit compliance and banking in the state. New Jersey's participation in the ZEV program helps in setting state adoption goals, but has a real and significant practical implication for the PEV market: automobile manufacturers prioritize allocation of PEVs to ZEV states like

New Jersey, thereby making stronger PEV adoption feasible. The ZEV program in New Jersey is covered in more detail in Section 4.1 below.

- **DEP Workplace Charger Incentive:** The NJDEP, in collaboration with the BPU, has sponsored an incentive program by providing rebates to employers that install PEV charging infrastructure for use by their employees after June 15, 2016. Current incentive levels are $250 for a Level One charger, and up to $5,000 per Level Two charging station. The program is part of the NJDEP's overall "Drive Green NJ" program[15], and given high levels of interest, the NJDEP currently intends to continue providing this incentive subject to funding availability. This incentive is available state-wide.

- **Utility Workplace Charger Program:** One New Jersey electric utility (PSE&G) currently provides an incentive for the installation of workplace chargers. This program targets commercial entities and supports the installation of chargers for use by employees. The program provides the charger equipment free of charge, and the customer pays for installation and all subsequent electricity use. Eligibility requirements apply, and this program is only available within the PSE&G territory. The program was funded to support up to 150 workplace charger installations.

- **Competitive Market Activity:** Electric vehicles require new infrastructure for charging, and the competitive markets – funded mostly through private capital – have launched efforts to serve that new market demand. A wide variety of companies now operate in New Jersey that can serve both private and public charging needs in a variety of segments. Some companies focus on hardware and/or services offerings, while others offer financing solutions for certain applications. In some cases, charging infrastructure companies have partnered with automobile manufacturers or other "channel partners" to provide the infrastructure required.

- **Market Planning and Development Efforts:** A variety of loosely coupled state entities and other organizations have been working over the last decade to assess and improve the EV market in New Jersey.

    - The State of New Jersey, primarily through state agencies such as the New Jersey Board of Public Utilities (NJBPU) and the NJDEP, have begun to integrate PEV considerations into state plans. Particular examples include the State's Energy Master Plan[16] (most recently published in December 2011 and updated in December 2015), the formation of an Alternative Fuel Working Group led by the NJBPU, and recently, the formation of a NJBPU Electric Vehicle Working Group to provide stakeholder input on various regulatory and policy matters. The NJBPU published a "pre-decisional draft" that was focused on Alternative Fueled Vehicles in August 2016, and commissioned an assessment and report on the New Jersey Plug-In market by the Regulatory Assistance Project, which was published in May 2017.

    - The NJ Clean Cities Coalition (led by Chuck Feinberg) has been active in the state for approximately a decade, and published an EV infrastructure development plan in October 2011.

- Several local environmental groups, especially Sierra Club, Environment NJ, and the Association of New Jersey Environmental Commissions (ANJEC) have been promoting PEVs over the last few years. Environment NJ published its "Driving Cleaner" report in June 2014, and a guide promoting "50 steps to carbon-free transportation" in the Fall of 2016.

- The local metropolitan planning authorities, including the North Jersey Transportation Planning Authority (NJTPA) covering north Jersey and the Delaware Valley Regional Planning Commission (DVRPC) covering the New Jersey region around Philadelphia, have become active in PEV matters, and NJTPA recently sponsored an initiative focused on municipal EV readiness.

- Sustainable Jersey, a not-for-profit organization focused on supporting schools and municipalities in sustainability advancements statewide, introduced Electric Vehicle actions in 2014 which have helped socialize the potential for municipal support of PEV market development by local government units.

- Most recently, a new coalition called ChargEVC has been formed that focuses specifically on PEV market development in New Jersey. The ChargEVC coalition, based on consensus building within its diverse stakeholder membership, published a roadmap for New Jersey Plug-In Vehicle Market Development in September of 2017. ChargEVC commissioned and funded the research project upon which this report is based.

- **Commercial Electric Vehicle Availability:** After an initial ban, New Jersey legislation allows Tesla to sell vehicles through its "factory direct" business model (i.e. not through independent retailers), but with limitations and requirements. Many consumers, however, will look to their traditional car retailer for purchase of a PEV. That commercial environment remains relatively immature compared with some other ZEV states, making widespread EV market growth difficult. The national Sierra Club completed a study of EV buying experiences across a variety of states, including New Jersey, and found that in many cases the consumer buying experience was not conducive to EV adoption[17]. New Jersey scored in the lowest category ("Barely Moving") on factors such as sales staff being knowledgeable about incentives and prominent display of EVs on the lot. The report attributes these conditions to automobile OEM policies as well as the retailers themselves. That situation has started to change in New Jersey, especially under the leadership of the NJ Coalition of Automotive Retailers (NJ CAR), which has been focused on increasing awareness and retailer support for this new class of vehicles. NJ CAR is a ChargEVC member, and is working on several programs to improve the EV buying experience and develop other supporting policies and programs.

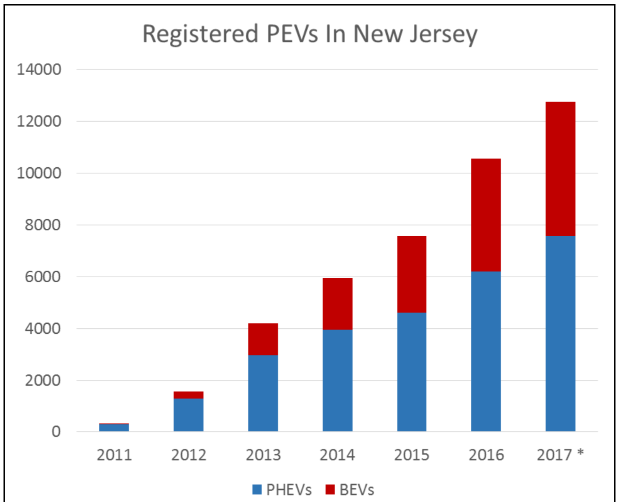
- **Other Market Development Stimulants:** As of January 2018, New Jersey has not taken many of the actions pursued by other leading states to encourage EV adoption. Key programs or policies pursued in other states, but not available in New Jersey, include:

    a) Setting of formal state goals;
    b) Authorization of state agencies to develop the EV market and encourage consumer adoption and infrastructure development;

c) Vehicle purchase rebates or other economic incentives (beyond the state sales tax exemption);
d) Potential non-monetary incentives;
e) Statewide public charging infrastructure development programs;
f) Programs to address private charging needs, especially in key under-served segments such as multi-family housing;
g) Engagement of the electric utilities in the widespread development of charging infrastructure where appropriate (beyond the workplace charging pilots underway), in conjunction with robust development of competitive solution provider markets;
h) Engagement of municipalities and other stakeholders in market development and promotion; and
i) Statewide programs for consumer awareness building and education.

3.2.2 Historical Sales Results

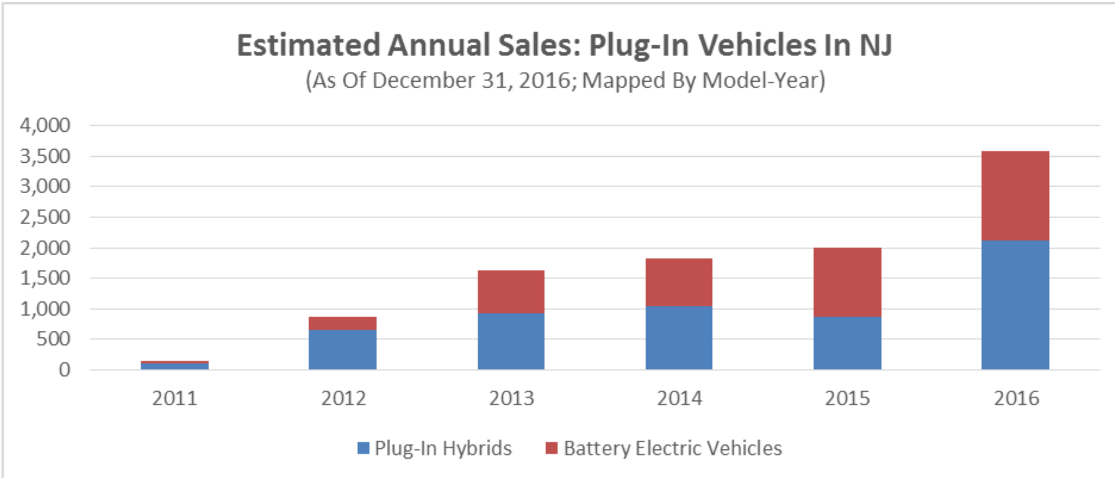
Based on vehicle registration data provided by the NJDEP, the following graph summarizes the growth of the plug-in fleet in NJ since 2011. This data captures only road-certified plug-in vehicles.



Based on data provided by NJ DEP from vehicle registration data.
* 2017 results reflect registrations through the end of June 2017.

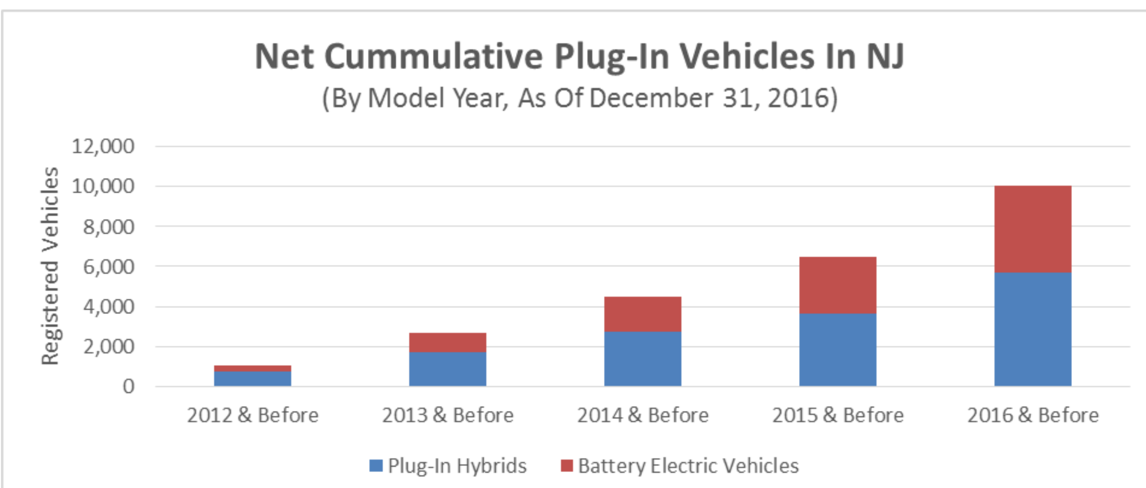
The above numbers reflect the net impact of new sales minus vehicle retirements on overall PEV fleet size. Separately, it is useful to understand the sales rate for new PEVs, and how that is growing over time. The following chart summarizes Plug-In sales in New Jersey since the introduction of first generation vehicles[b]. This captures only light duty vehicles with a plug, and does not include traditional hybrids (without a plug) or other alternative fuel vehicles (hydrogen, CNG, LPG).

[b] Registration data in New Jersey does not easily indicate NEW vehicle sales, only the total vehicles registered at a given point in time. There has not been consistent data capture over time to allow direct inference of new vehicle sales each year. The data does indicate model year, however, and this analysis uses Model Year (MY) as an indicator for when vehicles were sold. New processes are now in place with the NJDEP to enable more frequent and consistent measurement of market activity moving forward.

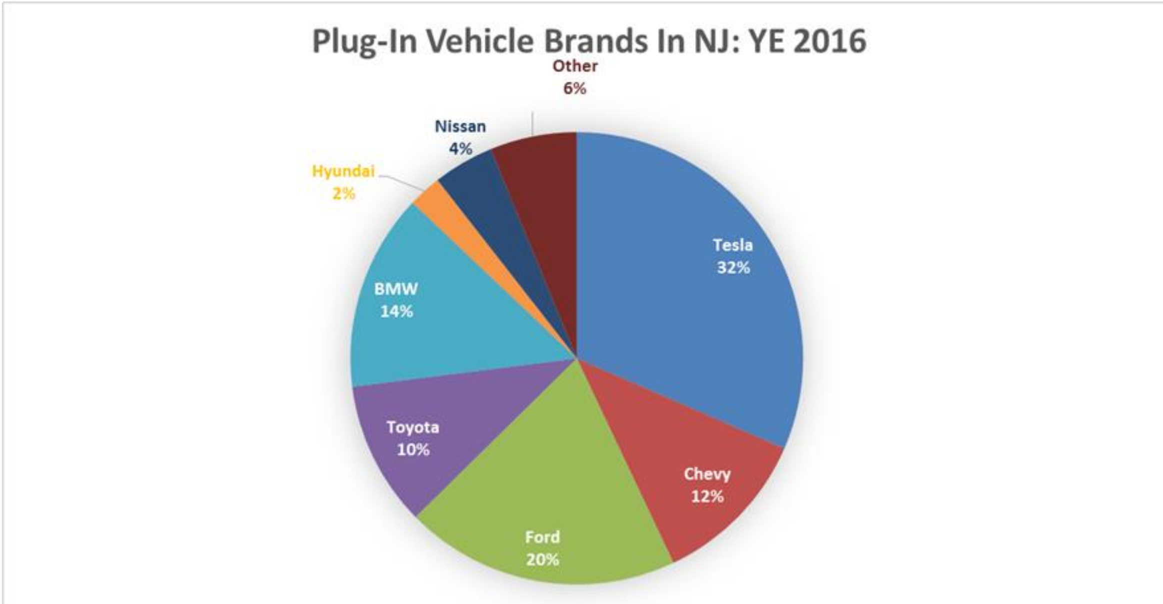


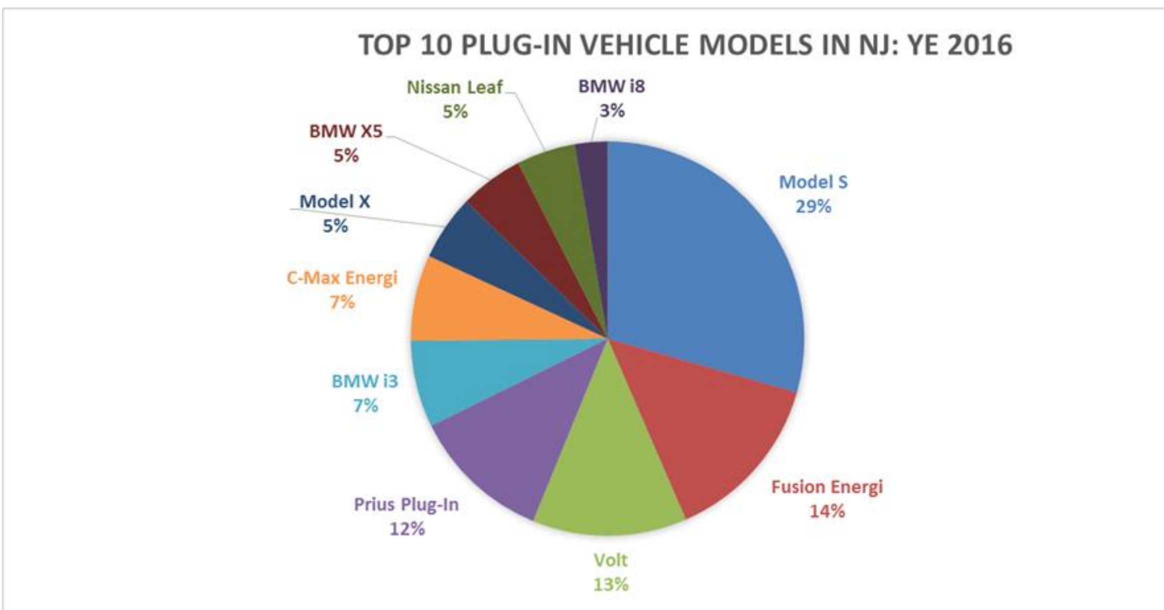
After several years of modest growth (from 2013-2015), sales increased sharply in 2016, and year-to-date data on 2017 sales (end of June) indicate that the strong sales demonstrated in 2016 have continued. Model Year (MY) 2016 PEVs grew 79% over MY 2015 sales, which implies that EV sales in New Jersey are over twice the national level of EV sales growth of 26%[18].

This level of annual sales, net of vehicle retirements, has resulted in 10,079 PEVs registered in New Jersey as of December 31, 2016. The number is slightly higher (by 531 vehicles) if MY 2017 vehicles sold at the end of 2016 are included. Based on 2017 year-to-date (YTD) results, PEV sales in New Jersey are likely to exceed 1% of all new vehicle sales for the first time.



The distribution of PEV sales in New Jersey are summarized in the two charts below, based on vehicle registration data as of the end of 2016.

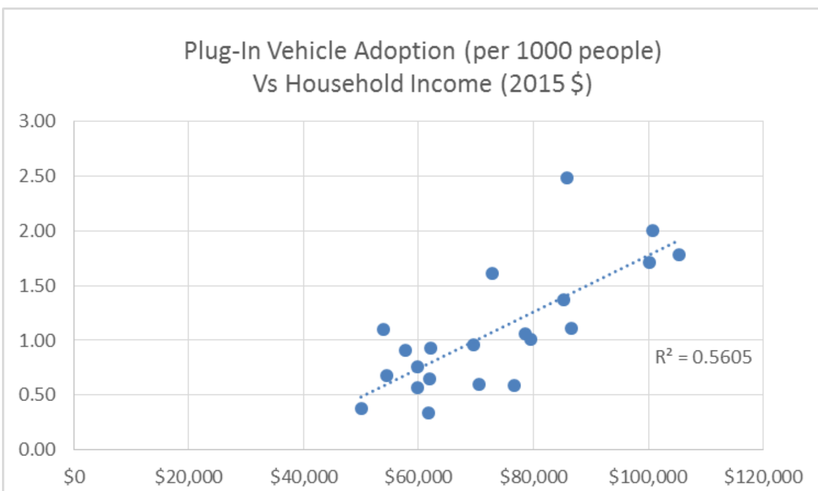




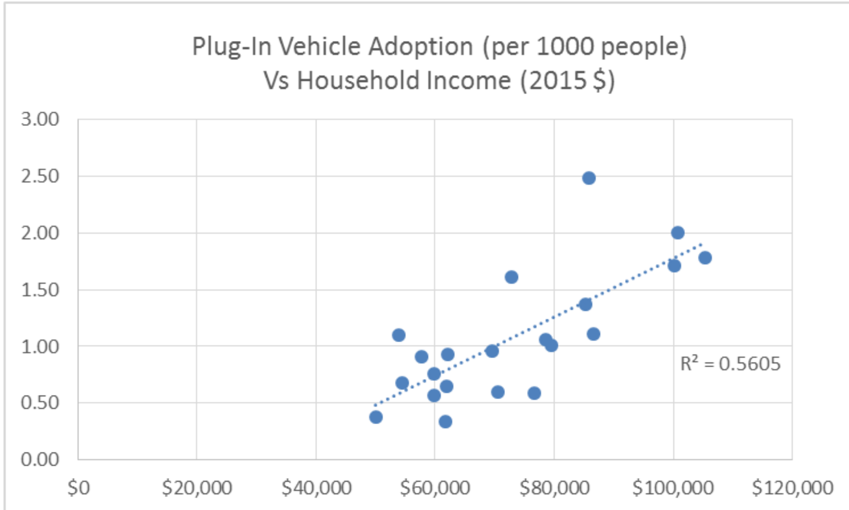
Based on analysis of the registration data, the distribution of PEV sales by county can be determined, as summarized in the following charge along with adoption metrics per capita and per square mile.

County	Battery Electric	Plug-In Hybrids	Total PEVs	PEV/1000 People	PEV/Sq-Mile
Atlantic	82	103	185	0.67	0.33
Bergen	959	1289	2248	2.48	9.61
Burlington	138	337	475	1.06	0.59
Camden	163	315	478	0.93	2.15
Cape May	26	62	88	0.90	0.35
Cumberland	21	38	59	0.38	0.12
Essex	400	459	859	1.10	6.82
Gloucester	56	113	169	0.59	0.52
Hudson	136	227	363	0.57	7.72
Hunterdon	95	134	229	1.78	0.53
Mercer	263	326	589	1.61	2.61
Middlesex	355	464	819	1.01	2.63
Monmouth	379	482	861	1.37	1.82
Morris	384	459	843	1.71	1.80
Ocean	87	284	371	0.64	0.58
Passaic	114	267	381	0.76	2.06
Salem	6	16	22	0.33	0.07
Somerset	337	311	648	2.00	2.12
Sussex	39	127	166	1.11	0.32
Union	257	257	514	0.96	4.99
Warren	17	48	65	0.60	0.18
Unknown	52	126	178		

As shown below, PEV sales are correlated with household income (by county), suggesting that vehicle prices are still a significant factor in adoption.



For comparison, the following chart demonstrates the correlation between traditional vehicle sales and household income (by county). Although vehicle ownership scales with income, it is a much "flatter" correlation, suggesting that vehicle ownership is feasible across a wider range of household income segments. By contrast, PEV sales depend more heavily on household income, due (at least in part) to higher vehicle prices. As a practical matter, \$55K PEVs are mostly being purchased by consumers that would have bought a \$55K traditional vehicle, which is more common in higher income households.



PEVs require charging infrastructure in a variety of segments, including home, work, and in public places (see further details in Section 5.3) – all of which need to be developed further. A key metric of PEV market maturity is the number of public charging assets – both charging devices and the number of charging plugs provided by those devices – on a per capita and per PEV basis.[19] [20] These metrics are considered especially important because they directly respond to consumer concerns about range anxiety. Within that range anxiety context, however, these two metrics characterize different market needs: stations per capita are, in part, a metric for general coverage and associated consumer perceptions by consumers who are not yet PEV owners, while plugs per PEV suggest the level of public charger availability for current PEV drivers that creates public-charging demand.[21] [22]

Based on the federal U.S. Department of Energy (USDOE) national database, as of November 2017, there are 217 PEV public charging stations, supporting 509 plugs. This translates to charging asset density factors as summarized in the following chart.[23]

	Total Count	Per 1000 People	Per Plug-In Vehicle
Public Electric Charging Stations	217	0.0241	0.0204
Public Charging Plugs	509	0.0568	0.0480
Public Station/Plug Types	**Total Count**	**Stations/1000 People**	**Plugs/Plug-In Vehicle**
Low Power (Level Two, J1772)	166/324	0.0185	0.0305
High Power (DCFC – Tesla)	7/46	0.0008	0.0043
High Power (DCFC – CCS)	33/40	0.0037	0.0038
High Power (DCFC – ChaDEMO)	30/33	0.0033	0.0031
Note: Individual asset types (level two, Tesla, etc.) do not sum to the totals shown since some stations include plugs for multiple vehicle types. (DCFC = Direct Current Fast Charger)			

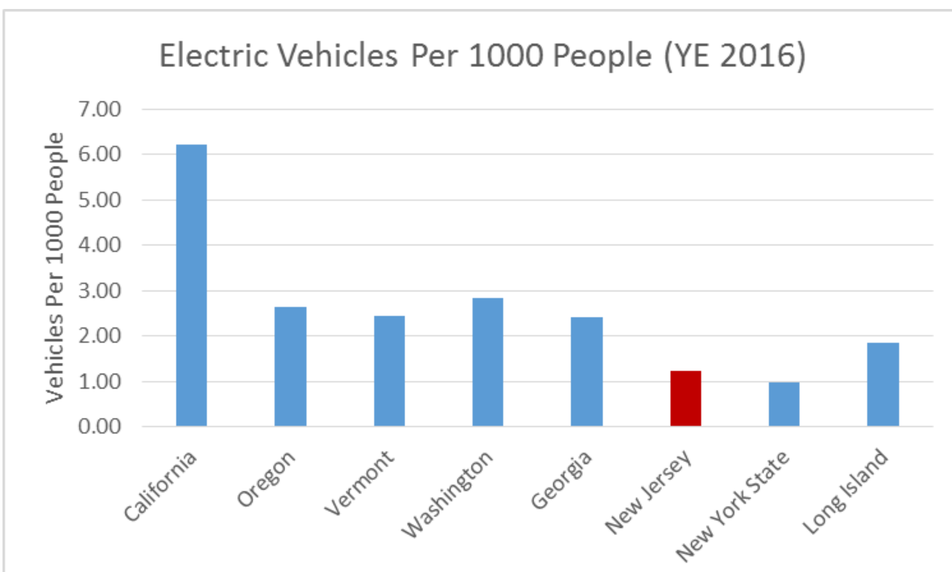
As detailed more completely in Section 3.3, these figures over-state the current status of public charger infrastructure in New Jersey, since not all stations/plugs are available at all times, nor do all stations support the full range of technical standards that current PEVs require. Given these conditions, it is highly likely that an EV driver in New Jersey would be unable to use one of these stations for either commercial or technical reasons. Compared with other states with higher levels of PEV adoption, these infrastructure density levels are relatively low.

3.3 Opportunities for Growth

While New Jersey has taken initial steps to develop the market, and recent sales have become more robust, there are indicators that there is significant untapped opportunity for PEV adoption in the state. States with higher levels of adoption have implemented market development measures that have not yet been pursued in New Jersey, and market benchmarks suggest that implementation of those market stimulants would result in higher levels of adoption.

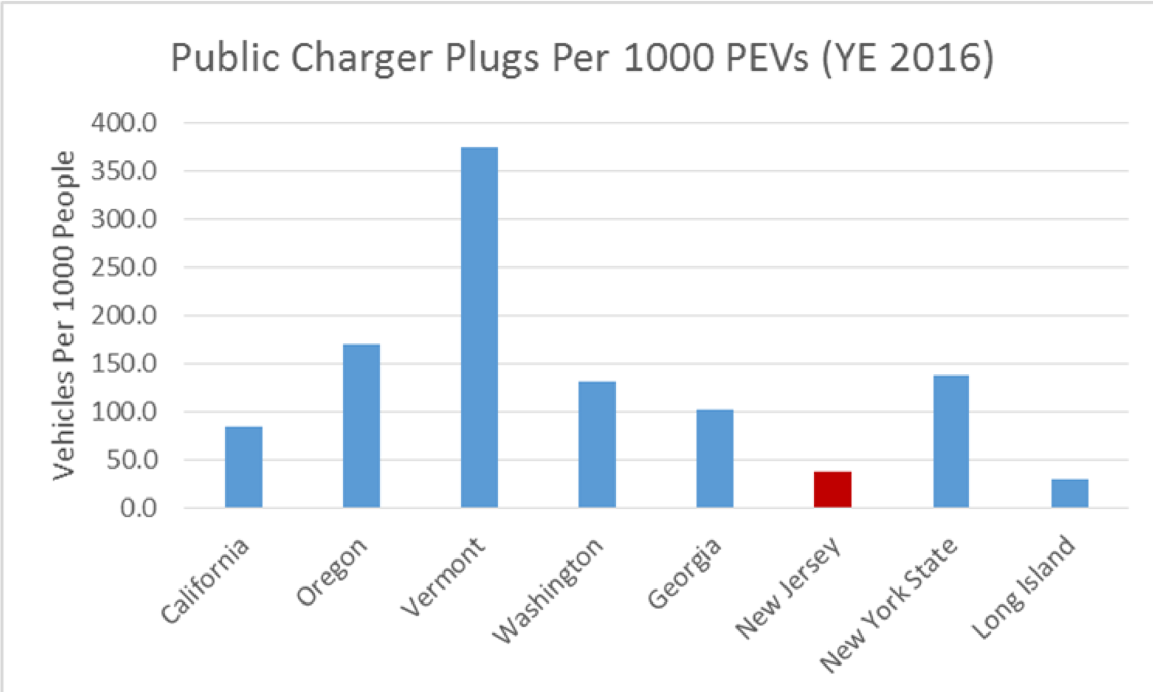
- New Jersey typically buys approximately 3-4% of all light duty vehicles nationally, but in 2016 only purchased 2.2% of new PEVs sold. This metric suggests that if New Jersey PEV adoption were to become consistent with overall light duty vehicle sales, the adoption rate would increase by 150-200%.

- As summarized in the chart below, by comparison with leading PEV states, New Jersey lags in vehicle penetration on a per capita basis. This metric suggests that higher vehicle sale rates are feasible. Consistent with the national sales benchmark noted above, New Jersey adoption is approximately half the level achieved by other leading states such as Oregon, Vermont, Washington State, and Georgia[c].



[c] 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.

- Similarly, New Jersey lags leading states in public charging infrastructure deployment. This benchmark affects both perceptions by potential EV buyers regarding range anxiety, and the level of public charging service available to existing EV drivers. Consistent with other data presented above, New Jersey public charger density is less than half that of other leading states.



Taken together, these benchmarks suggest that if New Jersey were to implement strong market development policies and programs, PEV sales have the potential to approximately double. Current market performance indicates that there is significant untapped opportunity in New Jersey, providing fertile ground for initiatives that have proven to be effective in other states, but which have not yet been pursued here. See Section 5.2 for more information about the current market dynamics in New Jersey, and Section 6 for further details about the key market development opportunities for the state.

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.

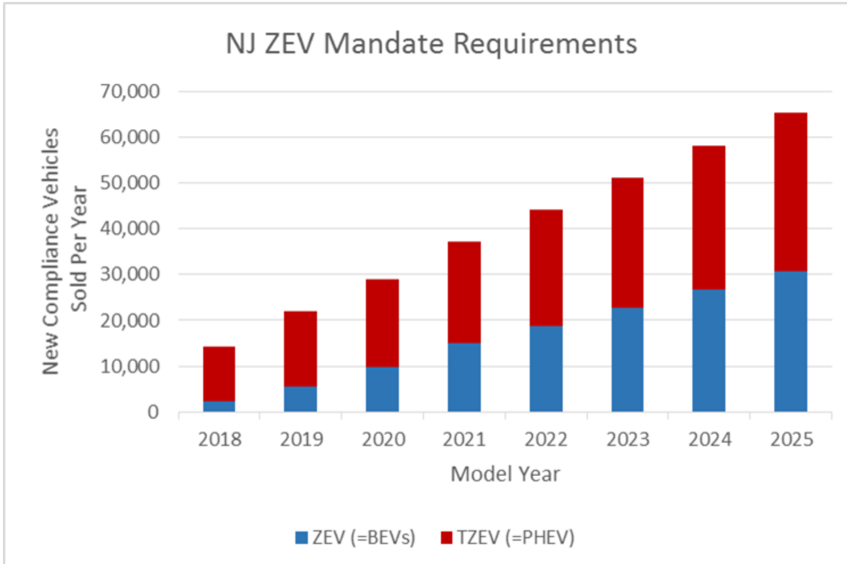
4.1 ZEV Framework

As noted in Section 3.2.1, New Jersey 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" overseen by the NJDEP, 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, 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.



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 New Jersey light duty fleet composition. Four scenarios have been defined, including a baseline under which no further EVs are sold, and three adoption scenarios representing low, medium, and high levels of adoption from 2018 to 2050. 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. Section 5.2 addresses study findings related to actual New Jersey market dynamics and how actual EV buying trends (evident in the current market) are related to these low/medium/high adoption profiles.

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

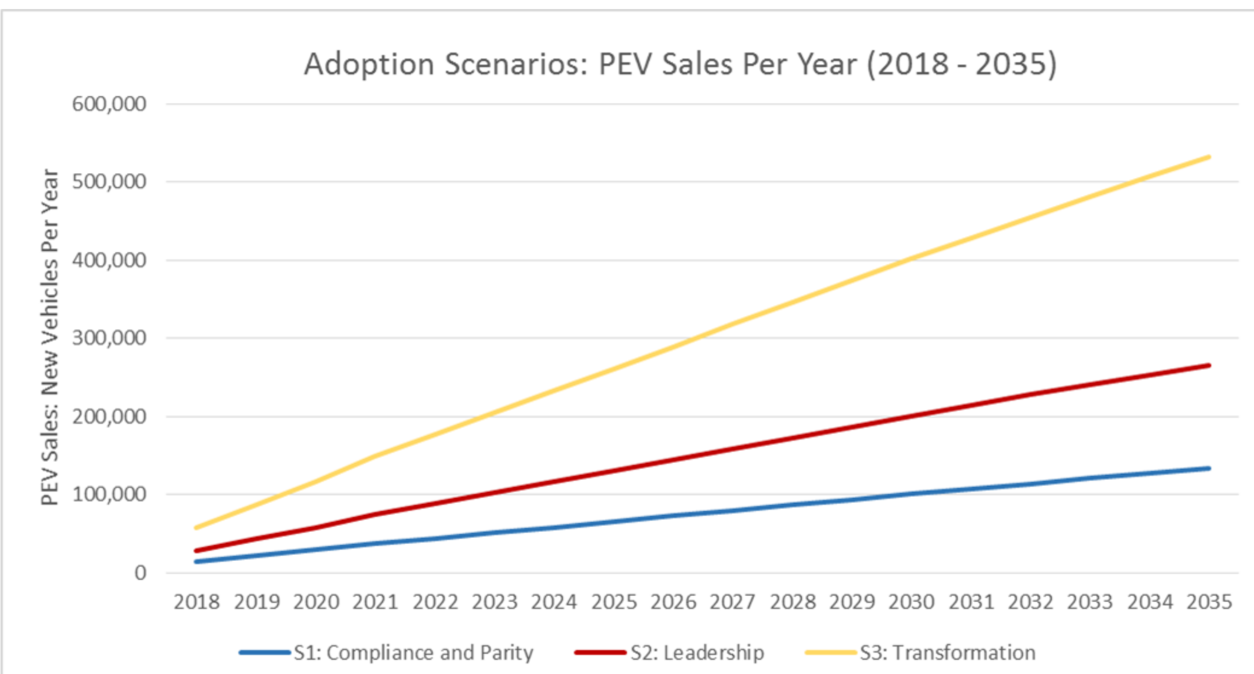
- **Baseline**: A continuation of current natural New Jersey light duty fleet trends, assuming no further PEV adoption (past 2017). This is not realistic since it is highly likely that additional PEVs will be sold, but it provides a solid baseline for what conditions would be absent PEV impacts. This baseline reflects the initial New Jersey fleet size and ongoing sales as well as per capita vehicle ownership trends.

- **Scenario One – Compliance and Parity:** The ZEV mandate, when translated to vehicles and extrapolated, as summarized in Section 4.1 above.   This adoption scenario is considered the “low adoption” case since it is consistent with basic compliance requirements already in place, and is approximately consistent with goals that have been established in other ZEV states. For that reason, it is referred to as the "Compliance and Parity" case.

- **Scenario Two – Leadership:** 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 after a few years of transition, this trajectory is considered achievable under market stimulation conditions consistent with what other leading states have implemented. This scenario represents the expected market outcome if the ChargEVC Roadmap is implemented fully, quickly, and effectively. For this reason, it is referred to as the "Leadership" case.

- **Scenario Three – Transformation:** The high adoption trajectory is consistent with the level of light duty vehicle electrification necessary to achieve the 80% CO_2 reductions mandated by the Global Warming and Response Act (GWRA, N.J.S.A 26:2C-37), and would result in approximately twice the adoption rate of Scenario Two. This trajectory represents nearly complete displacement of traditional gasoline vehicles by PEVs, with approximately 100% of new sales being PEV by 2040, and maximum levels of penetration of the overall fleet by 2050. This adoption curve represents the "Transformation" case based on almost complete displacement of fossil-fueled vehicles relatively quickly.

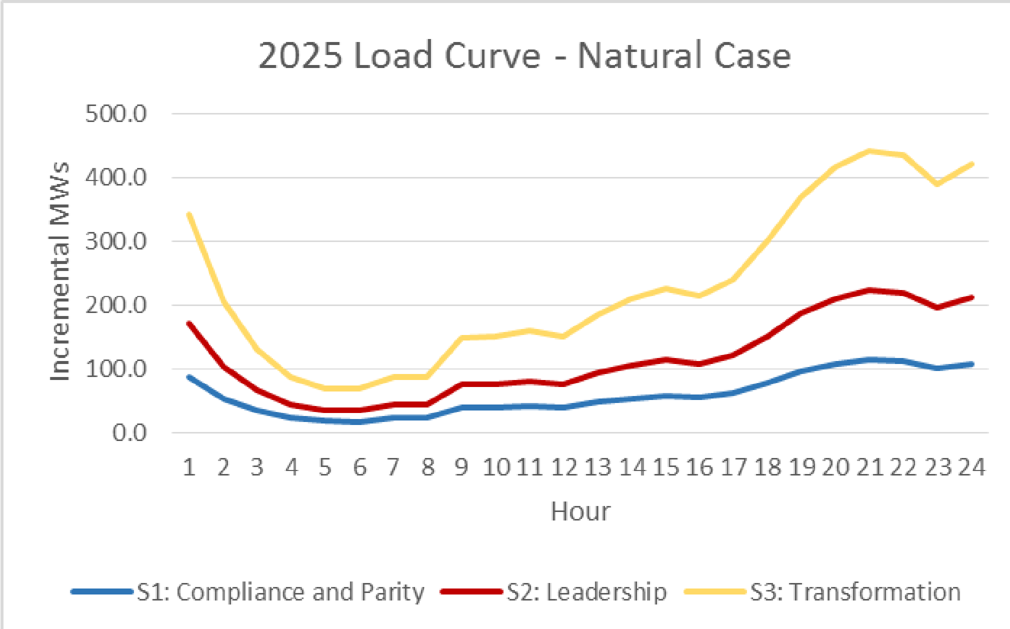
The following chart summarizes the three adoption scenarios, in terms of new PEV vehicles sold per year (statewide). It is useful to consider Scenario Two as the "nominal case" related to the ChargEVC Roadmap, with Scenario One and Scenario Three considered "sensitivities" for lower and higher levels of adoption respectively.

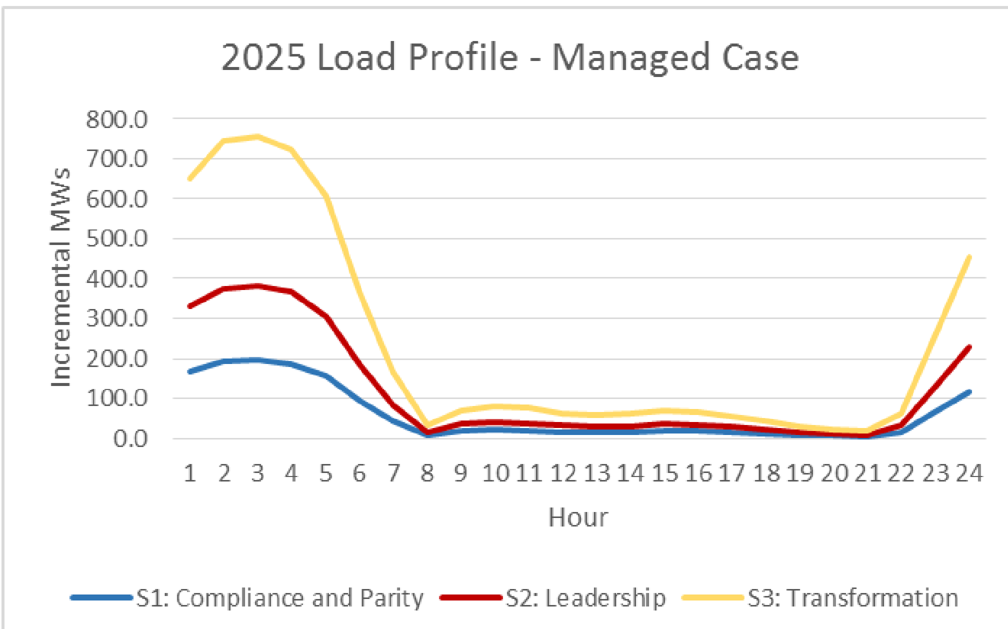


The model maps the statewide adoption scenarios to each electric utility based on population to allow for utility territory specific energy modeling.

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 “No-EVs”, which is known to be slightly unrealistic since in fact some EVs are being sold in New Jersey. The study team considered a variety of options for the baseline, including using a more realistic “most likely” growth trajectory based on recent sales results. After considering the trade-offs, however, the decision was made to use the “no-EV” case as the baseline for this initial study for several key reasons: a) the market is still VERY early, and for the next few years at least, the “no-EV” case is essentially the market reality, b) policy makers want to know the “value” of EV adoption regardless of where the market is today, c) the New Jersey market is so early it its development that projections of “likely growth” are still relatively uncertain, and most importantly d) continuation of the emerging growth trends depend upon continuation of key market elements that require ongoing policy commitment. The last point was a primary consideration, since comparison with the “no-EV” case allows quantification of the impacts of not continuing existing New Jersey market stimulants, especially the ZEV-framework opt-in, and the ZEV sales tax exemption. It would be risky to use a baseline that assumes continuation of key market development policies when in fact those policies need to be proactively continued and merit substantiating justification. Given the very early age of the New Jersey EV market, the “no-EV” baseline is a relevant foundation for analysis. As noted in Section 6, however, future versions of this study, with the benefit of additional market activity data and more mature knowledge of policy direction, may be able to develop a more sophisticated baseline that reflects the existing “do nothing” trajectory where some basic level of EV adoption is already emerging.

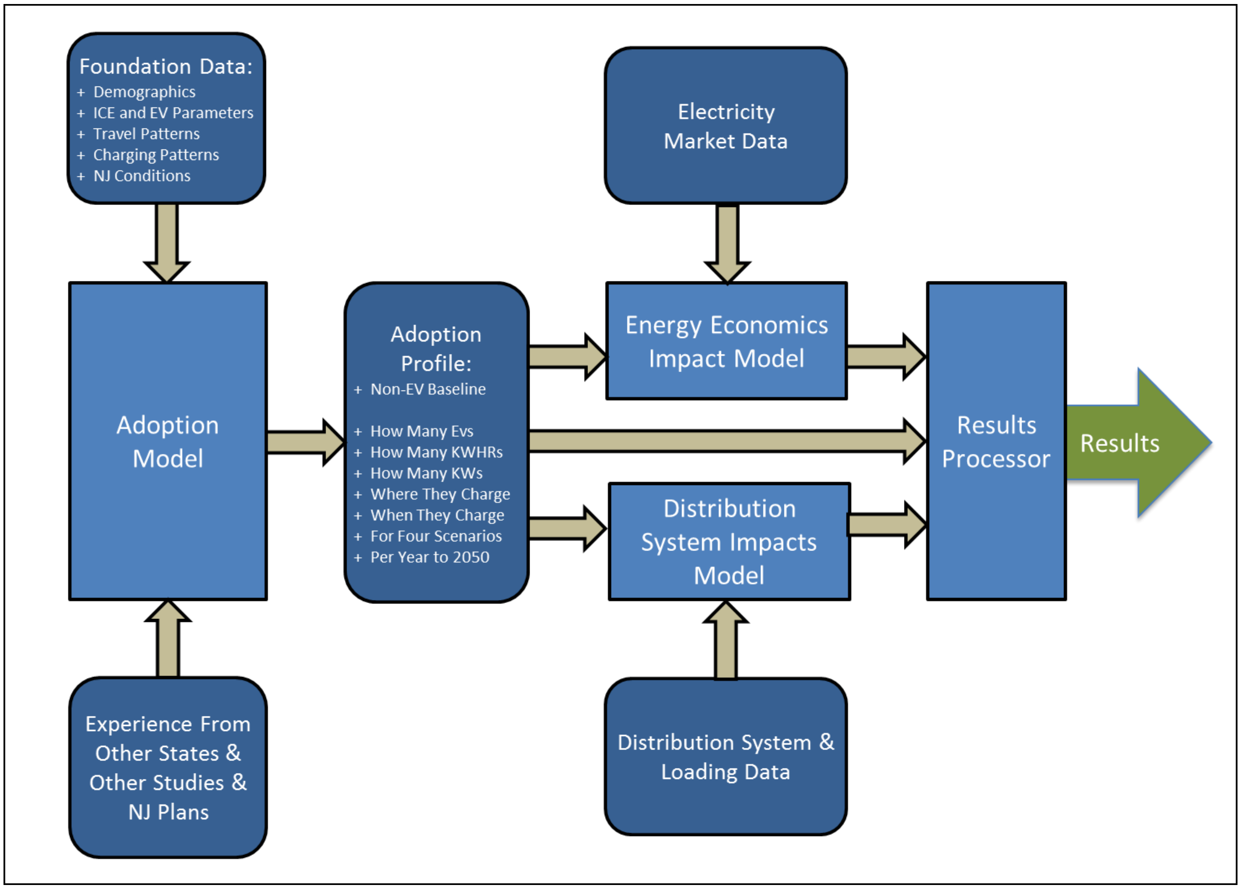
In addition to the three adoption scenarios and a no-EV baseline, two variations were developed that describe “natural” and “managed” residential charging schedules. “Natural Charging” reflects the default charge pattern that results when most people plug-in when they get home from work, versus a “Managed 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, for one of the New Jersey utilities.


2025 Load Curve - Natural Case
Incremental MWs
500.0
400.0
300.0
200.0
100.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
S1: Compliance and Parity
S2: Leadership
S3: Transformation


2025 Load Profile - Managed Case
Incremental MWs
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
S1: Compliance and Parity
S2: Leadership
S3: Transformation

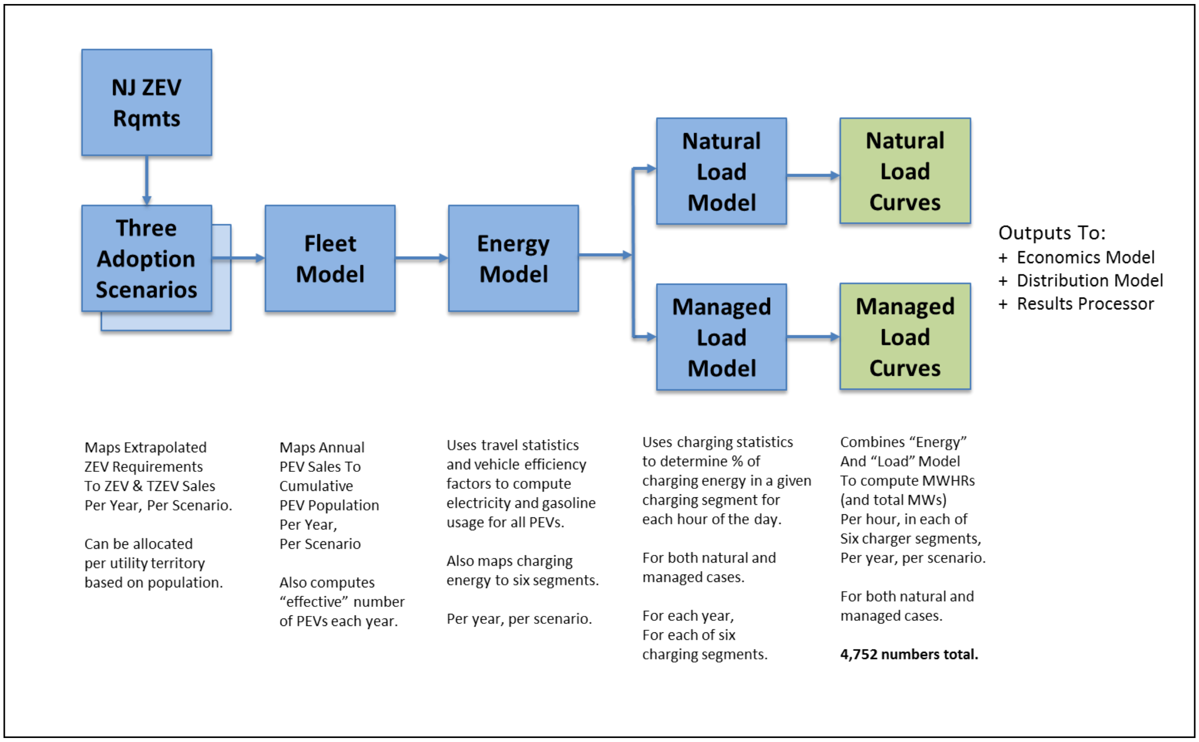
4.3 The Impact Model

The core model is based on four connected sub-models as summarized in the following diagram.



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, New Jersey 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 ChargEVC industry partners 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 the diagram below.



- **Energy Market Impacts:** A detailed market simulation of PJM[d]-wide 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 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 wholesale fleet in PJM 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 New Jersey 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 New Jersey specific energy market modeling, and translates ultimately to real cash impacts for electric utility customers.

[d] PJM is a regional transmission organization (RTO) that coordinate the movement of wholesale electricity in all or parts of 13 states, including Pennsylvania, New Jersey, Maryland, and the District of Columbia.

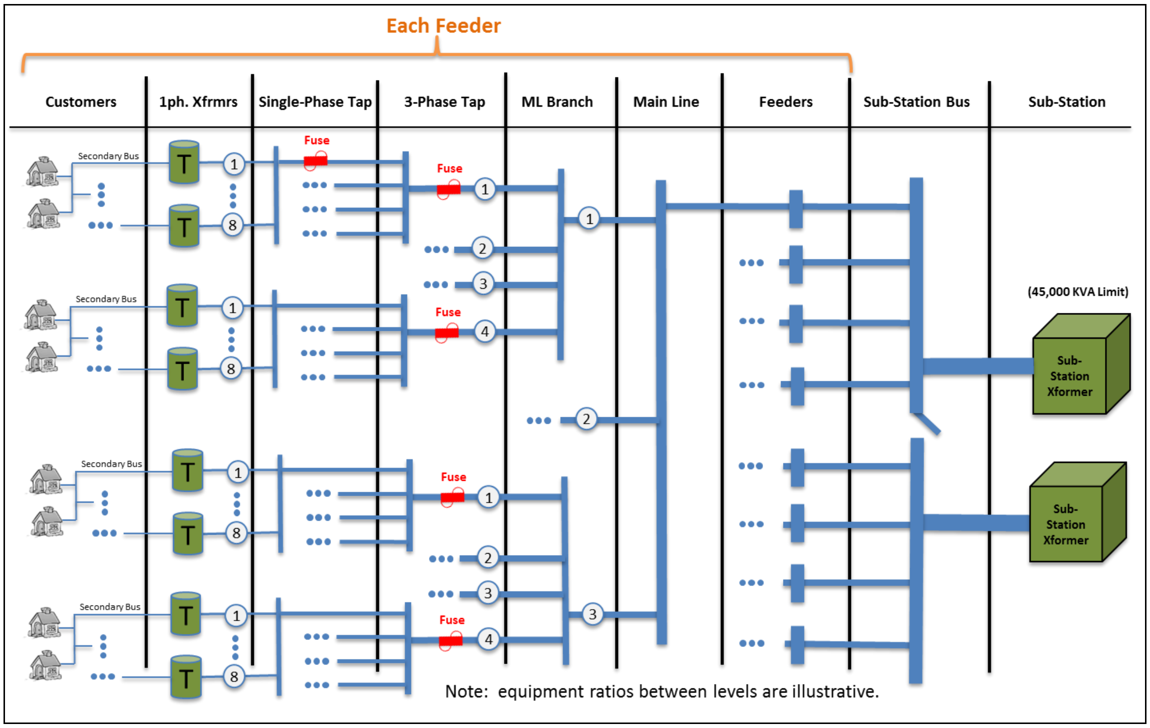
The economic impact for utility customers is based on two dynamics: changes in wholesale energy costs due to charging-related adjustment in the aggregate load curve, and dilution of fixed costs through a higher delivered energy volume (kwhrs). The wholesale analysis estimates overall changes in load-weighted average pricing, across all times and locations (within PJM) 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 (in PJM), 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 BGS 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. These emission impacts are modeled using two different accounting methods:

    - **Method One – Physical:** The summation of all PJM-wide emissions as allocated to New Jersey based on its share of PJM consumption on an annual MWhr basis, regardless of where all the generation assets are located. This is a classic "scope two" allocation method based on induced emissions. This accounting method most accurately reflects what happens physically, without consideration of accountability associated with state boundaries.

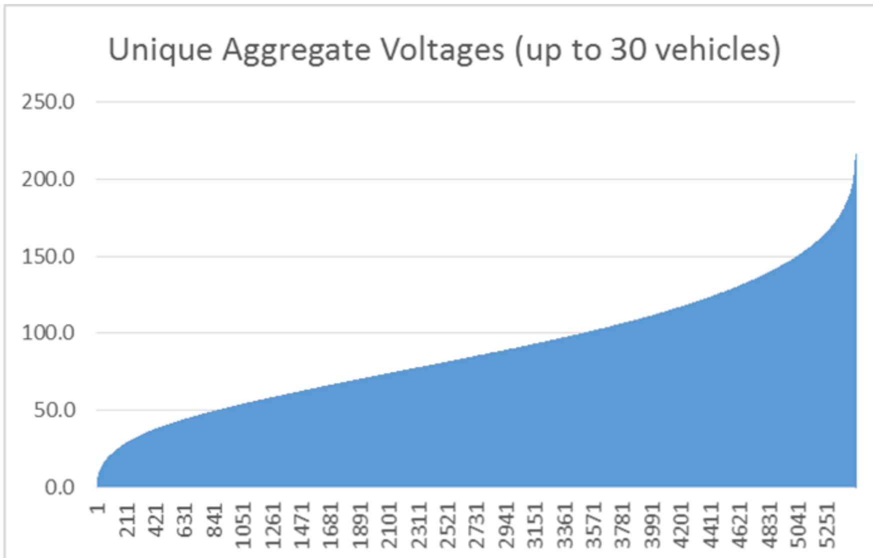
    - **Method Two – Consistent with GHG Inventory:** This method is consistent with the accounting practice used for the official New Jersey GHG Inventory provided by Rutgers University. It implicitly assumes that all generation assets physically located in New Jersey are dedicated to serving New Jersey load first, and then separately accounts for the emissions associated with any imports or exports that may be involved to meet the entire load. Although this method does not reflect the way the energy market works physically or commercially, this method is useful for measuring the cause-and-effect linkage between state-specific policies and state-specific results, in a form that is consistent with the established GHG accounting method. Given that generation in New Jersey is relatively clean compared with the rest of the PJM footprint, Method Two results demonstrate much lower emissions intensity than Method One results.

- **Distribution System Impacts:** Based on very detailed physical system data provided by one ChargEVC electric utility member, 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. Although these results are specific to the distribution configuration for the utility studied in detail, the loading impact conclusions are expected to be directionally applicable to all New Jersey utilities given similarities in feeder architecture. The following *representative* diagram illustrates one variation of the idealized feeder model used to determine distribution system impacts, with actual numbers modified to protect confidential system configuration information provided by the utility.



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, and d) whether the charging is natural or managed (which affects how the charging load is distributed over time). Transformer configuration and baseline loading characteristics were based on data provided by the utility.

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 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, the model takes a representative configuration consistent with the average power load for each customer-group size.



- **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 (MWhrs, tons CO_2, etc.) of a given scenario minus the reference (no PEV) 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 discussed below:

1. The demographic, vehicle, and travel statistics are based on New Jersey 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 entire PJM 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), using two different emission accounting methods 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 PJM peak loading.

6. The calculation of electricity cost impacts is based on a detailed analysis of electricity tariffs for all four New Jersey electric utilities (PSE&G, JCP&L, ACE, and Rockland). 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 NJBPU. All electricity cost calculations include the impact of the Renewable Portfolio

Standard (RPS), all delivery charges including known current riders, energy/capacity/transmission costs, PJM ancillary charges, and New Jersey state Sales and use Tax.

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 into the New Jersey Transportation Trust (NJTTF) to fund infrastructure as a replacement for lost gasoline tax revenues[e].

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 NJTTF replenishment) 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 NJDEP on an average per mile basis.

10. Energy characteristics of BEVs, PHEVs, and traditionally fueled vehicles are modeled separately and aggregated to assess the 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 a ChargEVC member 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.

[e] Although this study added a cents/kwhr premium to the cost of electricity to ensure that EV owners pay their fair share into the Transportation Trust Fund, 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 in New Jersey has positive bearing on energy costs, environmental impact including GHG emissions, consumer safety and public health, the operation of the public electricity grid, and numerous other strategic areas. **Vehicle electrification is unique in its breadth of impact and predominantly positive implications.** EV adoption is just beginning to grow in New Jersey 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, state-specific model described in Section 4, the following sections summarize the key impacts of Plug-In Vehicles in New Jersey over time.

5.1 Findings: Summary of Key Conclusions

The following sections describe the wide variety of impacts associated with widespread PEV adoption in New Jersey, including economic, environmental, and other strategic benefits. The following summary highlights several of the most important results and conclusions:

- **Untapped Opportunity and Potential for Growth:** The New Jersey EV market has untapped adoption potential and with focused investment the state could increase adoption levels significantly. PEV sales in New Jersey are already shifting upwards, based on a combination of existing market incentives and the expanding availability of second generation vehicles that have longer range and a lower price. Based on a comparison of New Jersey to leading states that have achieved higher per-capita PEV penetration**, investment in additional market development could reinforce natural growth by approximately a factor of two**, leading to sales of 129,000 new PEVs in the year 2025 (~23% of new sales) and over 263,000 new PEVs in 2035 (~46% of new sales). See Section 3 and 5.2 for additional details on these results.

- **Net Savings for Utility Customers:** Vehicle charging, especially if done at off peak times, creates cost efficiencies that deliver substantial economic savings for utility customers, even after accounting for potential investments in market development and infrastructure reinforcement. **Utility customer savings exceed costs by a factor of 1.99 through 2035, with savings averaging $156.7M annually. NET savings total over $2.9B by 2035 (NPV of $976M), and grow to a total of over $17.1B by 2050 (NPV of $3.8B) if Leadership Levels of EV adoption are achieved**. These net benefits potentially impact all New Jersey utility customers (not just EV owners), reflect only benefits delivered through lower electricity costs, and increase at higher levels of EV adoption.

- **Other Significant Benefits:** Beyond the direct impact realized by utility customers through lower electricity costs, widespread EV adoption brings a variety of additional economic benefits. EV owners realize reduced operating expense, especially due to the lower costs of fueling their vehicles with electricity rather than gasoline. The economic value of this reduced operating expense is significant: **based on CURRENT rates (for both electricity and gasoline), it will cost approximately 10.67 cents/mile to fuel an average vehicle with gasoline, compared with approximately 4.49 cents/mile for a BEV "fueled" with electricity at residential rates – a reduction of about 58%**. These fuel savings, along with estimated electricity cost reductions, has a direct positive impact on family cash flow: putting two EVs into the garage of an average New Jersey household will create **$1,440 of additional disposable income in 2018, and these savings will average $1,983/year through 2035**[24]. Net savings on operating expense totals $8.4B through 2035, growing to $34.8B by 2050 under the leadership scenario. There is also economic benefit to reduced environmental emissions, and even in the case where only CO_2 reductions are valued, those savings total $2.3B through 2035, and $13.0B through 2050.

- **Broad Portfolio of Societal Benefit:** As noted above, EV adoption enables a comprehensive portfolio of economic benefits realized by multiple beneficiaries. EVs are unique in the broad and diverse range of beneficial impacts they induce. Combining utility savings, reduced vehicle operating costs, and the value of lower emissions, these benefits (without consideration of potential costs) accrue to **$25.7B by 2035 (PV of $11.5B) for the Leadership case, and as high as $50.7B (PV of $22.6N) by 2035 for the maximum electrification case**.

- **Total Societal Benefits Far Exceed Potential Costs:** A formal Societal Cost Test (SCT) analysis indicates that overall societal benefits far exceed potential costs over a broad range of impacted populations. In the case where Leadership levels of EV adoption are achieved and vehicles charge at optimal times, **overall societal benefit exceeds costs by a factor of 2.19 through 2035**, delivering an average net benefit of $942.6M annually. S**ociety-wide benefits, net of all incurred costs, total over $24.0B by 2035 (NPV of $11.3B), and grow to a total of over $98.7B by 2050 (NPV of $50.6B)**.

- **Environmental Benefits:** EVs deliver significant environmental benefits, especially regarding the CO_2 emissions that drive climate change and NOx emissions that contribute to smog generation and directly affect public health. Air quality improves as EV use increases since tailpipe emissions are displaced by much smaller emissions at the power plant. **In 2018, very electrically "fueled" mile in New Jersey emits 69% to 79% less CO_2 than an average gasoline fueled mile**[f]. Widespread PEV adoption delivers the deep reductions in vehicle related CO_2 emissions needed to make the achievement of state goals feasible. Without electrification, CO_2 emissions from light duty vehicles will rise from 31.9 million tons in 2018 to 35.4 million tons in 2050. **When approximately 80% of the fleet is electrified, emissions from light duty vehicles (including both tailpipe and induced power plant emissions) will drop to about 9.6 million tons of CO_2 in 2050, which is very close to the 8.4 million tons of CO_2 emission goal established by the Global Warming Response Act.** Additional air quality improvements are realized if vehicle electrification is augmented with simultaneous reductions in power generation emission intensity through the increased use of renewable energy.

- **Utility and Energy Market Implications:** Widespread PEV use will create deep systemic changes in electricity use, with profound and potentially positive implications for electric utilities and the customers they serve.

  - In the Leadership case (Scenario Two, under managed charging), **total revenues for utilities statewide will be $2.8B higher through 2035 and $16.7B higher by 2050** (in nominal dollars, compared with the no-EV baseline).

[f] Impacts vary depending on the emissions accounting method used, as summarized in Section 4.3.

- These higher revenues are associated with increased electricity volume, but simultaneously, electricity cost efficiencies will be realized that could reduce costs for electric utility customers. Because EV charging is a large incremental load, and since scheduling of most of that load can be flexible and encouraged to occur off-peak, **EVs represent an unprecedented opportunity to optimize overall grid loading**.

- Aggregate wholesale rates will go down since a greater fraction of total MWHRs are during less expensive times. In addition, relatively fixed capacity, transmission, and distribution costs are diluted over a larger MWhr volume. For the same Leadership case (Scenario Two) where all cost efficiencies are passed through to electric utility customers consistent with current tariff structures, **electricity rates could decline by 9.6% by 2035, and 13.1% by 2050**.

- Widespread vehicle electrification therefore represents a rare case where utility revenues can increase even as electric utility customer unit costs ($/KWhr) decline. **These efficiencies and economic benefits directly impact all electric utility customers, not just EV drivers.**

- Detailed modeling of physical impacts of EV adoption on the distribution system indicates that the system will realize modest impacts in the short term, within existing operating parameters (for maintenance and repair). As statewide adoption exceeds 5% - 10%, however, the system will begin to experience more widespread impacts. By approximately 30% fleet penetration, significant reinforcements will be required. Most of these impacts are at the single phase distribution transformer level, and **by approximately 2035 (depending on the adoption rate), most of these transformers (and associated feeders) may need to be upgraded or reconfigured.** Those upgrades will increase grid capacity and potentially resiliency as well, and can deliver additional modernization benefits that are funded through increased EV charging volumes. The estimated costs associated with these reinforcements are included in the NET economic benefit noted above, and **even with high levels of upgrade, electric utility customer savings exceed estimated costs**.

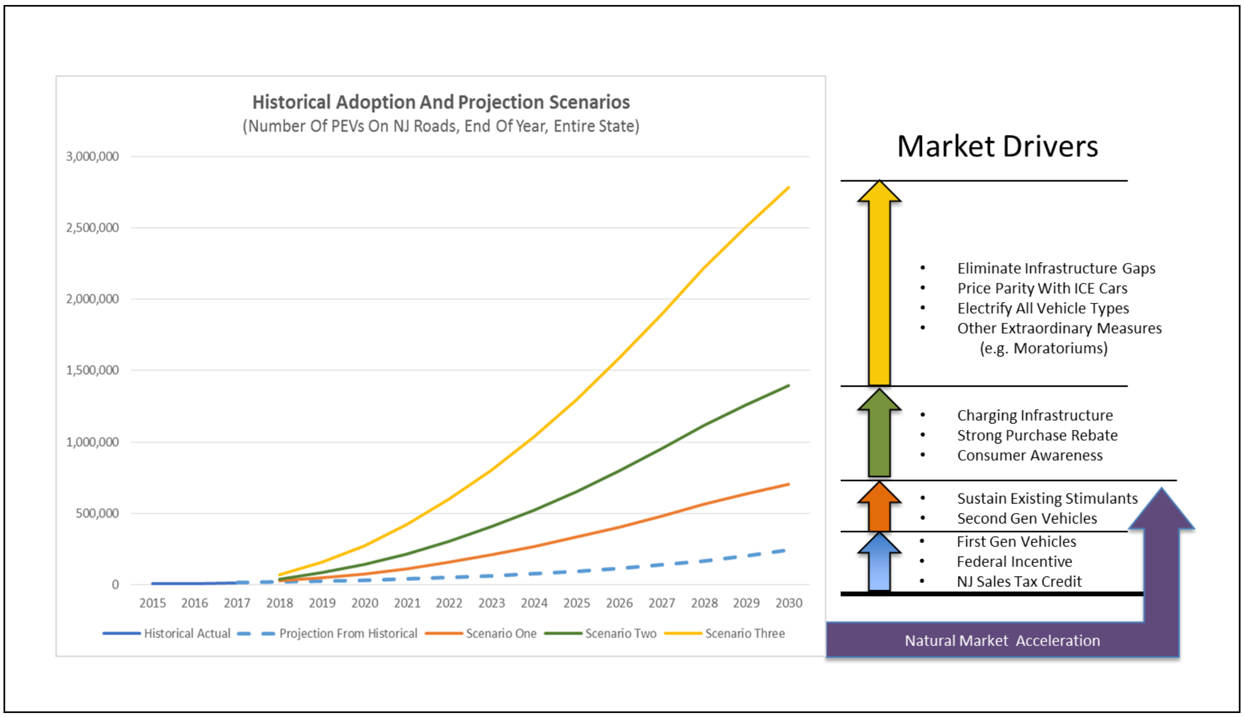
- In the short term, the additional MWhrs needed by EV charging can be accommodated by headroom in the existing wholesale fleet. At higher levels of adoption, however, **additional wholesale capacity will likely be needed, ranging from 0 to 2,800 incremental MWs that would be required due to EV charging loads (above capacity growth required in the baseline)[g]**.

- The study demonstrates significant differences between natural and managed charging: specifically, PJM coincident peak induced by EV charging can be reduced from 3,028 MW under natural charge scheduling to 546 MW under managed charge scheduling (under Scenario Two, in 2050). **Managed charging maximizes electric utility customer economic benefit by shifting more load to off peak times and avoids incremental load during expensive peak times, and also defers physical system impacts significantly.**

[g] The amount of additional capacity required varies depending on the adoption scenario and vehicle charging schedule (natural or managed charging), through 2050, and is incremental to the no-EV baseline.

5.2 Findings: New Jersey Market Dynamics

A key aspect of the study was developing an understanding of the relationship between various market drivers (rebates, the ZEV mandate, evolving vehicle characteristics) and PEV adoption over time. As noted in Section 4.2, the three adoption scenarios upon which the study is based were not intended to be predictions of actual market performance. However, they are useful reference trajectories for understanding how adoption changes in response to various market stimulation initiatives. Key data for this assessment was summarized in Section 3, which provided a summary of current New Jersey market conditions and a comparison of New Jersey adoption results with other leading states. By comparing incentives implemented in those states with what has been implemented (or not implemented) in New Jersey, along with most recent PEV sales statistics for each state, a high-level understanding of market drivers can be developed. The following chart summarizes key findings of the study related to the evolution of PEV sales in New Jersey, and how further adoption changes could emerge based on additional market development stimulants.



Key dynamics are as follows (through ~2030):

- The blue dotted line represents a projection of PEV adoption based on historical PEV sales rates in New Jersey. This extrapolation is based on the average growth rate over the last three calendar years (2014 – 2016). Adoption at this projected level is the aggregate result of: a) first generation vehicle acceptance in the market (especially range and price points, at current levels of consumer awareness), b) the existing federal tax credit (up to $7,500), c) the New Jersey ZEV mandate which facilitates allocation of EVs to the state, and d) the existing New Jersey sales tax exemption. This baseline essentially represents the sales rate *if there were no further changes in the market (new vehicles, market incentives, etc.).*

- The market is not static, however, and in fact changes are already underway that result in increased adoption. A primary driver is the expanding availability of second generation vehicles with longer range and lower price (Chevy Bolt, Tesla Model 3, 2018/2019 MY Nissan Leaf, and others expected soon), which is increasing PEV adoption nationwide. These vehicles became available in limited quantity at the end of 2016 and are expected to be widely available in early 2018. **Assuming a continuation of existing New Jersey baseline drivers (as outlined above), the widespread availability of second generation vehicles is expected to approximately double the uptake of PEVs in New Jersey.** Although the sales average over the last three years (2014 – 2016) was approximately 30%, the growth rate in 2016 increased significantly to 79%. Partial year results for 2017 (through June) confirm a continuation of this substantial increase in sales – approximately by a factor of two over the historical trend. **Recent results, as extrapolated to reflect the impact of new vehicles, suggest that New Jersey is naturally shifting from the historical-projection trajectory to approximately the Scenario One adoption trajectory.** This transition, absent any other market development activity, is estimated to occur over approximately the next two to three years.

- If no further actions were taken, current estimates are that New Jersey PEV adoption would follow approximately the Scenario One trajectory. Compared with other leading states, however, there appears to be untapped adoption potential in New Jersey due to the absence of market development incentives that are known to significantly increase adoption. **As outlined in Section 3.3, this untapped adoption potential is estimated to increase adoption by an <u>additional</u> factor of two if strong market development incentives are implemented within the state.** Based on a review of incentives that have proven successful in LEADING states, and their associated adoption levels (per capita), the set of market development actions that would improve PEV adoption in New Jersey is consistent with the market development actions proposed in the ChargEVC Roadmap. The primary market stimulants, assuming coincident availability of second generation vehicles and other policies already in place, include a) a strong focus on charging infrastructure (in all its forms), but especially as related to public charging infrastructure to reduce consumer range anxiety, b) vehicle purchase rebates, and c) significant increases in consumer awareness. **If these incentives are implemented, coincident with strong second-generation vehicle availability, the study estimates that PEV adoption in New Jersey would shift to approximately the Leadership (Scenario Two) trajectory over the next 3-5 years.**

- Given the existing state of market development in New Jersey, transition to the Transformation trajectory (Scenario Three) is probably out of reach *at the current time*. That level of adoption is currently being targeted by global PEV leaders (Norway, the Netherlands, France, the UK, etc.), and includes extraordinary measures such as moratoriums on the sale of petroleum fueled vehicles. That level of market development intervention is not currently under consideration in New Jersey, although transition to the Scenario Three adoption (as needed to fully achieve the Global Warming Response Act goals) becomes feasible as a subsequent phase of market development after Scenario Two Leadership has been attained. In short, New Jersey needs to get to Scenario Two adoption before it can aspire to the higher levels of penetration projected in Scenario Three.

- In summary, the New Jersey market is already experiencing increased PEV sales over the historical trend, and as augmented by the expanding availability of second generation vehicles, appears to be moving to adoption rates in line with the ZEV compliance framework (Scenario One). Additional market development measures such as those proposed in the ChargEVC Roadmap are projected to further lift PEV adoption by approximately a factor of two, putting it in line with the Scenario Two trajectory. This conclusion is based heavily on the results achieved in other states with leading PEV adoption rates (per capita), and the untapped adoption potential evident in New Jersey given the absence of market development investments to date. The combined impact of existing market growth and proposed market development stimulants are projected to lift PEV adoption in NJ by approximately a factor of four over historical trend. **The market development programs proposed in the ChargEVC Roadmap can therefore be aligned with the PEV adoption results represented in the Leadership Scenario (Scenario Two) adoption profile.**

- If the ChargEVC Roadmap market development investments are implemented fully, completely, and effectively, on top of strong continuation of existing incentives and robust availability of second generation vehicles, PEV adoption in New Jersey will shift beyond the Scenario One trajectory by 2025 (at least 65,000 new PEVs sold, ~11% of new vehicle sales), to approximately the Scenario Two sales rate by 2035 (at least 150,000 new PEVs sold, ~46% of new vehicle sales).

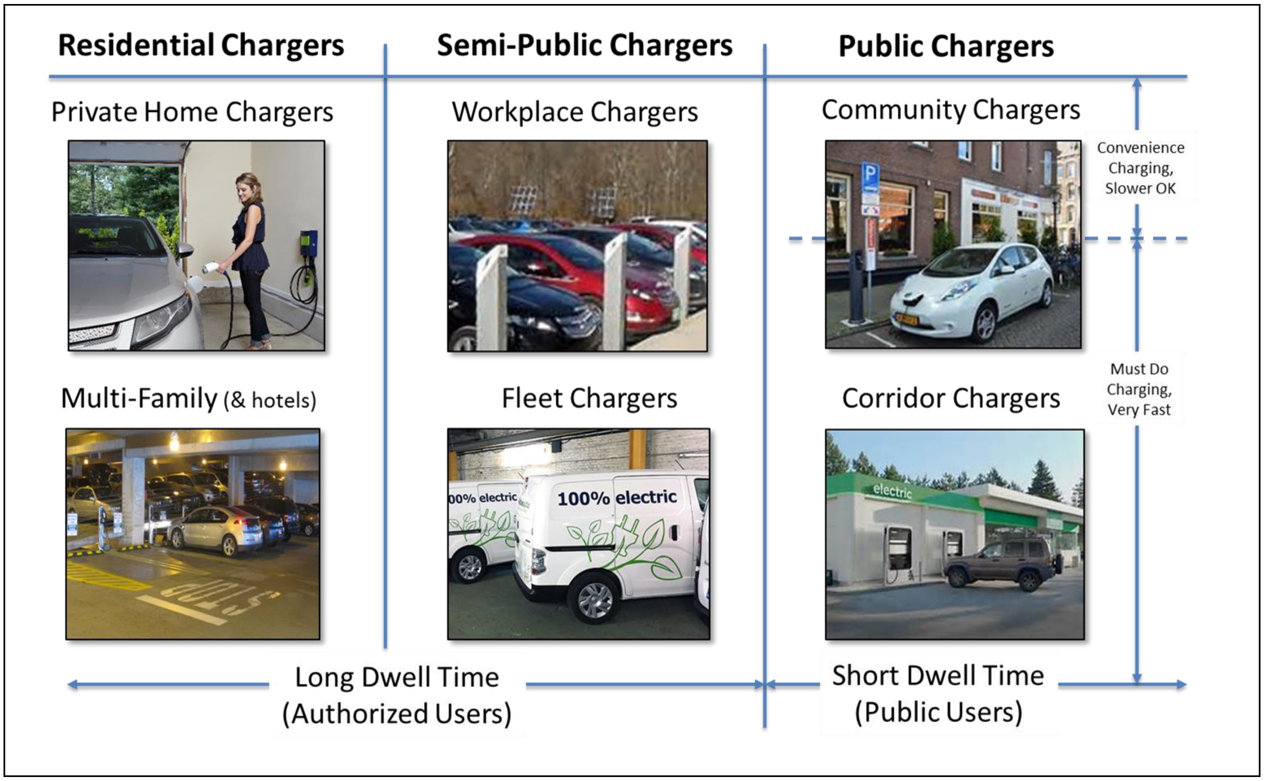
5.3 Findings: How Drivers Charge Their Vehicles

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 a viable alternative for mainstream consumers. Vehicle charging is a safe "do it yourself at home" transaction that most consumers will find manageable, similar to the way mobile phone charging has been widely adopted. For those relatively rare occasions when a public charge is needed, that technology is also evolving quickly: in the short term quick charge transactions can be almost as short as a gas station visit today, although a relatively infrequent occurrence (for most drivers).

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 ChargEVC members (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 ecosystem used in this study.



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[h], the commercial 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 New Jersey since a substantial portion of building stock is multi-family, and 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 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[i]. 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 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 will be paid for by the employee.

[h] 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.

[i] 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.

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. In New Jersey, 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 the 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 in New Jersey, the overnight charge will average about 10 KWhrs a day.

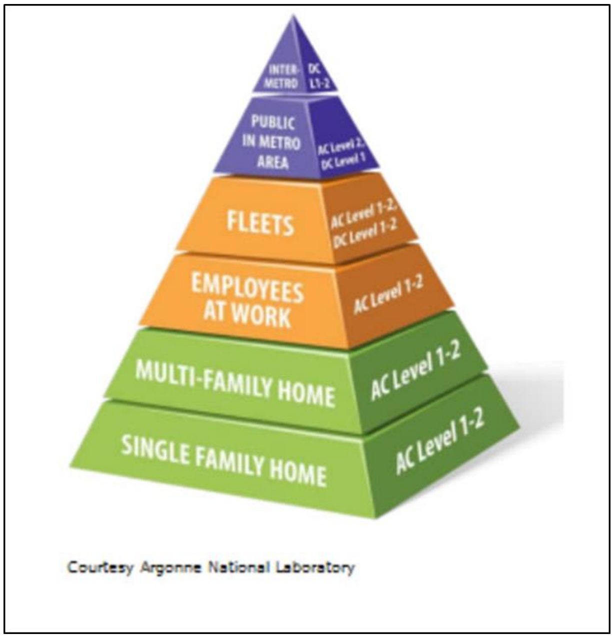
- This residential charging dynamic represents a fundamental departure from the way traditional vehicles are fueled today. **EV drivers will charge their cars similar to the way they charge their cell phones.** Unlike traditional gasoline fueled vehicles – which for most drivers MUST be fueled at a commercial gas station – charging an EV at home is a viable, usually more cost effective, and frequently a preferred option[j]. 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 roles.

- Although they do not deliver much charging energy on a MWhr basis, Public Chargers, are absolutely critical for market adoption since they address consumer concerns about range anxiety.[25] 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. 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 diagram 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.

[j] 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.



- 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.

5.4 Findings: Impact of EVs on Achievement of State Goals

New Jersey has formally adopted a variety of laws, goals and strategies that are positively impacted by widespread EV adoption. In fact, key 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 those goals. Based on the New Jersey GHG Inventory developed by Rutgers[26], combined with new research as part of this study, several key trends and conclusions are evident:

- **GHG emission reductions required by state law can be effectively achieved through widespread vehicle electrification.** The state's Global Warming Response Act calls for an 80% reduction in CO_2 emissions by 2050, compared with a baseline in 2006.[27] The consumption of gasoline by light duty vehicles was the single largest CO_2 emissions segment in 2006, representing 29.9% of the energy related CO_2 emissions. Given emission reductions in other segments, gasoline use in light duty vehicles has become an even larger portion of New Jersey's carbon footprint, increasing to 35.4% in 2012. **An overall 80% reduction is not possible without massive reductions in transportation emissions in particular, especially in the predominant light duty vehicle segment**[28].

- **Opportunities for CO_2 reduction through vehicle electrification remain almost completely untapped in New Jersey, despite strong progress in other sectors.** CO_2 emissions from electricity generation dropped by 32.6% between 2006 and 2012, and that trend has continued into 2015[k] based on the reduced use of coal, the near elimination of CO_2-intensive electricity imports, and the increased use of carbon-free renewable energy. Similarly, CO_2 emissions from the use of fuels for space and water heating has declined by 23.0% over the same six-year period, primarily through improvements in energy conservation and building efficiency, and the transition from fuel oils to natural gas. Both of these absolute reductions were achieved despite increasing GDP and population, and progress is evident even when normalized for weather. In sharp contrast, vehicle emissions have declined only slightly over the same period (2006 – 2012), with CO_2 emissions from gasoline use dropping by only 7.6%. Although the state has made significant investments in clean energy through renewable electricity market development and energy efficiency and conservation programs, there are very few policies or programs in place to advance EV adoption to a similar degree. Vehicle electrification remains a primary, and mostly untapped, opportunity for GHG reductions (especially CO_2) in New Jersey, and should be considered an essential strategy for achieving the 2050 GHG reduction goals.

- **Fueling vehicles with electricity in New Jersey is much cleaner than using gasoline, so vehicle electrification makes extraordinary reductions in CO_2 emissions possible.** EVs displace 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. In New Jersey, where the generation fleet is particularly clean, every electrically fueled mile is between 69% and 79% lower in CO_2 emissions than a gasoline fueled mile (depending on the emissions accounting method used, see Section 4.3). 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.** Other air pollutants, especially criteria emissions such as NOx[l] are also substantially reduced through vehicle electrification. Based on data provided by the NJDEP, NOx emissions from multiple sources have been reduced by 57% between 2002 and 2017 in New Jersey. On-road sources (primarily light duty vehicles) now account for 70% of the projected 2017 NOx emissions level, and further reductions – as required to achieve compliance goals – will need to come primarily from NO_x reductions in on-road sources. 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

[k] The most recent year for which data is available.
[l] Particulates are also expected to be reduced through vehicle electrification, including both light duty vehicles and especially diesel-fueled heavy duty vehicles, but they have not been specifically quantified as part of this study.

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. 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-KWhr) of electricity declines. There are similar impacts related to diluting relatively fixed costs (for infrastructure) through higher electricity volume, and these impacts are significant. The New Jersey Energy Master Plan specifically targets reduced electricity costs as a key goal, and widespread vehicle electrification contributes directly to realizing that objective for utility customers. See Section 5.5.2 for more details.

- **The state targets improved air quality to improve public health, and electric vehicles contribute directly to that outcome.** Vehicle electrification directly reduces NOx in particular, which has a strong impact on a wide variety of public health conditions (asthma, etc). See Section 5.7 for more details.

5.5 Findings: Economic Benefits

Vehicle electrification brings a variety of economic impacts, particularly to New Jersey electric utility customers, but also to society at large and to owners of electric vehicles. Two economic tests were applied to quantify EV adoption impact: a strict utility customer NPV, and a broader societal cost test.

- **Utility Customer Impact:** This test strictly aligns potential costs that might be recovered from utility customers through electricity rates, and compares that with only those savings that apply to all utility customers through lower electricity costs. Although this test under-estimates the overall economic value that will likely be induced by increased EV adoption since it characterizes only the impact specific to utility customers. But this test addresses equity considerations related to the population that provides potential funding and benefits realized by that same population.

- **Society Cost Test (SCT):** This test takes a broader look at all expenditures related to electric vehicle adoption, and compares that to the more complete portfolio of benefits across a variety of impacted populations. The SCT provides a more comprehensive look at net benefit, considering the wide range of economic implications that result from increase EV adoption.

These two tests provide very different, but complimentary views of the net benefits associated with electric vehicle adoption. Sections 5.5.1 through 5.5.4 summarize the benefits used in both tests, independent of potential costs. Section 5.5.5 outlines potential costs and investments. Based on those benefit and cost profiles, sections 5.5.6 and 5.5.7 summarize the net benefit cost analysis for the Utility Customer Impact and the Societal Cost Test respectively. Readers interested primarily in the NET benefit analysis can skip to Section 5.5.6 for the Utility Customer NPV test, or Section 5.5.7 for the more complete Societal Cost Test.

NOTE: In all summaries of economic benefits below, "total savings" refers to the nominal sum of annual savings from 2018 to either 2035 or 2050 without discount. All references to "Present Value" (PV) are based on the present value of annual savings from 2018 to either 2035 or 2050 at a discount rate of 6.3%.

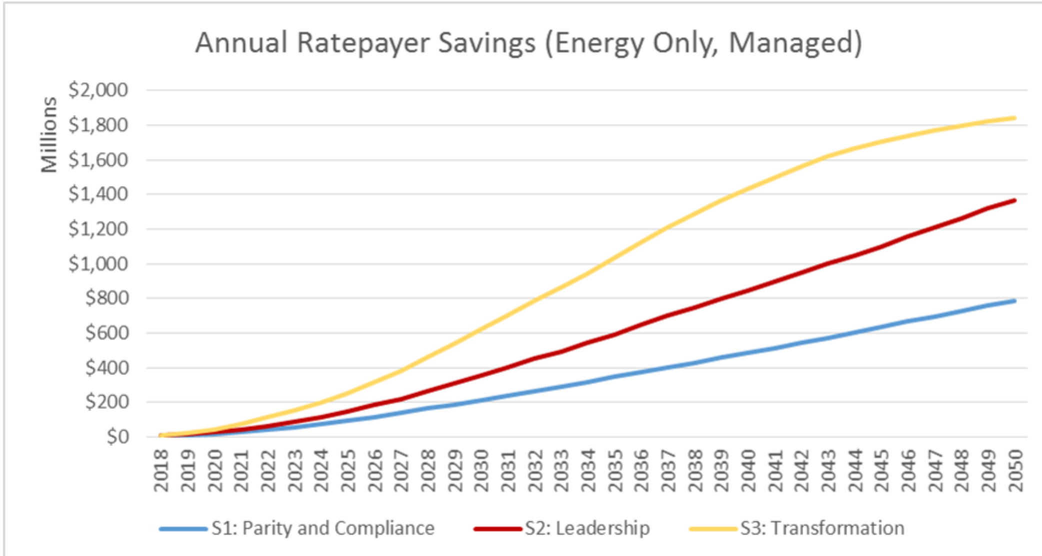
5.5.1 Economic Benefits Due to Reduced Electricity Costs

The average unit cost of electricity will go down as EV use increases, and this results in an aggregate cost reduction that flows to all New Jersey electric utility customers[m]. This Charging Induced Price Effect results from the fact that most vehicle charging will happen during off-peak periods, resulting in an increased fraction of annual MWhrs generated during lower cost off-peak times[n]. In addition, average unit costs decline due to increased utilization of existing assets (power plants 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 simulated detailed hour-by-hour dispatch of PJM assets as needed to support the EV adoption scenarios under consideration, and estimated the impact on electricity costs including wholesale $/KWhr charges, capacity costs, and transmission and distribution costs. To be conservative and avoid the impact of uncertainty about how overall cost reductions translate to individual tariffs, only fixed-cost changes that flow to consumers through KWhr-based charges were included in the savings assessment. All the following savings estimates noted in this section are gross savings, without consideration of any costs that may apply.

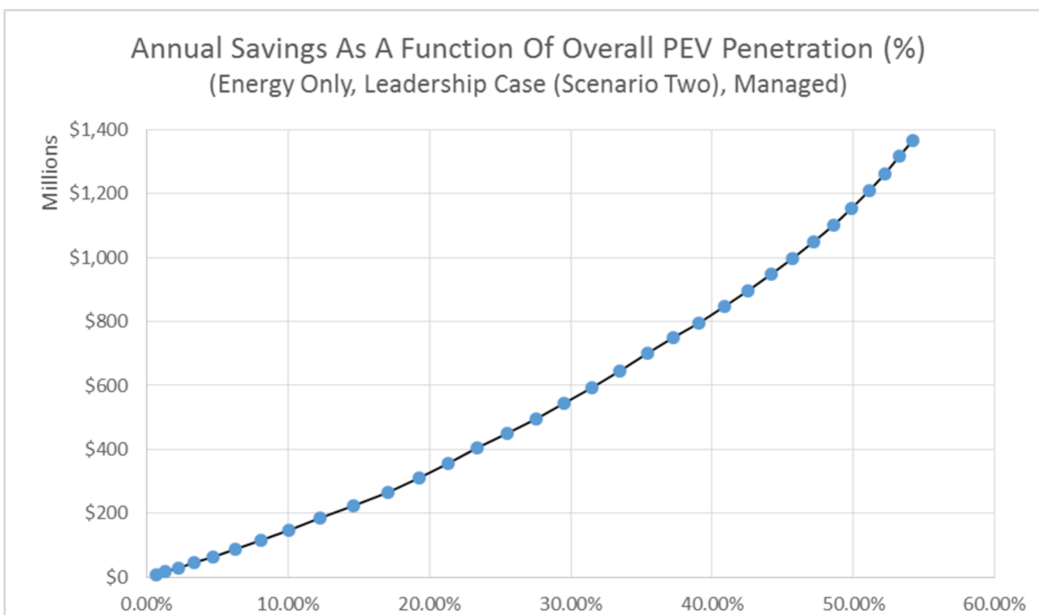
- **Electric utility customers will benefit from a total of $4.3B in electricity cost reductions through 2035 (PV of $1.9B)** for the Leadership Case (Scenario Two, Managed Charging) relative to the no-EV baseline. These savings result from structural changes in the market, (i.e. the shifting of load to lower cost off-peak times), and grow as EV adoption continues to increase, resulting in a total of $19.4B in cost reductions through 2050 (PV of $4.9B). These benefits will benefit electric utility customers overall, not just the EV owners, and reflect the savings only on non-vehicle charging consumption. **In the Leadership case (Scenario Two) when managed charging is common, electric utility customers will average $587M in savings each year, reaching approximately $593M in annual savings in 2035, and nearly $1.4B in annual savings in 2050.** 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.

[m] 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. Individual customer prices and actual electricity bills will depend on further additional factors, such as their individual load shape and contracting arrangement. 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.

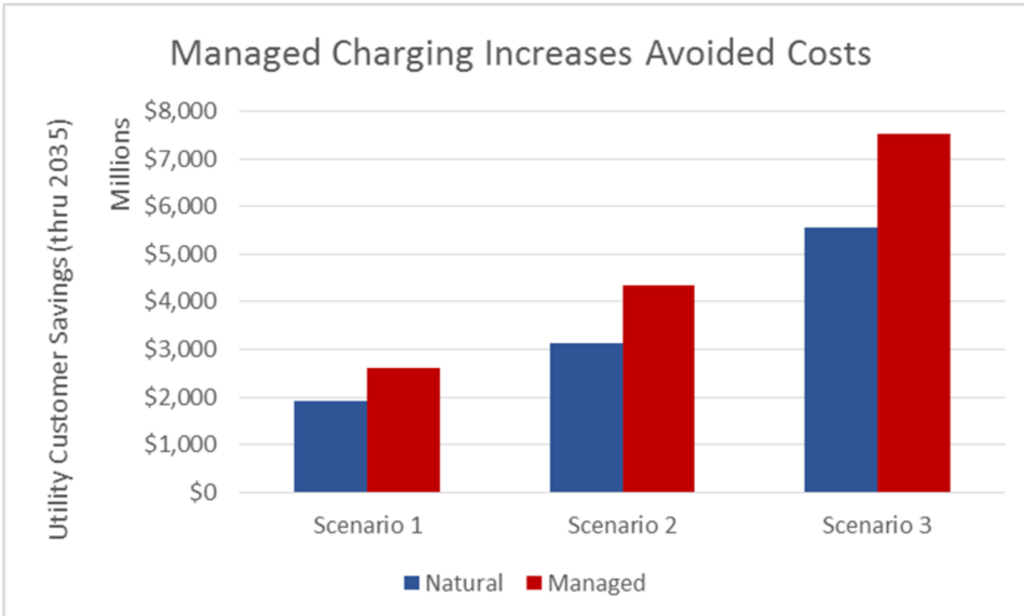
[n] For example, taking representative days in March, June, September, and December, in the year 2050 for Scenario Three, Managed Charging results in an average of 40% of the energy used during the day being during the off-peak hours from 10PM to 7AM, compared with an average of 33.5% for the no-EV baseline. That means that Managed Charging moved ~6.5% of the day's consumption into lower cost off-peak times.



- **Savings increase in proportion to EV adoption.** Electric utility customer savings are strongly proportional to the pace of EV adoption, with the maximum adoption scenarios realizing the greatest savings. The following chart demonstrates the strong nearly-linear correlation between aggregate PEV adoption level (as a percentage of the total light duty fleet) and annual electricity cost savings. This correlation applies across all managed charging scenarios.



- **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 savings are amplified significantly if programs and policies are implemented that encourage more optimal managed charging profiles. Through 2035, this impact ranges from as low as $701M in *additional* savings (compared with natural charging) for the low adoption case (Scenario One), to as high as $1.97B in *additional* savings (compared with natural charging) for the high adoption case (Scenario Three). Averaged through 2050, managed charging delivers approximately 28.5% more savings than natural charging. These managed charging benefits apply in all scenarios, as summarized in the following chart.



- **Managed charging is therefore extremely important, and has a large impact on economic benefits: in the Leadership Case (Scenario Two), managed charging delivers an additional $1.2B in total savings compared with natural charging through 2035 (and an additional $4.3B by 2050).**

- **The study identified multiple beneficial impacts of managed charging.** It represents a "grand slam" of benefits, including a) avoiding incremental load at existing peak times which would increase consumer costs, b) shifting consumption to off-peak times that lowers costs (i.e. "trough-filling" the aggregate load profile), c) deferring impacts (and associated costs) on transmission and distribution assets, and d) creating the opportunity for future use of V2G technology that allows EVs to contribute to active demand reduction (through "peak shaving" of the aggregate load profile). The above savings estimates of the incremental benefit of managed charging probably under-estimate the true impact, since it is likely that natural charging would result in increased capacity and transmission costs that were not assumed in the no-EV baseline.

- **All components of utility costs are reduced.** Savings are likely to be realized in all four components of utility rates as, past a basic adoption threshold, EV use increases. The study examined the wholesale cost of power ($/KWhr) based on competitive dispatch, as well as dilution of capacity, transmission, and distribution costs. Only those cost efficiencies that flow through to KWhr-based charges (based on current tariff structures) were considered in this assessment. Note that the savings associated with wholesale cost efficiencies emerge naturally in the market, and flow to rate payers through impacts on aggregate pricing as the competitive market responds to more optimal load profiles (induced by off-peak EV charging), especially for Basic Generation Supply[o] customers. Longer term, the dilution impacts on capacity, transmission, and distribution costs become the dominant factor, shifting from 36% of the induced effect in 2018 to 87% in 2050 (Scenario Two, managed).

- In summary: even when considering only impacts on electricity costs, EV adoption provides 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.

5.5.2 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, as summarized below:

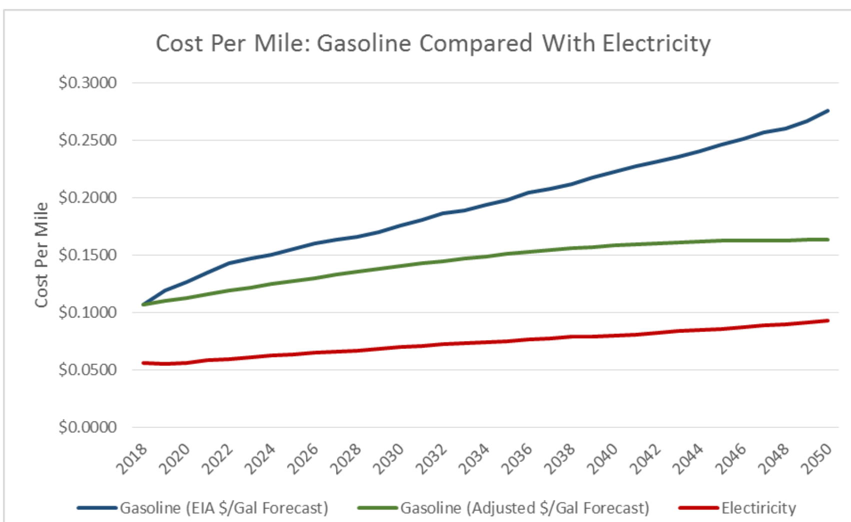
a) **EV owners will realize approximately $16.8B in total savings on vehicle operating expenses through 2035** for the Leadership Case (Scenario Two, managed charging), growing to $71.5B in savings by 2050[p]. Operating savings average $2.2B annually over the period, with annual impact scaling linearly with PEV adoption level. For context, New Jersey drivers are projected to spend $663B on fuel and maintenance from 2018 to 2050 (in the no-EV baseline case), but that number reduces by approximately 11.7% in the Leadership case (Scenario Two). The PV of operating expense savings ranges from $3.8B (Scenario One, natural) to a high of $15.21B (Scenario Three, managed), with the **Leadership Case (Scenario Two, managed) delivering PV savings of $7.54B over the 2018-2035 period.** Fueling with electricity rather than gasoline, combined with the lower maintenance associated with EVs, delivers substantial cash savings for New Jersey EV drivers, and this benefit results in a direct cash benefit that improves disposable income.

b) **Fueling costs represent the majority of these savings, representing approximately 87% of these benefits for both nominal sum and PV savings across all scenarios. In 2018, each electrically fueled mile will average 4.49 cents/mile (for a BEV), compared with an estimated 10.67 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 expected 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.

[o] Basic Generation Supply, or BGS, is the default supply contract under which many customers, especially residential customers, purchase electricity if they do not elect to exercise their rights to select a different supplier.
[p] This savings calculation assumes that a sur-charge is added to EV charging KWhrs equivalent to the current New Jersey gasoline tax that funds the NJTTF, and that gasoline costs grow at reduced rates due to softening petroleum demand.

c) **These OpEx benefits are minimally affected by perceived higher costs of EVs.** At the current time, the average purchase price for new[q] EVs is higher than the average price for gasoline fueled vehicles, and may experience faster depreciation due to quickly changing technology and (potentially unfounded) uncertainties about battery life. As such, some studies attempt to quantify the net benefit of operational expense savings in the context of increased investment and faster depreciation. Those affects are treated more fully in the Societal Cost Test summarized in Section 5.5.8 below, but this study generally found those impacts to be minimal overall. There is emerging consensus that EVs will become price competitive by around 2025, and the majority of EVs assumed under the study scenarios are purchased after that point. As a result, the offset (if any) of higher vehicle purchase costs in the early years are significantly diluted over the overall study period. See more complete discussion on this consideration in Section 5.5.8.

d) **Fueling with electricity exposes drivers to less cost volatility, and those economic benefits are likely to grow over time.** The estimated growth rate of gasoline prices is higher than current projections of the growth rate for electricity rates. As a result, under almost any scenario, EV drivers will benefit from increased savings as the gap between gasoline costs and electricity rates grows over time. Gasoline prices are also fairly volatile relative to electricity prices, being highly sensitive to global politics, extreme weather, and other effects beyond local control. The following chart illustrates the difference in forecasted $/gallon costs over time: the blue line represents the most recent (2017) Energy Information Administration (EIA) forecast of gasoline prices, while the green line represents an adjustment of that forecast to reflect softening gasoline demand due to EV adoption. As noted above, these adjusted gasoline costs were used in estimating EV driver savings. The red line shows projected costs based on residential electricity rates, assuming a sur-charge for the NJTTF.



[q] Conversely, EVs appear to be moving into the secondary market quickly, and with substantial discount. Many consumers prefer to purchase used cars, and one strategy for "lower the cost" of EV acquisition for all consumers is to ensure development of a robust, and heavily discounted, secondary market. That appears to be happening naturally.

e) **Some EV owners will also benefit from federal tax incentives that offset vehicle purchase costs.** The federal government provide a tax credit for plug-in vehicle purchases, up to $7,500. This is represented as a benefit for the New Jersey EV market since it represents revenue for New Jersey vehicle owners. The federal credit begins to decline as EV brands surpass 200K vehicles sold, and so this incentive is modeled as declining every year, and disappearing entirely in 2028 and thereafter. For the Leadership case (Scenario Two), this represents $3.4B in benefit captured by New Jersey vehicle owners.

5.5.3 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.[29] 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 Leadership case (Scenario Two) will avoid at least $4.65B in costs due to reductions in CO2 emissions, with a savings PV of $2.0B. These avoided environmental costs continue to accrue, growing to a sum of $25.7B by 2050, with a savings PV of $6.1B. These savings are based on the more conservative Method One emissions accounting (New Jersey fraction of PJM-wide emissions), which is appropriate given that CO_2 has regional impact.

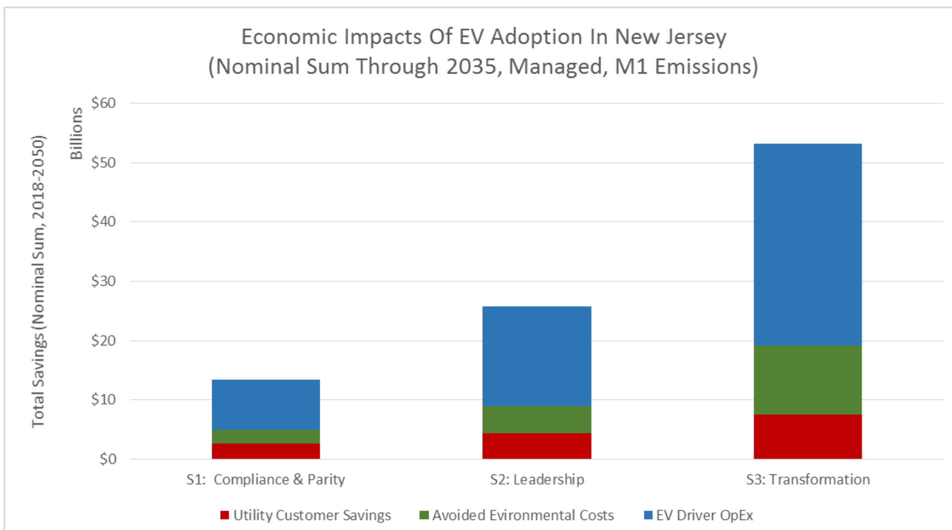
- This cost avoidance (i.e. total savings) through 2050 could be as low as $11.9B ($2.9B PV) in the low adoption case (Scenario One), and up to as high as $41.9B (PV of $10.6B) in total savings for the high adoption case (Scenario Three). The savings that result from reduced CO_2 emissions vary minimally between natural and managed charging scenarios.

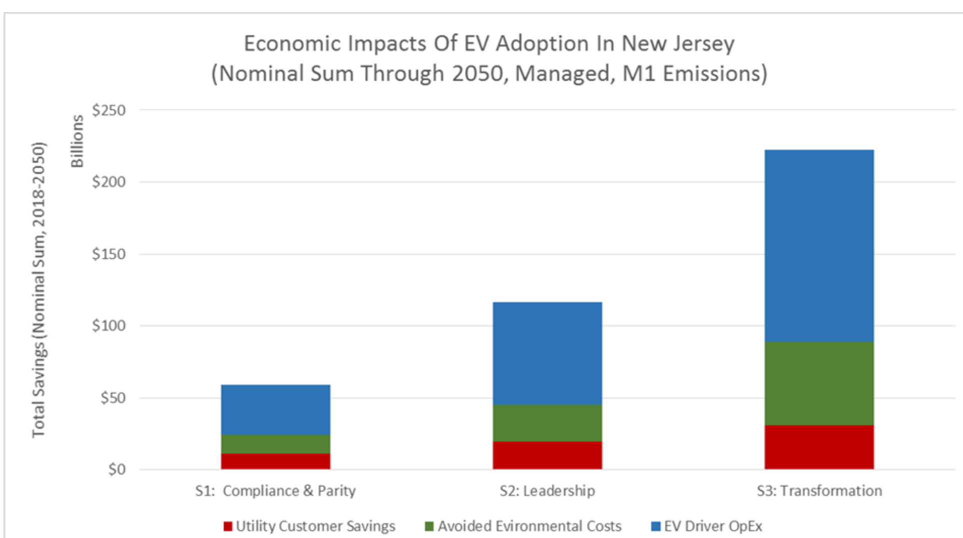
- Note that these estimates of the economic value of environmental impact consider only CO_2 emissions – the largest pollutant (by mass) impacted by vehicle electrification. Similar reductions apply for other pollutants (such as NOx, particulates, VOCs, etc), but those were not fully quantified in this 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.

5.5.4 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 all electric utility customers), (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 Leadership case (Scenario Two, managed), total savings from all three benefit domains are $25.7B, delivering a PV of $11.5, through 2035 (using the more conservative Method One emissions estimate). These benefits could be as high as $53.2B in the high adoption case (Scenario Three) with an PV of $23.7B through 2035. These savings assume managed charging. These combined benefits continue to accrue through 2050, and scale in direct proportion with aggregate EV adoption. The following charts summarize total gross savings for all three domains, through both 2035 and 2050.





- **Widespread EV adoption will have a direct impact on disposable income for New Jersey households.** Focusing on two of the benefit streams that directly affect consumer cashflow – reductions in residential electricity costs and the reduced cost of fueling vehicles – savings are substantial. For EV owners in particular, the economic value is significant: putting two EVs into the garage of an average New Jersey household will create **$1,440 of additional disposable income in 2018, and these savings will average $1,983/year through 2035[r].** It is important to note that these are real cashflow savings for New Jersey households that are realized directly through avoided costs – they are not more abstracted "externalities", and therefore have a real impact on disposable income.

- **There may be broader economic uplift from these savings, which increases economic activity in New Jersey.** As noted in more detail above, EV owners will spend less on vehicle operation. Similarly, all New Jersey electric utility customers will spend less on electricity. Those savings represent enhanced disposable income that will have a multiplier effect on the economy when spent on other goods and services. This effect is expected to be especially impactful for low and middle-income consumers. It is also significant that this shift represents spending LESS money on commodities imported to New Jersey (petroleum), and instead spending MORE money for goods and services, many of which are likely to be produced within the state.

- The multiple economic impacts quantified above represent a broad portfolio of benefits that impact a variety of populations, but due to conservative assumptions adopted within the study, may under-estimate the true economic impact – especially at higher levels of EV adoption. There are several factors that could result in real economic impacts larger than those quantified above:

  a) Wholesale rates decrease for ALL PJM customers, not just those in New Jersey.
  b) Very conservative assumptions about long term gasoline prices – approximately half the rate of gasoline price increases projected by the EIA.
  c) Infrastructure upgrades (transformers) are also driven by a number of factors, and those upgrade costs shouldn't be "booked" exclusively against EV-related benefits.
  d) The value of reduced emissions is based on CO_2 impacts only -- full consideration of all GHG emission reductions and other pollutants would increase those benefits substantially.
  e) 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.
  f) Economic impacts of public health implications are probably significantly under-represented. The Social Cost of Carbon method only partially accounts for public health impacts.
  g) Since widespread EV adoption will reduce demand for gasoline, the cost of gasoline will likely decline even for owners of traditional gasoline powered vehicles.

[r] These cashflow benefits do not reflect potential costs, which are covered in more detail in Sections 5.5.6 and 5.5.7.

h) The full benefits of increased electricity infrastructure utilization may not be fully captured, especially for the power plant fleet.
i) 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.

5.5.5 Potential Costs And Investments

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 resulting from 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 (such as the ChargEVC Roadmap), and reinforcement of the public grid due to additional EV-induced loading. To allow for determination of NET benefit – after applicable costs and investments – the study estimated potential expenses[s] associated with EV adoption in three broad categories:

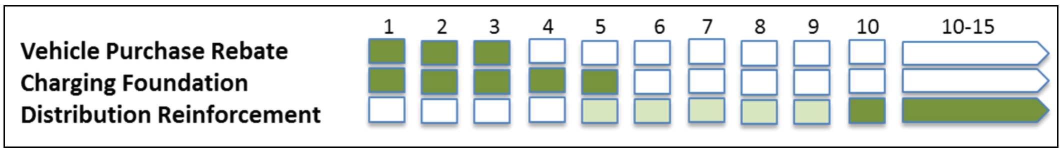
- **Market Development Costs:** The ChargEVC Roadmap proposes several actions that will incur costs, potentially supported by electric utility customers (or tax payers) in some form. These program actions and resultant costs total an estimated $700M, and include a $300M vehicle rebate program, a standardized public high power DCFC network (estimated to require approximately $150M in incentive support), and support for meeting high priority needs for Level Two chargers in certain segments (assumed to be $250M). Note that the exact form of this public support is not yet defined – if the rebate program is funded from the existing Societal Benefits Charge (SBC) provision, which is a cost that is already carried by electric utility customers, it would not represent an additional cost. Similarly, if some of these programs are funded through programs like the Regional Greenhouse Gas Initiative (RGGI), it may not result in a direct charge exclusively on New Jersey electric utility customers. Nonetheless, all estimated costs are included in full, for purposes of having a clear and conservative benefit/cost understanding regardless of how funded or whether those costs are incremental.

- **Utility Infrastructure Upgrades:** As noted in Section 5.8 below, 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 stess conditions especially on single phase distribution transformers. Consistent with the findings in other studies, minimal impact is expected at substation or transmission levels in the

[s] In most cases, the programs and policies considered for this cost assessment have not been defined or proposed, making detailed cost estimates difficult. The study is based on a good faith estimate of POTENTIAL costs, based on estimated costs for the ChargEVC roadmap, high level estimates from the electric utilities and other subject matter experts on possible reinforcement costs, and input from a variety of industry sources and other studies on typical EV adoption costs by other market participants.

architecture. The cost program assumes replacement of all single-phase distribution transformers, at a pace determined by EV adoption, using threshold factors determined by the study as necessary to minimize local transformer overload risks. That represents an estimated $2.3B in upgrade costs (spread over 10 to 20 years) for the Leadership case (Scenario Two) with managed charging.

- **Recovered Costs:** The market development and infrastructure costs are assumed to be planned programs that could potentially be recovered from utility customers through rates. This is probably an extreme worst case scenario, but for purposes of being conservative, both those recovered costs are assumed in the cost model. They are modeled in the cash flow over a multi-year period, as summarized below.



- **Costs By Other Market Participants:** Beyond planned expenses incurred through organized programs or policies as noted above, a variety of other market participants may make investments related to the adoption of electric vehicles. These costs typically would not be allocated to ratepayers or taxpayers through cost-recovered programs, but represent expenses made by individual market participants. The following costs are accounted for as part of the broader Societal Cost Test:

    a) **Vehicle Purchase Premium:** As noted in Section 5.5.2, the average cost of EVs is higher than the average cost of traditional vehicles. This is an early market condition, and as the industry increases scale and battery costs decline, this premium expected to decline until cost-parity is achieved around 2025. Meanwhile, there is a perception that EVs carry a purchase premium. As a practical matter, it is not clear that this premium exists at a transaction level – a buyer with a $25K budget does not by a $35K vehicle. Regardless, to determine costs most conservatively and transparently, a vehicle purchase premium is included in the model. Based on a combination of market research and reference to approved utility filings that also quantified vehicle purchase premiums, a premium of $9,660 was used for battery electric vehicles, and $8,979 for plug-in hybrids[30]. This premium was assumed to decline by 10% each year, and was eliminated entirely in 2031 and thereafter. The premium was assumed to apply to ALL BEV and PHEV purchases in NJ, with total costs ranging from $3.3B for Scenario One, to $13.5B for Scenario Three through 2031. These costs are carried by EV vehicle buyers only.

    b) **Non-Utility EVSE Investment:** The market development program assumed state and utility-enabled programs that supported early stage installation of public and private charging infrastructure. These programs only pay for part of those system installations, and the balance of costs are carried by private investors (site hosts, project financiers, etc). The model assumed that 100% of new BEVs and 50% of new PHEVs required a networked L2 charger installation at home, plus development of workplace L2, public L2, and public DCFC facilities consistent with the infrastructure development roadmap published for New Jersey by the DOE[31]. These assumptions likely overstate actual costs, since a) they assume that equipment installation costs remain flat through 2050 (although in reality they are likely to go down over time), and b) by assuming that every new EV sold will require a new L2 charger installation. This latter assumption is expected to more than cover any turn-over/replacement of equipment that may be required over time. The total of these investments range from $2.1B for Scenario One through 2035, to $21.0B for Scenario Three through 2050, and reflect private investment net of any utility or state funded incentive programs assumed in the market development portfolio.

The cost model assumptions vary by adoption scenario, consistent with different degrees of market development incentive and the EV adoption rate. Key assumptions include:

- **Scenario One:** No market development incentives, but transformer upgrades as driven by EV adoption rates.

- **Scenario Two:** Full market development incentive costs (rebate, DCFC, Level Two, totaling $700M over a multi-year period), plus transformer upgrade costs as driven by EV adoption rates.

- **Scenario Three:** The same market development incentives as Scenario Two ($700M total), plus transformer upgrade costs, but on an earlier and faster schedule given the more accelerated EV adoption schedule.

- **Natural vs. Managed:** The cost models account for the differences in natural vs managed charging, both their different saving totals, and the fact that managed charging defers the need for transformer upgrades in time and pace (i.e. later and slower).

- **New Jersey Transportation Trust Fund (NJTTF):** A sur-charge has been added to the projected cost of electricity, equivalent to the $/gallon tax on gasoline used to fund the NJTTF. The “costs” of ensuring that EVs replace the revenues associated with the NJTTF gasoline tax are therefore already incorporated into the savings analysis.

- **Fuel Costs:** The cost of gasoline, which affects EV driver “fueling savings” was estimated very conservatively – approximately half the price escalation projected by the EIA, based on an assumed softening of gasoline demand and associated reductions in gasoline costs.

5.5.6 Net Benefits for Utility Customers

Given that some of the potential costs and investments 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, are not included. This test is therefore very conservative, but provides a rigorous assessment of NET ratepayer impacts. The details for this test, and associated results, are summarized below (a discount of 6.3% was used for all Net Present Value calculations).

- Only savings realized by utility customers through lower electricity costs are considered as a benefit, as defined in Section 5.5.1. Costs include only those programs that could potentially be recovered from utility customers through rates, including the market development investments, and infrastructure reinforcement defined in Section 5.5.5.

- Since the investment programs are intended to create conditions where managed charging dominates, benefit estimates for Scenario Two and Scenario three are based on managed charging. Benefits for Scenario One are based on natural charging, since the market development program is not included in cost assumptions. The NPV of avoided electric costs benefits for these key scenarios are as follows:

    A. Scenario 1 - Natural: $854M by 2035, $2.2B by 2050
    B. Scenario 2 – Managed: $1.9B by 2035, $4.9B by 2050
    C. Scenario 3 – Managed: $3.4B by 2035, $8.2B by 2050

- Potential costs reflected in the NET benefit test include the market development program anticipated by the ChargEVC roadmap ($700M over five years, including a vehicle purchase rebate ($300M over three years), utility (or other state enabled) investment in a critical mass of charging infrastructure ($400M over 5 years)), and distribution system reinforcement over an extended timeframe ($2.2B over 15-20 years). The NPV for these investments for the key cases are summarized below:

    A. Scenario 1 - Natural: $315M by 2035, $489M by 2050
    B. Scenario 2 – Managed: $981M by 2035, $1.2B by 2050
    C. Scenario 3 – Managed: $1.5B by 2035, $1.5B by 2050

- Key results from the utility customer impact test are summarized below:

		By 2035		By 2050	
	Charging	**B/C Ratio**	**NPV**	**B/C Ratio**	**NPV**
Scenario 1	Natural	2.71	$529 M	4.55	$1.7 B
Scenario 2	Managed	1.99	$975 M	4.28	$3.8 B
Scenario 3	Managed	2.26	$1.9 B	5.44	$6.7 B

- Note that although the B/C ratio for Scenario One is higher due to lower costs (i.e. no market development investment), the net benefit returned to rate payers is approximately half that returned in the Scenario Two case that includes more market development, and realizes higher EV adoption as a result.

- These NET savings likely under-estimate actual electric utility customer benefit, since savings have been estimated conservatively (with only per-KWhr energy-related benefits considered) and costs have been generously estimated. For example, the cost assumptions reflect replacement of all single phase distribution transformers in the state and that all those upgrade costs are booked exclusively to EV-based motivations. In addition, utility benefits may be lower than what is estimated for Scenario One if natural charging (due to the assumed lack of market development investment) results in increased capacity and/or transmission chargers.

In summary, when accounting for the market development and utility infrastructure upgrade costs noted above, **all scenarios deliver positive NET benefits and a B/C ratio of approximately two or highe**r. In other words, the savings realized by electric utility customers through reduced utility bills are sufficient to fully recover estimated costs, with significant additional economic benefit remaining. **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.**

5.5.7 Societal Cost Test

As detailed in the sections above, widespread adoption of PEVs will realize a diverse range of benefits across a variety of beneficiary groups. The Societal Cost Test captures ALL estimated benefits (regardless of who receives that benefit), and compares with ALL potential costs or investments (regardless of who carries that expense). This test appropriately captures the full portfolio of EV-induced impacts, although some of those benefits are “externalities” that may apply to only subsets of the overall population. The details and results of the Society Cost Test (SCT) are summarized below. All Net Present Value (NPV) calculations are based on a 2.77% discount rate.

- All savings or avoided costs that result from EV adoption are captured, as defined in Section 5.5.1 through Section 5.5.4. Potential costs include market development investments, infrastructure reinforcement, vehicle purchase premiums, and private investment in charging infrastructure (above what is already captured in the market development program), as defined in Section 5.5.5.

- Since the investment programs are intended to create conditions where managed charging dominate, benefit estimates for Scenario Two and Scenario three are based on managed charging. Benefits for Scenario One are based on natural charging, since the market development program is not included in cost assumptions. Benefits include avoided electricity costs, net reduced operating expense for EV owners, the economic value of reduced CO_2 emissions, and federal tax incentives that can be captured at the point of vehicle purchase. The New Jersey sales tax waiver is not quantified, since it should be modeled as both a benefit (for EV recipients) and a cost (for NJ tax payers) with approximately zero net impact overall. The NPV of benefits for the key scenarios is as follows:

A. Scenario 1 - Natural: $10.3B by 2035, $32.2B by 2050
B. Scenario 2 – Managed: $20.8B by 2035, $66.2B by 2050
C. Scenario 3 – Managed: $42.7B by 2035, $125.4.2B by 2050

- Potential costs for the test include the market development program anticipated by the ChargEVC roadmap ($700M over five years, including a vehicle purchase rebate ($300M over three years), utility (or other state enabled) investment in a critical mass of charging infrastructure ($400M over 5 years)), and distribution system reinforcement over an extended timeframe ($2.2B over 15-20 years), as well as vehicle purchase premiums ($13.6B through 2030), and private investment in charging infrastructure (which varies widely by adoption scenario and time frame, but ranging from $2.1B to $21.0B). The NPV for these investments for the key cases are summarized below:

A. Scenario 1 - Natural: $4.7B by 2035, $7.1B by 2050
B. Scenario 2 – Managed: $9.5B by 2035, $13.9B by 2050
C. Scenario 3 – Managed: $18.9B by 2035, $25.3B by 2050

- Key results from the Societal Cost Test are summarized below:

		By 2035		By 2050	
	Charging	**B/C Ratio**	**NPV**	**B/C Ratio**	**NPV**
Scenario 1	Natural	2.18	$ 5.5 B	4.42	$ 24.3 B
Scenario 2	Managed	2.19	$11.3 B	4.63	$ 50.7 B
Scenario 3	Managed	2.26	$23.8 B	5.95	$100.1 B

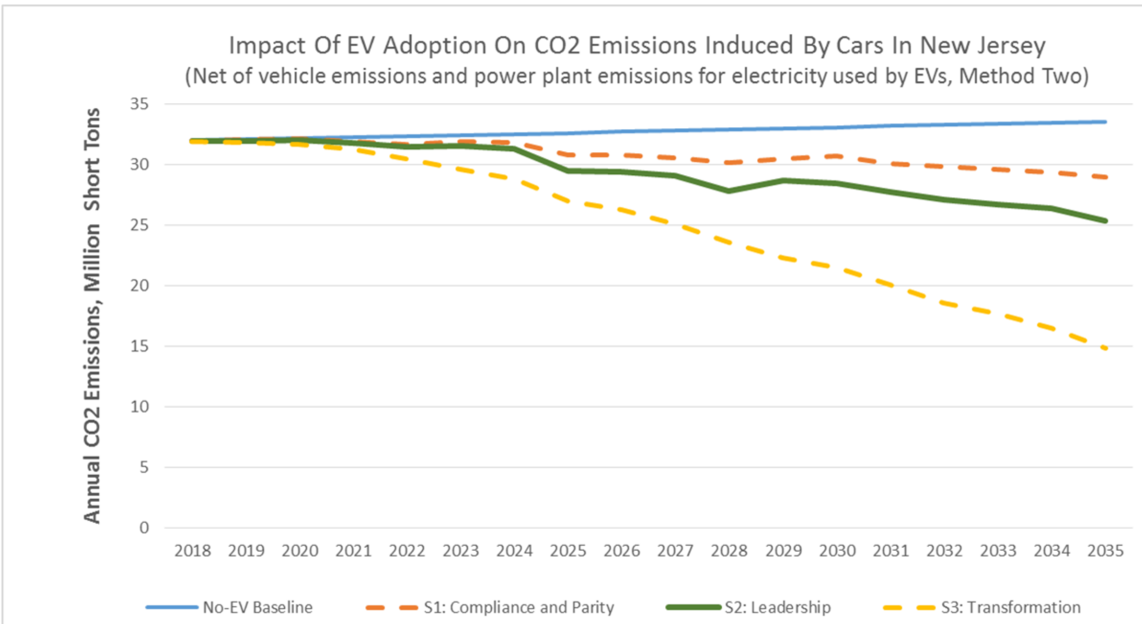
- Note that although the B/C ratios for the SCT are similar to that realized by the Utility Customer Impact test, the NPV of NET benefits are much higher. A primary driver for these higher net benefits is the substantial savings realized by EV drivers, primarily due to the lower costs for fueling with electricity rather than gasoline.

In summary, when accounting for all identified benefits and costs, across a combination of impacted population groups, **all scenarios deliver positive NET benefits and a B/C ratio of approximately two or higher**. When this broader portfolio of benefits is considered, EV adoption benefits far exceed potential costs under any scenario, but the combination of managed charging and higher adoption levels achieve the greatest beneficial impact.

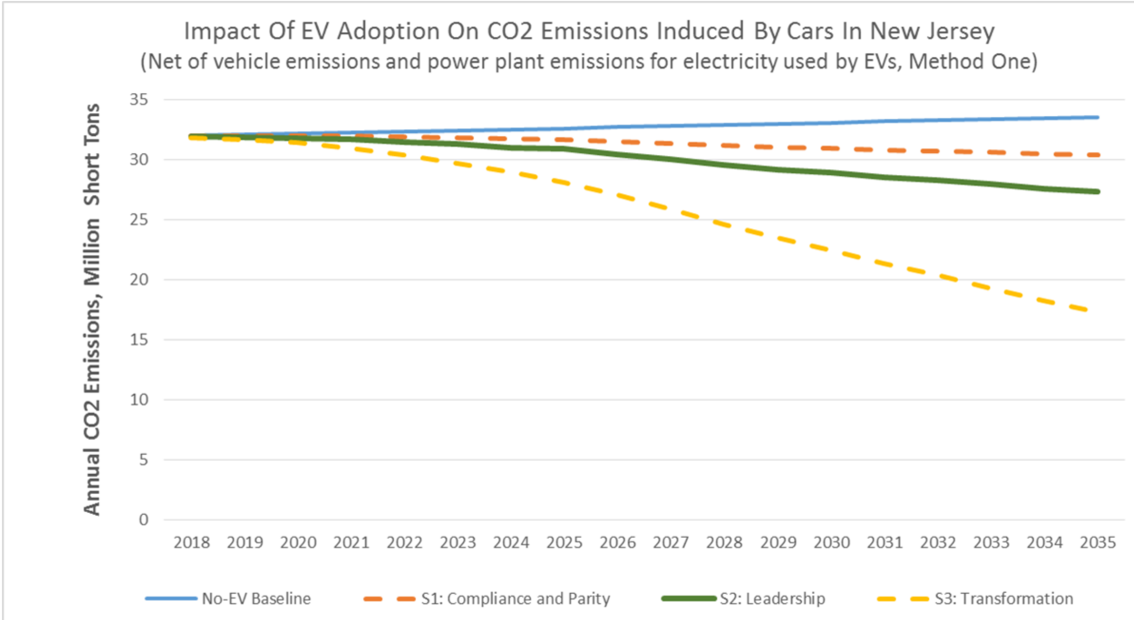
5.6 Findings: Environmental Benefits

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 in New Jersey (as reflected in the "Method Two" protocol used for New Jersey GHG emissions), 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 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.** Using a CO_2 accounting method consistent with New Jersey's statewide GHG inventory (Method Two), **the Leadership case (Scenario Two) decreases transportation related CO_2 emissions by 40.0% in 2050, and as much as 63.0% under the high adoption trajectory (Scenario Three) compared with the no-EV baseline. The following chart illustrates the reduction of NET CO_2 emissions for each scenario through 2035.**

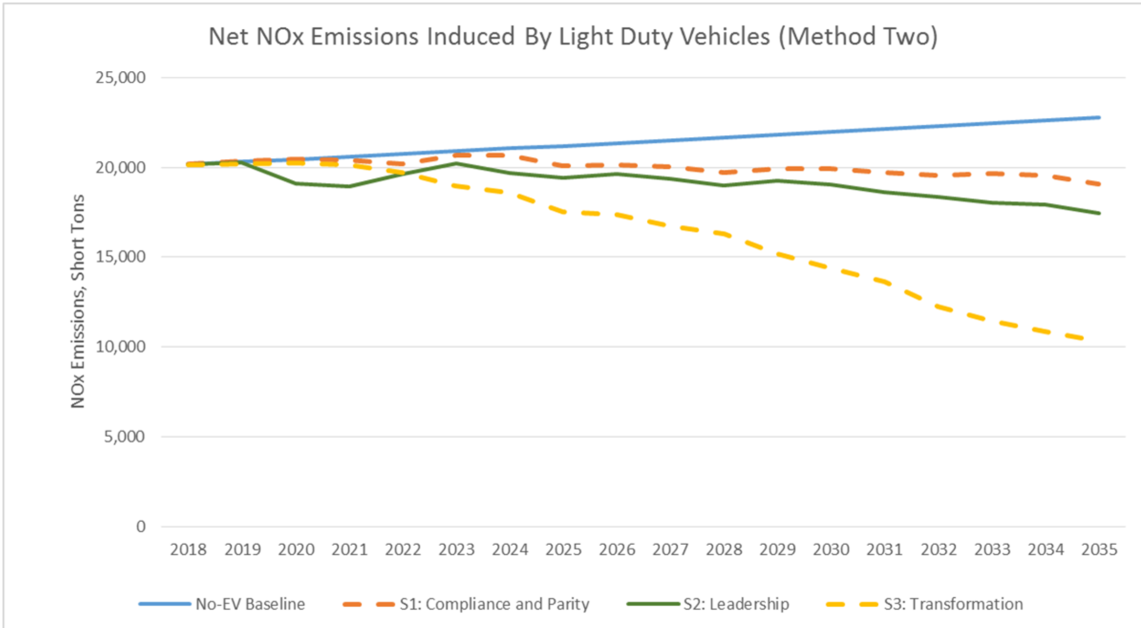


- **Net CO_2 emission reductions are less pronounced under a more conservative emissions accounting methodology, but CO_2 reductions are still substantial.** Using Method One for calculating power plant emissions, the Leadership case (Scenario Two) reduced CO_2 emissions by 31.9% in 2050 (compared to the no-EV baseline), increasing to a 46.1% reduction for the high adoption scenario (Scenario Three).



- **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 in New Jersey.** This benefit is especially important since New Jersey has not yet attained compliance with current federal NOx standards, and these pollutants have a particular impact on public health (see Section 5.7 below). Given progress made on NOx reduction from stationary sources, the primary opportunity for continued NOx reduction is in the transportation sector, and vehicle electrification is a highly effective strategy for achieving those goals. The Leadership case (Scenario Two) results in a 30.4% reduction in NOx emissions in 2050, increasing to as much as a 44.1% reduction under the high adoption case (Scenario Three). The following chart summarizes NOx impacts for various scenarios through 2035.



- **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 the Leadership case (Scenario Two) will add approximately 7,000 tons of SOx emissions per year in 2050 (using emissions Method Two). Note that the magnitude of emission for this pollutant is approximately 1,000 times smaller (in absolute mass) than CO_2 emissions. Further study on this issue is needed, including synchronization with NJDEP measurement and reporting methods.

- **The 80% CO_2 reduction goals are nearly achieved in the high electrification scenario.** According to the Rutgers GHG Inventory, the 2006 baseline for gasoline consumption (primarily in light duty vehicles) was 42.02 million tons of CO_2. An 80% reduction implies CO_2 emissions of 8.4 million tons, including the net impact of increased power plant emissions. This study estimates that at high levels of electrification under Scenario Three, NET CO_2 emissions falls to a low of 9.6 tons (under Method Two, consistent with the Rutgers GHG inventory, managed charging), with approximately 83% of the fleet being a PEV at that time. Achieving further CO_2 reductions is possible, based on: a) higher levels of PEV penetration (90% at least, by 2050), b) the grid could decarbonize further than the business as usual plant-build assumptions in this study, and c) vehicles could transition to mostly pure battery electric vehicles (not plug-in hybrids that continue to consume fuel). This conclusion highlights the synergy between simultaneous commitments to grid de-carbonization and vehicle electrification. Even with the more basic assumptions used in this study, however, the 80% reduction goals are nearly achieved - but it requires extremely high levels of EV adoption by 2050.

5.7 Findings: Impacts on Public Health

Air quality is not an abstract issue – it has a real and direct impact on the health of all New Jersey citizens, especially within urban cores and along dense travel corridors where disadvantaged communities are frequently located. There are numerous ways in which reduced air pollution improves public health – especially regarding a lower volume of case-incidence of various air pollution induced ailments. This study built on research by the American Lung Association (ALA) to specifically identify case incident benefits associated with reduced NOx emissions resulting from vehicle electrification[t].

- **As noted in Section 5.6, vehicle electrification reduces the emission of NOx (and other air pollutants), and reduces the NOx-induced case incidence by 10-33%, depending on the adoption scenario.** The sum of Minor Restricted Activity days (from 2018 to 2050) are estimated to decline by 118,163 days in the Leadership case (Scenario Two), and as much as an estimated 240,004 fewer restricted days in the Transformation case (Scenario Three). Work Loss Days are estimated to decline by 19,721 in the Leadership case, and will result in as many as 40,037 fewer lost days in the Transformation case. Significant reductions were seen across all estimated case types, as summarized in the table below.

Health Incidence Category	Scenario One			Scenario Two			Scenario Three		
	Total	% Change	Avg/Year	Total	% Change	Avg/Year	Total	% Change	Avg/Year
Premature Mortality (deaths)	-168	-10.2%	-5.1	-269	-16.4%	-8.2	-548	-33.4%	-16.6
Morbidity									
Respiratory Emergency Room Visits	-54	-10.1%	-1.6	-87	-16.2%	-2.6	-176	-32.9%	-5.3
Acute Bronchitis & Respiratory Symptoms	-4,844	-10.0%	-146.8	-7,789	-16.1%	-236.0	-15,824	-32.8%	-479.5
Minor Restricted Activity Days	-73,467	-10.0%	-2,226.3	-118,163	-16.1%	-3,580.7	-240,004	-32.6%	-7,272.8
Work Loss Days	-12,255	-9.9%	-371.3	-19,721	-16.0%	-597.6	-40,037	-32.4%	-1,213.3
Asthma Exacerbation	-6,830	-10.1%	-207.0	-10,978	-16.2%	-332.7	-22,310	-32.9%	-676.1
Hospital Admissions (Cardio and Respiratory)	-68	-10.3%	-2.1	-109	-16.5%	-3.3	-222	-33.6%	-6.7
Non-fatal Heart Attacks	-131	-10.3%	-4.0	-209	-16.6%	-6.3	-427	-33.7%	-12.9

Note: "Total" in the preceding chart represents the number of incidents in each scenario relative to the no-EV baseline, totaled from 2018-2050. Negative numbers represent a REDUCTION of incidence.

- **The health impact improvements achieved over time are significant and will persist long term.** The air quality improvements achieved at the end of the study period are expected to continue long term. By 2050, Minor Restricted Days are estimated to be reduced by 7,087 days each year, while Lost Work Days are estimated to be reduced by 1,181 days – both of which represent a reduction of about 32% in the Leadership case (Scenario Two) compared with the no-EV baseline. Similar improvements are evident across all case types, and will recur annually past the study period – i.e. a permanent reduction in NOx results in a reduced case incidence every year long term. **Vehicle electrification creates a beneficial structural change in the state's emission profile which improves the quality of life for all New Jersey citizens long term and reduces**

[t] The ALA study quantified impacts from a wide variety of air pollutants, including NOx and numerous others. As a first step, this study focused only on NOx since it is a particularly impactful pollutant, and NJ is striving to attain compliance with federal NOX standards as a high priority. Broader consideration of all health impacts from reductions in other pollutants would increase the benefits quantified in this study, in some cases substantially. All incidence rates noted are for NOx-induced events only, not all air pollution related impacts.

health burdens. The chart below summarizes the incidence reductions in 2050 for each scenario, and the percentage change relative to the no-EV baseline.

Health Incidence Category	Scenario One		Scenario Two		Scenario Three	
	# in 2050	% Change	# in 2050	% Change	# in 2050	% Change
Premature Mortality (deaths)	-9	-18.1%	-16	-31.9%	-27	-53.2%
			0			
Morbidity			0			
Respiratory Emergency Room Visits	-3	-18.1%	-5	-31.9%	-9	-53.2%
Acute Bronchitis & Respiratory Symptoms	-8	-18.1%	-15	-31.9%	-25	-53.2%
Minor Restricted Activity Days	-106	-18.1%	-187	-31.9%	-312	-53.2%
Work Loss Days	-151	-18.1%	-266	-31.9%	-443	-53.2%
Asthma Exacerbation	-4,030	-18.1%	-7,087	-31.9%	-11,820	-53.2%
Hospital Admissions (Cardio and Respiratory)	-672	-18.1%	-1,181	-31.9%	-1,970	-53.2%
Non-fatal Heart Attacks	-375	-18.1%	-659	-31.9%	-1,100	-53.2%

- **This study focused on the case incidence of NOx-induced ailments, but there are economic consequences to many of these events as well.** Economic impacts include lost days at work or school, lower productivity, and the expenses associated with health care -- all of which decline as case incidence reduces. This study did not attempt to quantify those economic impacts – which should be counted as EV adoption benefits – since they are partially captured in the “Social Cost of Carbon” calculation. However, the inter-governmental panel on the Social Cost of Carbon notes that their assessment probably significantly under-estimates public health impacts. Please see the ALA report for more details about the economic impact of public health consequences[32].

5.8 Findings: Impacts on the Utilities, Energy Markets, and Electric Infrastructure

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. The study looked specifically at many of these impacts and was able to characterize a variety of significant implications. 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 one of the New Jersey electric utilities. These conclusions, although specific to one utility territory, are expected to be more generally applicable to all utility systems.

- **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, overload conditions can materialize based on only a few clustered vehicles. These strain 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 5% aggregate EV adoption (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 residential electricity consumption (KWhrs) by at least a third 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 2,800 KWhrs per year short term, increasing to 3,570 KWhrs per year by 2030 as a wider range of vehicles become available. Typical homes in New Jersey range from approximately 4,000 KWhrs/year to 16,000 KWhrs/year, with an average around 8,400 KWhrs/year. Annual residential KWhr-consumption will therefore increase 33% - 43% per EV charged at home, with that number doubled for a typical New Jersey household with two vehicles. **This outcome implies that widespread adoption, when two EVs per home (or more) become common, is similar to approximately doubling the number of homes on a residential circuit 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 (MWhrs) is during lower cost, off-peak times. Meanwhile, relatively fixed capacity, transmission, and distribution costs are diluted over a larger MWhr volume. At Leadership levels of EV adoption, assuming optimal scheduling of vehicle charging, **electricity unit costs could decline by 9.6% by 2035, and 13.1% by 2050**.

- **EV adoption will increase utility revenues, even though unit costs are declining.** If Leadership levels of EV adoption are achieved, **total revenues for utilities and electricity suppliers statewide will be $2.8B higher through 2035 and $16.7B higher by 2050** (in nominal dollars, compared with the no-EV baseline) resulting from increased electricity use.

- **Although EVs represent significant annual consumption, daily charging requirements will be relatively modest on average, typically around 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 31.6 miles, and EVs currently achieving 3.5 miles/KWhr, daily charging requirements will average just over 9.1 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 New Jersey home is 3-4KW. Adding a single 7.2KW charger to a home that normally peaks at 3KW is therefore a significant change in load, with aggregate impacts on distribution infrastructure overall.

- **Beyond physical impacts on the distribution system, EV charging will re-shape the aggregate load on the wholesale generation fleet.** The implications of these changes in load shape are especially impactful on aggregate economics, as noted in the economics discussion in Section 5.5.1.

- **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 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 a New Jersey utility. 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 overload 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 initial point of EV charging induced overload was the single phase distribution transformer – often at relatively low levels of adoption. In some neighborhoods, even a single EV would overload the local transformer. More typically, adoption between 10% and 30% created overload 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 some point a, 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 overload conditions emerge. This dynamic doesn't eliminate the need for reinforcement eventually, but it can defer the timing of that change and spread it out over time.

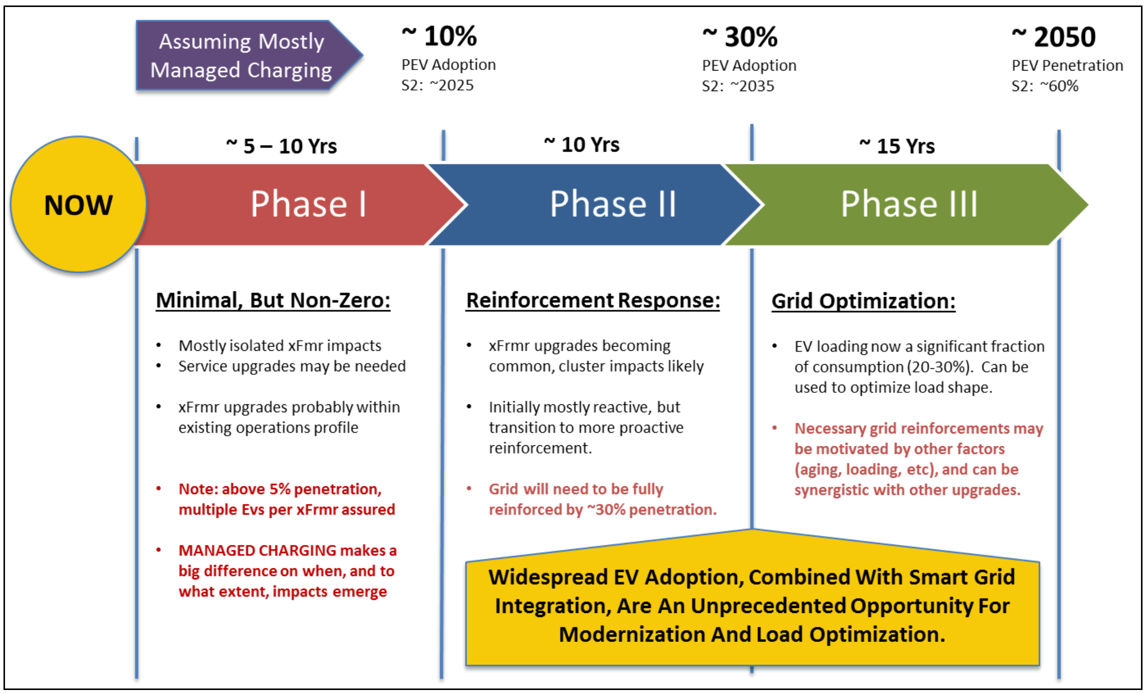
- **These system reinforcements may be forced by EV loading conditions, but they are also motivated by other factors and can potentially bring other benefits.** Utilities are upgrading and re-configuring distribution transformers all the time, and many of them are in need of attention as part of routine maintenance, repair, and load matching and balancing. The EV loading noted above becomes an additional, but significant factor (eventually) that influences 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 (~25% of overall electricity consumption at maximum electrification of the light duty fleet), 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.

- **Simple managed charging solutions can evolve to more sophisticated Vehicle-To-Grid systems in the medium term, and the beneficial impact of those systems are even larger than the 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 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 **60GWHRs of dispatchable storage available during peak time through residentially connected vehicles.** That is enough to completely support New Jersey's peak load for 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, 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.



- **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.

5.9 Findings: Other Strategic Implications

Beyond the economic and environmental impacts of increased EV adoption, there are a wide variety of more qualitative benefits that also accrue. Based on a survey of existing literature, the following general outcomes could reasonably be expected to result from increased EV use, most of which are directly related to the reduced use of petroleum.

1. As noted in several sections of the report, some of the impacts (especially emissions) will accrue disproportionally along travel corridors. There are therefore significant social equity implications to widespread EV adoption, which will have an exceptionally large positive impact on air quality in urban centers and along travel corridors where low income and environmental justice communities are often located.

2. The EVs introduced to date have been well rated from a safety perspective, and EVs benefit especially from a low center of gravity due to the batteries. Widespread EV adoption could therefore reduce vehicle-related safety risks for the traveling public.

3. EVs are much quieter than traditional vehicles, and reduced vehicular noise will be a significant benefit along some travel corridors. There is a related risk that needs to be addressed as well, which is that EVs are so quiet that pedestrians may be unaware of approaching vehicles, especially those pedestrians that are blind and depend on vehicle noise indicators to navigate safely.

4. EVs can be used to provide power to the home in the event of a grid outage, although this feature is not yet widespread across currently available vehicles. There are therefore potential resiliency benefits from “stored on-site power” in the residential sector.

5. A significant fraction of the US trade deficit is related to the use of imported petroleum. As EV use increases, petroleum use, especially imports, will decline. Widespread vehicle electrification could therefore have a strong positive impact on the overall US trade balance.

6. The geopolitical implications of the existing petroleum industry are substantial, including impacts on where conflict zones emerge, global trade balances, the fact that petroleum revenues are a primary source of income for terrorist organizations, etc. The geopolitical implications of a world with dramatically reduced petroleum use are profound.

7. The majority of the transportation sector depends primarily on a single source of energy: petroleum. An added advantage of “fueling” vehicles with electricity is that electricity generation benefits from a highly diversified based of primary sources – potentially including lower carbon sources in the future. Overdependence on petroleum as the sole source for transportation energy is evident through the impact increased oil prices have on the broader economy. Vehicle electrification therefore provides significant strategic benefit through diversification of the primary energy supplies that support the crucial transportation sector.

8. As a practical matter, vehicle electrification has been coupled strongly with other emerging vehicle innovations, especially changes in the vehicle ownership paradigm (car sharing, ride hailing, subscription services), and autonomous vehicles. Some of those impacts could be profound, and represent broader implications enabled by widespread EV adoption.

6 Areas For Further Study

Throughout the study process, several opportunities for expanded investigation were identified, including:

1. Expand the scope to include diesel and medium/heavy duty vehicles.

2. Allow for consideration of seasonality and day-of-week impacts.

3. This study assumed "business as usual" for any additional electricity generation capacity required, and continuation of the existing established generation base (except where known retirements could be documented). The study could be extended to consider other cleaner forms of generation, both displacement of existing assets, and in support of new capacity required. This will increase the emission reduction benefits identified in this study. A broader study that characterized the interplay between various RE growth assumptions, other grid-storage levels, and EV adoption would be useful in overall strategic policy planning. The potential benefits of timing EV charging to coincide with natural RE generation patterns could be quantified, although these benefits don't emerge until much higher RE penetration levels are achieved.

4. Explore the use of Vehicle-To-Grid (V2G) technology to shave peak, in addition to using EVs to increase loading during the "trough times" overnight. This development has a close linkage with modeling of renewable energy supply, since solar and wind each have very different time-of-day profiles.

5. Expand the model to consider other emissions, especially particulates and VOCs, and include additional pollutants (beyond CO2) in estimation of the economic value of emission reduction.

6. Expand consideration of public health impacts to include all GHG emissions (not just CO_2).

7. Update the New Jersey market statistics with the latest sales results, and develop a "most likely" adoption case based on the state's emerging market development policies. This approach might result in a better baseline definition upon which updated savings could be based.

8. Refine the NET benefit analysis based on actual cost estimates for programs being developed.

9. Although the study considered three different charging trajectories (Scenario One – Three), and the differences between natural and managed charging, additional "sensitivities" could be considered. The benefit results are relatively immune to variations in key assumptions, since all savings are calculated based on changes to a baseline, and many assumptions are common in both the baseline case and the alternative under consideration. Nonetheless, there is merit to

further exploring how sensitive key conclusions are to variations in certain assumptions. Potentially high-impact opportunities for sensitivity analysis are a) the cost of gasoline over time, and b) variations in assumptions about average miles traveled per year per vehicle.

10. This study assumes that consumers don't change their driving habits as a result of replacing their traditional vehicle with an EV. That approach (for this initial study) has the benefit of avoiding introduction of an additional variable (about behavior changes) that could cloud conclusions. A more detailed study could examine how driving behaviors might change with EV adoption, particularly regarding "induced travel". Since EVs cost much less to operate (especially for "fueling"), there is a possibility that lower cost induces additional driving. If that is significant, the benefits noted in this study might be slightly over-stated, since they don't account for that additional driving. This dynamic is similar to the "rebound" or "snap-back" effect noted in energy efficiency programs. Future studies (or sensitivities) could account for potential changes in driving as a result of lower operating costs.

11. The study inherently assumed continuation of the current vehicle ownership and use paradigms. A future study could explore the implications of advanced mobility solutions that drive different strategies, some of which have strong overlap with vehicle electrification. Key examples include car hailing, ride hailing, fractional or subscription ownership, car sharing, and a variety of autonomous vehicle implications.

12. Implications for commercial circuits could be more deeply considered, especially in the context of evolving vehicle ownership and use trends noted above.

13. There are a wide variety of broader benefits that have been identified qualitatively but which have not been factored into the benefit portfolio. Examples include benefits that might accrue to sites that host public charging infrastructure (more customers), the benefits to non-EV drivers of softening petroleum demand and lower gasoline prices, how load optimization might lower prices for PJM customers outside of New Jersey, etc.

14. The definition of "managed charging" was fairly simple quantitatively, and focused on concentrating the majority of residential charging into known off-peak times. The model would benefit from a more sophisticated approach to quantifying what an optimum managed charging profile looks like, and using that as the basis for dispatch simulation, potentially including some characterization of how pricing dynamics change with large changes in load profile.

15. A broader "Total Resource Test" (TRC) could be completed, which would be similar in scope to the Societal Cost Test already provided. That calculation would need to take the scope of energy consumption back to primary sources, including at power plants.

7 Conclusions and Recommendations

This study characterized current EV market conditions in New Jersey, and explored the potential for expanded EV adoption within the state. 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, cost assumptions, and emission accounting methods. Key conclusions include:

1. New Jersey has taken some initial steps to grow its EV market, but there is significant untapped adoption potential within the state. Sales are already beginning to grow based on the availability of second generation vehicles that offer longer range and lower prices. But as demonstrated by other states with higher levels of adoption, investment in market development policies and programs represent an opportunity to approximately double the EV growth rate in New Jersey over the increased adoption emerging naturally. Achieving the Leadership adoption path (Scenario Two) identified in this study would result in approximately 46% of new sales being fueled through a plug, and conversion of about 29% 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 all rate payers 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 all scenarios and economic tests, benefits exceed costs by at least a factor of two on a net present value basis. 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 5% - 10%), 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.

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

Appendix A: ChargEVC Members

The following list summarizes all ChargEVC members as of the date of this study. Please go to www.chargevc.org for more details.

AAA New Jersey Automobile Club

A.F. Mensah

Association of NJ Environmental Coalitions (ANJEC)

Atlantic City Electric

ChargePoint

Clearview Energy

Electric Spokes

Energy Initiatives Group (EIG)

Environment New Jersey

Environmental Defense Fund

EVgo

Greenlots

Independent Energy Producers of NJ

Isles, Inc.

Jersey Central Power & Light

Natural Resources Defense Council

New Jersey Clean Cities Coalition

New Jersey State Electrical Workers Association

NJ Coalition of Automotive Retailers (NJ CAR)

Plug-In America

Proterra Inc.

PSE&G

Rockland Electric

Sierra Club NJ Chapter

Sussex Rural Electric Cooperative, Inc.

Work Environmental Council (WEC)

End Notes and References

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