Benefit-Cost Analysis of Electric Vehicle Deployment in New York State

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Benefit-Cost Analysis of Electric Vehicle Deployment in New York State

Draft Report

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Abstract

Transportation electrification has the potential to deliver significant benefits to society and utility customers. Despite early and modest success in the electric vehicle (EV) market, there are still significant barriers to more rapid adoption of the technology. Most notably, the transition to higher rates of EV adoption requires consumers to take on higher upfront costs (compared to conventional vehicles), and complementary investments in charging infrastructure and, in some cases, utility distribution infrastructure. This work describes a benefit-cost analysis of EV deployment in New York State, conducted via collaborative engagement between Energy and Environmental Economics (E3), ICF, and MJ Bradley & Associates, with funding and project direction provided by the New York State Energy Research Development Authority (NYSERDA). The benefit-cost analysis considers adoption in three cases—a base case, a behavior modification case, and a high infrastructure case—across three regions in the State, including the New York Metropolitan area, Long Island, and Upstate New York. In the base case, EV owners face flat residential rates and charge their EVs when and where it is convenient. In the behavior modification case, the analysis considers financial incentives to customers that charge outside of peak hours. And lastly, the high infrastructure case assumes increased deployment of direct current (DC) fast charging equipment. The analysis uses various cost tests to analyze the impacts of EV adoption and EV charging in each of the three cases and regions—including the societal cost test, the participant cost test, and the ratepayer impact measure. The modeling includes inputs and assumptions on key variables, including but not limited to: likely EV adoption, vehicle costs, fueling costs, charging rates/fees, charging infrastructure investments, and emission factors for key pollutants (including greenhouse gas emissions and criteria air pollutant emissions). The results of the analysis are used to describe the types of policy mechanisms and utility interventions that might help remove or reduce hurdles to EV adoption in New York, with the findings contextualized for the state and sub-regional geographies.

Keywords

Electric vehicles, benefit-cost analysis, utility investment, EV charging infrastructure

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Acronyms and Abbreviations

EPA	Environmental Protection Agency
BCA	benefit cost analysis
BeMod case	Behavioral Modification case
BEV	battery electric vehicle
BNEF	Bloomberg New Energy Finance
CARB	California Air Resources Board
CO_2	carbon dioxide
ConEd	Consolidated Edison
CPUC	California Public Utiltiy Commission
DCFC	direct current fast charging
DEC	Department of Environmental Conservation
DER	distributed energy resources
DOE	Department of Energy
DPS	Department of Public Service
EIA	Energy Information Administration
EV	electric vehicle
eVMT	electric vehicle miles traveled
EVSE	electric vehicle supply equipment
ft	feet
GHG	greenhouse gas
Hi-Infra Case	High-Infrastructure Case
ICE	internal combustion engine
kWh	kilowatt hours
LDV	light-duty vehicle
LIPA	Long Island Power Authority
m/s	meters per second
MMT	million metric tons
MOU	memorandum of understanding
mpg	miles per gallon
MT	metric tons

MW	megawatts
NO_x	nitrogen oxides
NPV	net present value
NRDC	National Resource Defense Council
NYPA	New York Power Authority
OEM	original equipment manufacturer
PCT	Participant Cost Test
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
PSC	Public Service Commission
REV	Reforming the Energy Vision
RIM	Ratepayer Impact Measure
SCC	Social Cost of Carbon
SCT	Societal Cost Test
SEP	State Energy Plan
SO_2	sulfur dioxide
T&D	transmission and distribution
TNC	transportation network companies
TOU	time of use
TRC	Total Resource Cost
UC	University of California
UCS	Union of Concerned Scientists
V2G	vehicle-to-grid
VOC	volatile organic compounds
W	watts
ZEV	zero emission vehicle

Summary

New York State has identified transportation electrification as a key strategy to reduce harmful greenhouse gas (GHG) emissions as part of its State Energy Plan (SEP). The transportation sector accounts for more than one third of the State's GHG emissions, and New York spends more than $25 billion annually on transportation fuels. The SEP includes a vision of a "cleaner, more efficient, and sustainable transportation system" as part of the broader goal to reduce GHG emissions 40% by 2030 and 80% by 2050. As party to the Multi-State Zero Emission Vehicle (ZEV) memorandum of understanding (MOU), New York State has targeted deployment of approximately 850,000 light-duty electric vehicles (EVs) by 2025.

The expanding EV market in New York State, as of August 2018, has sold more than 38,000 EVs since 2010. About 31% of those EVs are battery electric vehicles (BEVs) such as the Tesla Model S and Model X, the Nissan LEAF, and the BMW i3; the other 69% are plug-in, hybrid electric vehicles (PHEVs) such as the Toyota Prius Prime, Chevrolet Volt, and the Ford Energi series (including the Fusion and C-Max models).[1] New York State's EV market differs considerably from national averages, which are generally closer to 50% BEVs and 50% PHEVs.[2]

A rigorous benefit-cost analysis (BCA) is a key contribution towards developing innovative policy and regulatory initiatives to encourage EV adoption. This study was designed to provide the level of detail required to develop policy interventions by either public or private market actors and to support assessment of the cost-effectiveness of potential utility transportation electrification programs. To develop well-grounded modeling inputs and assumptions the study team consulted with members of key stakeholder groups, including Original Equipment Manufacturers (OEM), EV service providers, utilities, and regulators. The BCA methodology is adapted from the cost-effectiveness framework that the New York State Public Service Commission (PSC) uses to determine when the utility and societal costs of energy production avoided by load reductions from energy efficiency, demand response, and distributed generation (collectively distributed energy resources or DER) are greater than the costs of programs promoting them.[3]

The analysis aims to inform policy discussions about transportation electrification in New York State by considering the following key questions:

- What are the net benefits to EV owners, other utility ratepayers, and society from achieving New York State's 2025 EV target?
- How do the costs and benefits differ across regions with variations in electricity rates, gasoline prices, driving patterns, and charging infrastructure availability?
- How do charging behavior and total societal costs change as access to charging infrastructure varies across regions?
- How could implementation of smart charging[4] affect the costs and benefits of EV adoption?
- If increased availability of direct current fast charging equipment (DCFC) can increase electric vehicle miles traveled (eVMT), can EV owners' savings on maintenance and fuel costs offset the cost of deploying additional charging equipment?

S.1 Modeling Approach and Data

To address these questions the team developed three discrete cases and for each assessed the costs and benefits of EV adoption from the societal, ratepayer, and EV owner perspectives.

- **Base Case** assumes that EV owners continue to face flat residential rates and charges when and where it is convenient. It represents a continuation of *status quo* conditions and provides a baseline against which the other cases can be compared.
- **Behavior Modification Case** assesses the impact of implementing smart charging measures that provide financial incentives for customers to charge outside of peak hours. For the New York Metropolitan Area, the team examined the costs and benefits of full deployment of a time-of-use (TOU)-style smart charging program currently being piloted by ConEd. The team's analysis of the Long Island and Upstate New York regions effectively measures the technical potential of smart charging by exposing customers to real-time rates that reflect the hourly marginal cost of service throughout the year.
- **High-Infrastructure Case** assesses the economics of increased deployment of direct current fast chargers (DCFCs). Range anxiety, the fear of running out of charge with no chargers nearby, is widely seen as a leading adoption barrier. Deploying more DCFC to overcome this barrier is costly, but some stakeholders contend that it will stimulate EV adoption and give EV owners the confidence to drive them more. This case explores the tradeoff between cost of adding more DCFC and the incremental operating cost savings that could accrue from increased electric vehicle miles traveled (eVMT) due to diminished range anxiety.

A case was developed for each of three distinct regions of New York State as well as one for the entire State. To assess differences in the costs and benefits of EV adoption in each region, the team used local values for fuel prices, utility rates, infrastructure costs, and socio-economic data such as population, housing type, vehicle ownership, and driving patterns. The three regions are as follows:

- **New York Metropolitan Area** includes New York City and Westchester County and accounts for 28% of current EV registrations in NYS and 49% of the NYS population.[5] Rates from Consolidated Edison (ConEd) serve as a proxy for electricity charges in the region.
- **Long Island** includes Nassau and Suffolk Counties and accounts for 31% of current EV registrations in NYS and 15% of the NYS population.[6] Rates from the Long Island Power Authority (LIPA)/PSEG Long Island (PSEG-LI) serve as a proxy for electricity charges in the region.
- **Upstate New York** includes the remainder of the State north and west of Westchester and represents 41% of current EV registrations in NYS and 36% of the NYS population.[7] Rates from National Grid serve as a proxy for electricity charges in the region.

The costs and benefits of EV adoption were examined from the point of view of EV owners, other utility customers and society as a whole. Each perspective offers distinct insights that are helpful in understanding the overall impact of EV adoption in New York State and inform development of policy and programs. The three perspectives are as follows:

- **Societal perspective** includes the direct, monetary benefits that will flow to New York State as a result of the transition from gasoline powered vehicles to EVs, as well as the indirect benefits of reduced carbon and criteria pollutant emissions and enhanced energy security by decreasing the need for imported oil. Federal tax credits to EV buyers are included in this perspective as they represent a transfer from all U.S. taxpayers to New York State residents. New York State purchase incentives are not included; at a societal level they net out because incentives are funded by State residents. Positive societal benefits indicate that residents of the State or region are better off as a result of EV adoption.
- **Participant perspective** focuses on the value proposition for prospective EV purchasers. It compares the cost of buying, operating, and maintaining an EV to corresponding expenses for a comparable vehicle with an internal combustion engine (ICE)—taking into account monetary purchase incentives for EV buyers. Both State and federal purchase incentives are factored into this perspective. Positive participant benefits indicate that over the entire study period EV purchasers would save money by choosing an EV instead of a conventional vehicle.
- **Ratepayer perspective** spotlights the effects of EV adoption on all utility customers. It compares the marginal costs of serving new EV charging load to the revenue collected from EV drivers via utility bills. Neither State nor federal purchase incentives for EV owners are included in this view. Positive ratepayer benefits indicate that EV adoption by some customers is not imposing new costs on a utility's other customers.

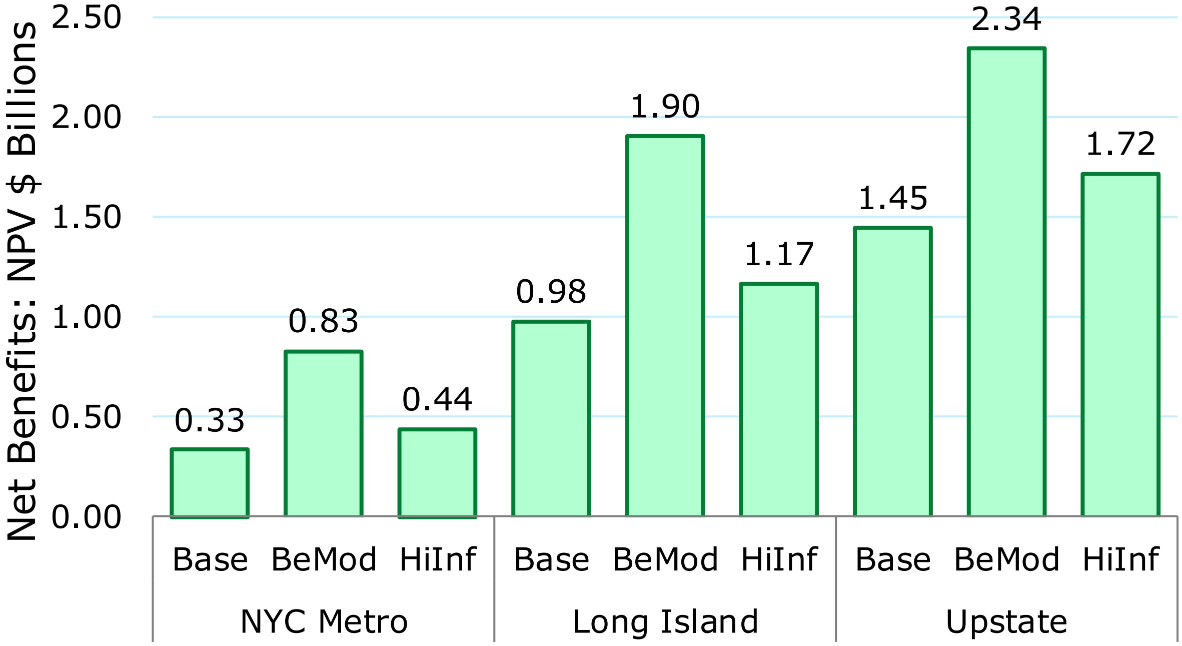
The BCA was conducted using E3's EV Grid Impacts Model (EVGrid). The model approaches each scenario by first developing charging load shapes by simulating charging behavior. The incremental impact of charging on the grid, emissions, utility cost of service, and customer bills is then calculated and net benefits from each perspective are computed. EVGrid uses a linear optimization program to produce hourly load profiles that would result from EV owners' scheduling their charging to minimize out-of-pocket costs, while maintaining enough charge to be able to complete unanticipated trips. The simulated profiles were benchmarked against anonymized data provided by ChargePoint and the Ford Motor Company (Ford).

S.2 Key Findings

S.2.1 Electric Vehicles Provide Significant Societal Benefits across New York State

Net societal benefits are positive for every case and region (Figure S-1). The net present value (NPV) of societal benefits ranges from $2.8 billion to $5.1 billion in aggregate for the State (Figure S-2). Avoided gasoline and operations and maintenance (O&M) costs, collectively referred to as eVMT savings, outweigh the cost of charging EVs and account for most of the benefits of EV adoption.

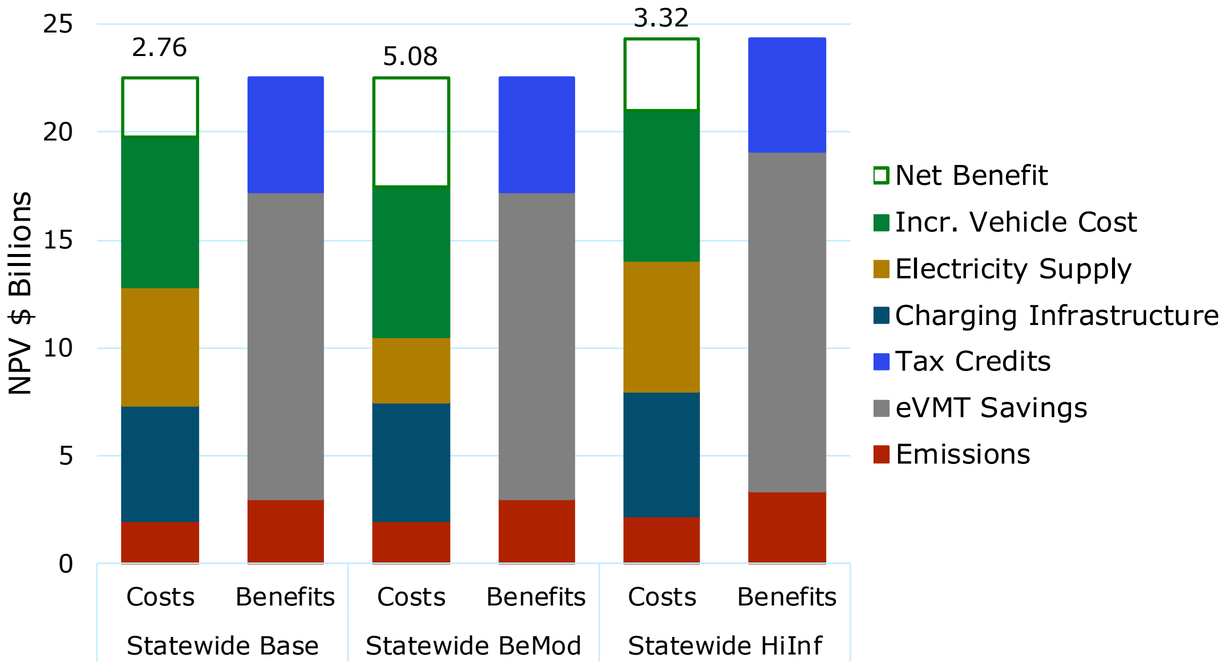
Figure S-1. Net Societal Impact of EV Adoption by Region and Case



S.2.2 Smart Charging Reduces Grid Upgrade and Energy Costs, Increasing Societal Net Benefits

The statewide and regional Behavior Modification (BeMod) cases show that smart charging can significantly reduce electricity supply costs, further improving the economics of EV adoption (Figures S-1 and S-2). Savings arise from delayed distribution and system capacity upgrades to accommodate EV charging, as well as from the shift to charging when energy is less costly. Utilities and regulators have numerous options to implement smart charging, including direct control by utilities or third parties, time-varying electricity rates that encourage off-peak charging, or incentives to charge during periods when the marginal cost of electricity is lowest.

Figure S-2. Net Societal Impact of EV Adoption: New York State

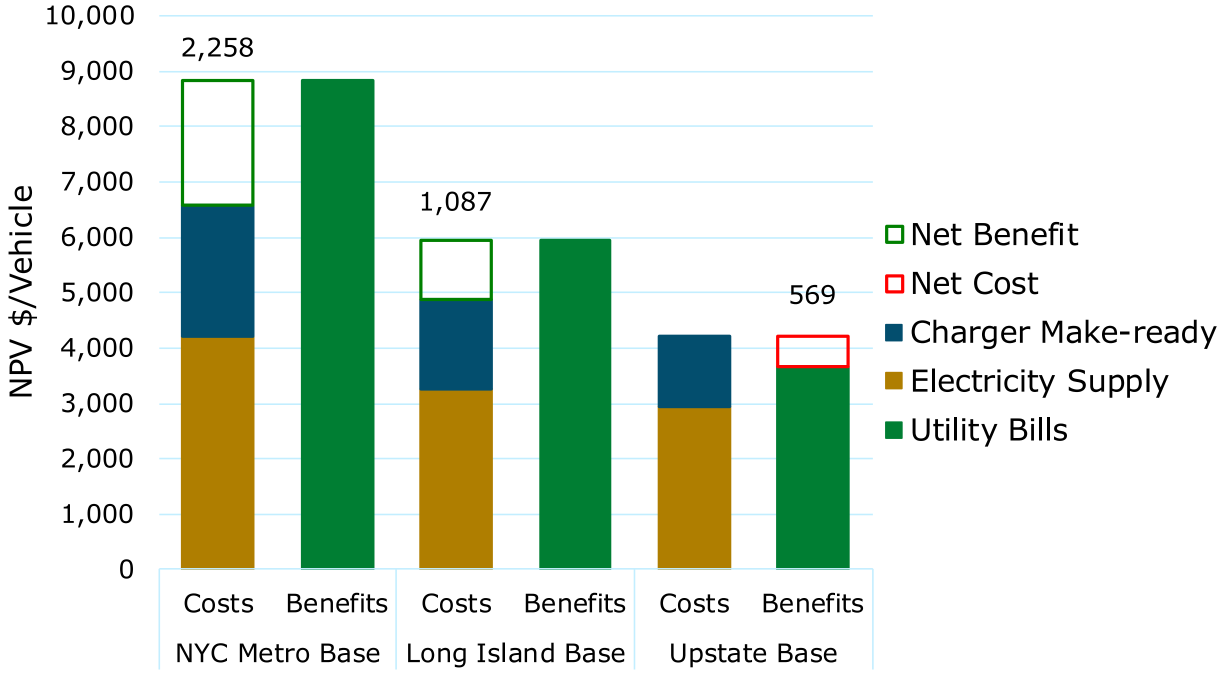


S.2.3 EV Adoption Yields Ratepayer Benefits

In all regions the revenues from EV charging exceed the marginal cost (electricity supply) of serving that load (Figure S-3). The difference is much larger in the BeMod Cases than in the Base Cases, as shown for Long Island in Figure S-4 (see Figures 19 and 37 in section 4 for the corresponding charts for the New York Metropolitan Area and the Upstate New York regions). This is because the smart charging approaches that were modeled almost entirely eliminated the need for capacity upgrades on both the distribution and bulk-power systems through 2030. Unlike some other distributed energy resources, EV adoption *lowers the average cost of service,* which *exerts downward pressure on rates.*

New revenue from serving EV load may be used to fund utility programs to enable or promote EV adoption, invest in grid modernization, offset other costs, or reduce rates. For illustrative purposes, this study assumes that the utilities use a portion of the additional revenues generated from EV charging to finance make-ready infrastructure for chargers at workplaces and public locations. This assumption results in net ratepayer costs in the Upstate New York Area.

Figure S-3. Ratepayer Impact of EV Adoption by Region: Base Case



S.2.4 Ratepayer and Participant Benefits of Smart Charging Depend on Program Design

The magnitude of costs savings from smart charging and its relative impacts on EV drivers and ratepayers depends on the design of utility programs and rates. The study's regional BeMod cases provide bookend values that illustrate alternative smart charging approaches and discuss the disparate implications for cost savings and how those savings are shared between EV owners and other utility customers.

- The Long Island and Upstate New York BeMod cases highlight the technical potential of smart charging by assuming that all EV owners are served on a real-time rate that reflects their utility's hourly marginal cost of service and adjust their behavior accordingly to minimize their cost of charging. The modeled electricity supply cost savings represent an upper bound on what could be realized in an actual program. Current TOU rates from each region were used to calculate EV owner bills, which resulted in large ratepayer benefits (Figures S-4 and 37) and modest savings to EV owners (Figures S-5 and 36) in both regions.

- The New York Metropolitan BeMod case illustrates how a smart charging program that yields electricity supply cost savings and societal benefits (Figure S-1) and increases benefits to EV owners (Figure S-5) can nevertheless raise costs for other utility customers (Figure S-6). This case assumes that all EV owners in the region participate in a scaled-up version of ConEd's ongoing SmartCharge NY pilot. It is reasonable to expect that the pilot program's relatively generous incentives would be reduced if it were implemented at scale, which could shift some of the cost savings to non-participating customers but most likely would also reduce participation and compliance.

Figure S-4. Ratepayer Perspective Benefits and Costs per EV, Long Island Region

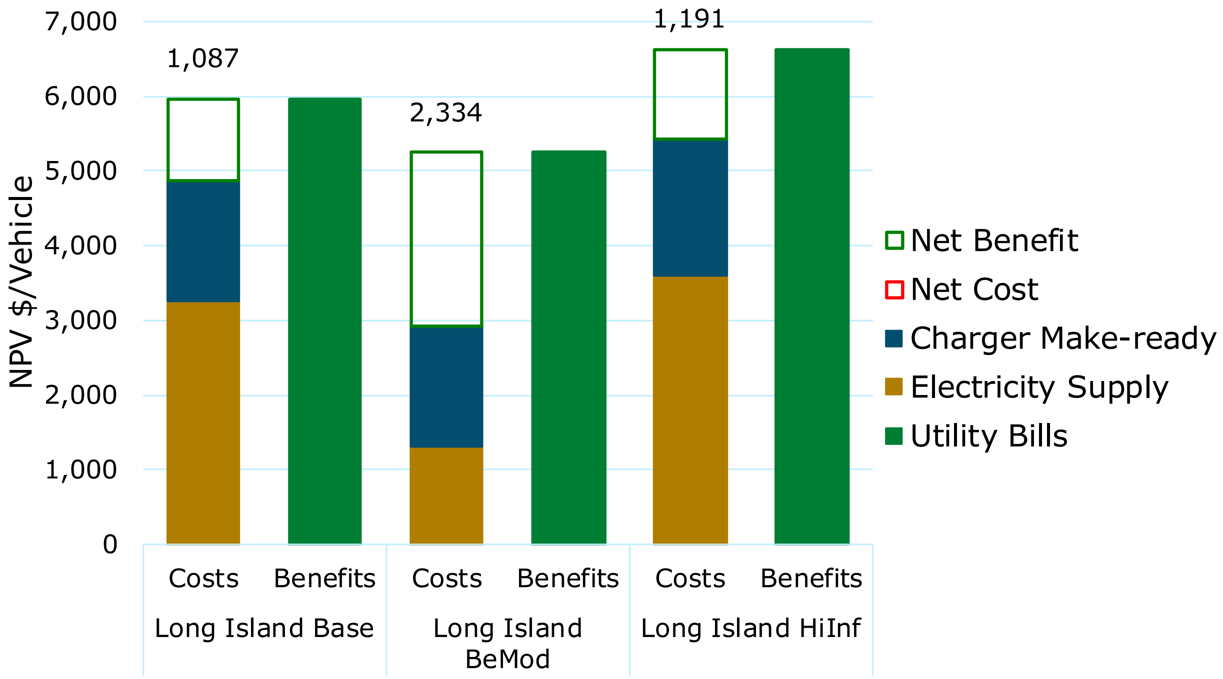


Figure S-5. Net Participant Impact of EV Adoption by Region, Base Case

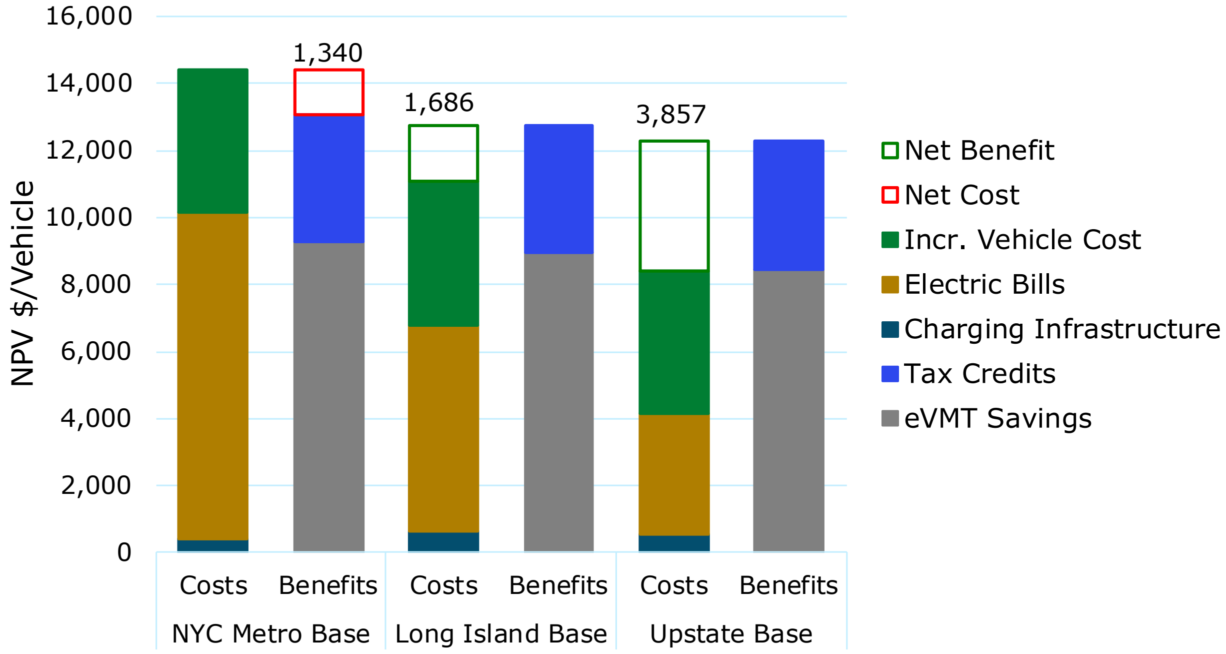
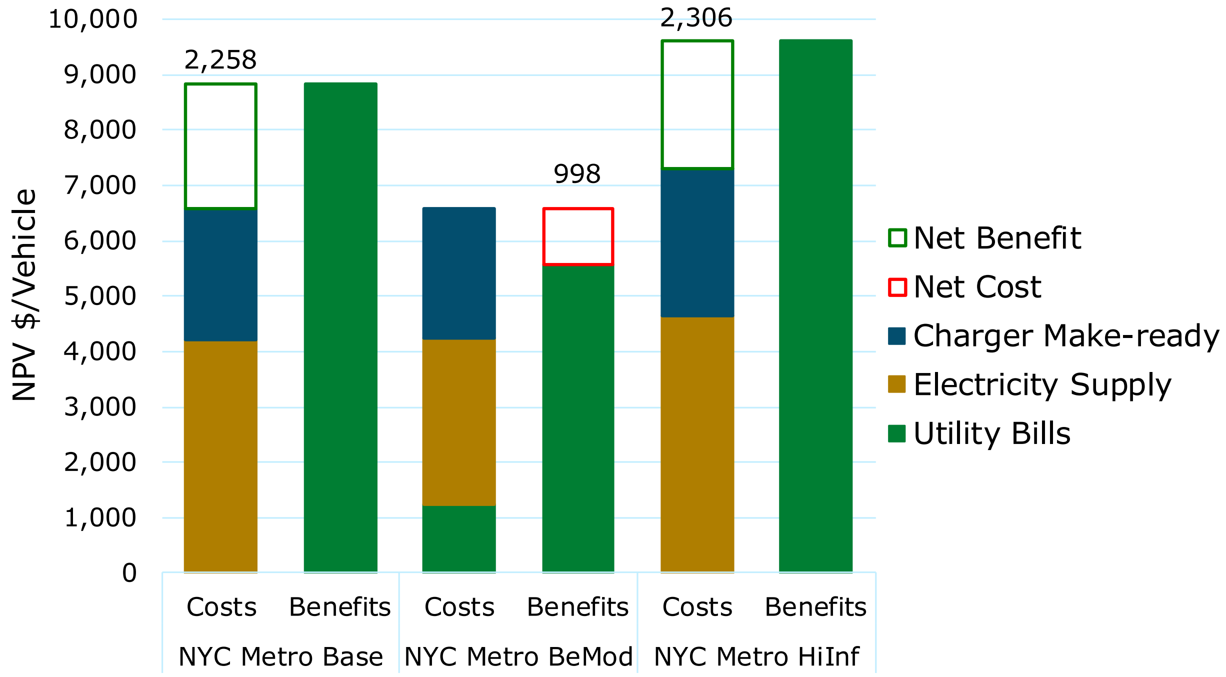


Figure S-6. Ratepayer Perspective Benefits and Costs per EV, New York Metropolitan Area



S.2.5 Participant Benefits Vary Regionally

Regional variation in retail electricity rates leads to significant differences in the customer value proposition for EVs across NYS (Figure S-6). Most notably, under Base Case conditions, drivers in the NYC Metropolitan Area face an NPV *cost* of about $1,300 per vehicle, compared to an NPV *benefit* per vehicle of $1,686 on Long Island and $3,857 Upstate New York. The greater cost to drivers in the NYC Metropolitan Area results primarily from the area's higher electricity rates. There is comparatively little variation in gasoline prices around the state, so savings from avoided gasoline consumption do not differ much across regions.

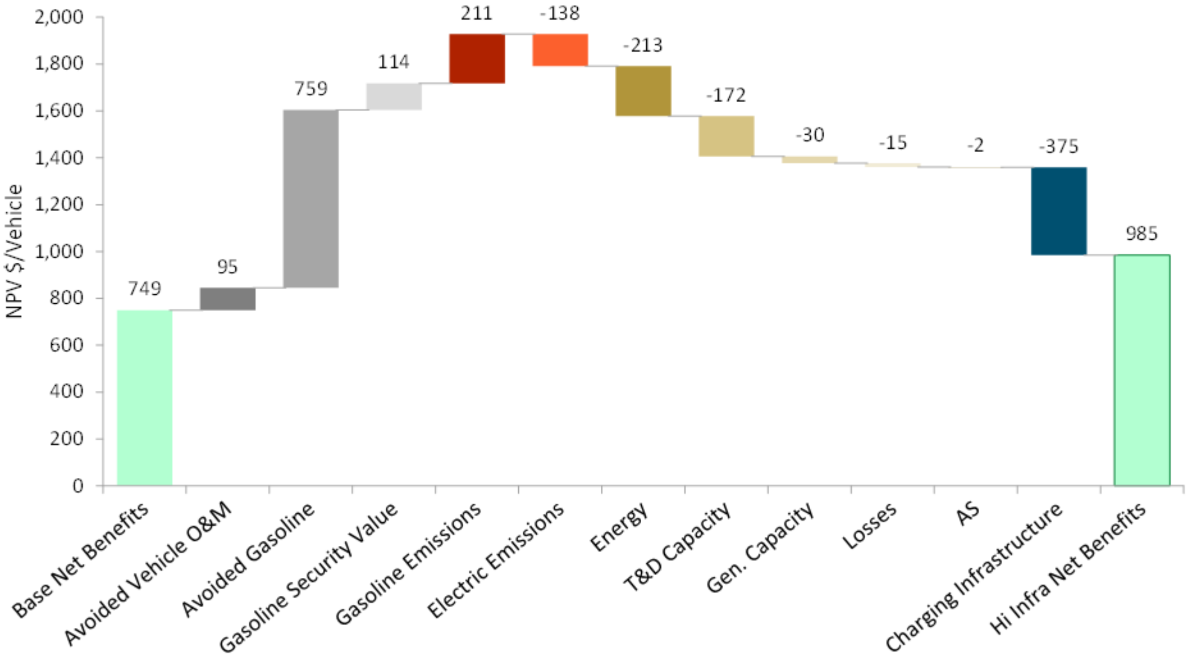
S.2.6 EV Purchase Incentives Are Crucial to the Value Proposition for Prospective EV Buyers

Even with the forecasted decline in EV prices, their premium relative to comparable gasoline vehicles remains a significant cost component during the timeframe of this analysis, which focuses on vehicles purchased through 2030. Without the State and federal purchase price incentives at the levels assumed, EV purchasers would not realize net benefits in the Base Case in any region (Figures S-6). These observations reinforce the need to maintain some level of vehicle purchase incentives for EV drivers for at least the near-term future.[8] It is also important to note that there is an implicit causal linkage between the study's assumptions about the persistence of tax credits and trends in EV sales and prices, that is, the incentives drive sales, which lead to manufacturing economies of scale, and in turn yield the declining EV price trajectory included in the modeling.

S.2.7 Expanded Public DCFC Networks May Increase Net Societal Benefits

Many stakeholders contend that widespread availability of DCFC, especially along major travel corridors, is essential to meet New York State's EV adoption goal. While survey research supports this argument, empirical evidence from market data is scarce. This is because experience is still limited and there are numerous confounding factors that make it difficult to isolate the effect of differences in DCFC access across geographic areas on EV adoption. Weighing the evidence for the induced effect is beyond the scope of this analysis. Instead, the study focuses on the relation between availability of DCFC and eVMT: the study posits that expanding the DCFC network will give EV owners the confidence to drive their EVs further and more often, increasing annual eVMT by 10%. Net societal benefits increase relative to the Base Case statewide (Figure S-1) and in each region (Figures S-7, 26 and 35), because operating and fuel cost savings from increased eVMT offset the additional spending on public chargers.

Figure S-7. Changes in Societal Net Benefit Components between the Base and High-Infrastructure Cases, New York Metropolitan Area



S.2.8 Reduced Charging Infrastructure Costs and Right-Sizing Public/Ratepayer Funding

Charging infrastructure costs, mainly for public Level 2 and DCFC, account for a significant portion of the societal cost of EV adoption. The cost, amount, and type of charging infrastructure ultimately needed (and deployed) in NYS are uncertain. If realized costs are lower than the team assumes for either of these reasons, net benefits will rise, and vice versa. For this analysis it was assumed that make-ready infrastructure at workplaces and public locations would be provided by the utilities and funded by ratepayers, which still left net ratepayer benefits in the Long Island and NY Metropolitan Area but pushed them into net costs in Upstate New York. More targeted utility investment and/or cost-sharing with hosts and others would increase the net ratepayer benefit. Driving down infrastructure costs through innovation, economies of scale, or other means would increase the benefits of EV adoption. Ongoing survey research, customer engagement by utilities and third-party EV service providers (EVSPs), and insights from OEMs' marketing studies are critical to inform public and ratepayer investment deployment strategies.

1 Background

New York State has identified transportation electrification as a key strategy to reduce harmful greenhouse gas (GHG) emissions as part of its State Energy Plan (SEP). The transportation sector accounts for more than one third of the State's GHG emissions, and New York spends more than $25 billion annually on transportation fuels. The SEP includes a vision of a "cleaner, more efficient, and sustainable transportation system" as part of the broader goal to reduce GHG emissions 40% by 2030 and 80% by 2050.

1.1 State of EV Market

In New York State's expanding electric vehicle (EV) market, as of June 2018, there were more than 27,000 registered EVs on the road. More specifically, about 33% of those EVs were battery electric vehicles (BEVs) such as the Tesla Model S and Model X, the Nissan LEAF, and the BMW i3; and 67% of the EVs were plug-in, hybrid electric vehicles (PHEVs) such as the Toyota Prius Prime, Chevrolet Volt, and the Ford Energi series (including the Fusion and C-Max models).[9] New York State's EV market differs considerably from national averages, which are generally closer to 50% BEVs and 50% PHEVs.[10]

Recent surveys indicate that consumers are interested in EVs; for instance, a recent AAA survey indicated that 20% of Americans are interested in purchasing an EV as their next vehicle—up from a previous estimate of 15% in the same survey a year prior.[11] The Fuels Institute reported in 2017 that more than 50% of potential car buyers said they were very or somewhat likely to purchase an all-electric vehicle.[12] Generally speaking, however, EV adoption is still small—representing about 1% of the new vehicle market in New York State. The EV market continues to be hampered by a variety of factors, including the higher upfront cost of the vehicle relative to conventional or hybrid vehicles, limited model availability, access to charging infrastructure, and general consumer awareness.

Despite the interest in EVs, the Manufacturer's Suggested Retail Price (MSRP) of EVs remain considerably more expensive than their conventional counterparts. The Toyota Prius Prime, for instance, has an MSRP about $4,000 more than the standard Prius (without plug-in capabilities). While not as strictly comparable, the MSRP Chevrolet Volt is priced about $10,000 to $16,000 higher than a well-equipped Chevrolet Cruze. These price differences are reduced drastically with incentives like the federal tax credit and State rebates. For instance, the Toyota Prius Prime qualifies for a $4,500 federal tax credit and a $1,100 rebate in NYS, resulting in a net purchase price *lower* than that of the standard Prius. Similarly, the Chevrolet Volt qualifies for a $7,500 federal tax credit and a $1,700 rebate in NYS, making the Volt's incentivized price competitive with a well-equipped Cruze. To be clear, EVs often have a competitive incentivized price, but there are concerns about consumer awareness regarding the incentives (see details in the following paragraphs).

Most EVs available today are compact and subcompact cars, characterized as sedans or coupes, thereby limiting consumer interest. There are obvious outliers, such as the Chrysler Pacifica (a PHEV minivan) and the Volvo XC90 (a PHEV SUV). The roster of EVs available to consumers and the variety of body types and styles have expanded considerably from 2011, when consumers were generally limited to the Chevrolet Volt or the Nissan LEAF. And there are an increasing number of EV makes and models expected from automobile manufacturers in the near-term future (two to five years); however, the limited models on the market today have likely prevented more rapid EV adoption.

EV owners today tend to do most of their charging at home (about 70 to 80% of charging occurs at home).[13] As such, EV owners tend to own single-family homes. There have been a variety of dedicated efforts to increase access to charging infrastructure at multifamily dwellings and to increase access to charging away from home. Despite these efforts, consumers are still concerned about the range of EVs. For instance, in the aforementioned AAA survey, among the respondents that were unsure or unwilling to choose an EV for their next car, 63% cited not enough places to charge as a detractor while 58% expressed concern over running out of charge while driving. AAA reports that these percentages are down 9 and 15% from the same survey in 2017, leading them to conclude that so-called "range anxiety" may be starting to ease.[14] However, it still remains a critical concern for some consumers.

Reported interest in EVs does not align with consumer purchasing patterns—about 1.1% of total sales in 2017 were EVs in the U.S., and 1.0% in New York State.[15] Part of the discrepancy between reported interest and purchasing patterns is likely attributable to consumer awareness. Consider for instance a recent post by University of California (UC), Davis researchers Ken Kurani and Scott Hardman, in which they review their consumer survey findings from five studies conducted between 2014 and 2017. They conclude the following:

> The excitement among policymakers, automakers, and advocates as more EV models enter the market place, more charging is installed, and more EVs are sold each successive year is utterly lost on the vast majority of the car-buying public—even in California, touted as being among the global EV market leaders. The problem is the number of car-owning households that are paying attention to EVs is not growing.[16]

There are surveys with similar findings as those highlighted by UC Davis across the country over the last several years.[17] Consumer awareness around critical issues—including incentives, vehicle models available, charging infrastructure availability, and other topics—continues to be a barrier to broader EV adoption.

Despite the variety of challenges and obstacles, the EV market has shown considerable growth in New York State over the last several years, and there are a number of regulations and policies in place that will continue to support EV adoption.

1.1.1 Regulations and Policies Supporting EV Adoption

New York State is a signatory to the Multi-State Zero Emission Vehicle (ZEV) memorandum of understanding, which established a collective goal of 3.3 million ZEVs by 2025; for New York, this is equivalent to about 800,000 to 900,000 ZEVs on the road by 2025. New York State is also a ZEV state, adopting California's motor vehicle emission standards set forth in Title 13 of the California Code of Regulations. To comply with these regulations, manufacturers must meet a minimum requirement for the percentage of ZEVs made available for sale in the State. Under the program, manufacturers who sell or lease qualified ZEVs can earn and use vehicle equivalent credits that can be sold to other manufacturers. While ZEV adoption has been concentrated in California to date, this is expected to change considerably in the next several years in part because of increased EV offerings and because the "travel provision" of the ZEV Program expires with model year (MY) 2018 vehicles. The travel provision enables automobile manufacturers to count the sale of a ZEV in California towards requirements in other states. In other words, the ZEV credit generated in California can "travel" and be counted towards requirements in New York (albeit at a discounted rate). The provision was intended to encourage early action by automobile manufacturers and put some downward pressure on ZEV requirements in later years (closer to 2025). As the travel provision is phased out, automobile manufacturers will be pressed to sell more ZEVs in states like New York. There is also a so-called pooling provision in the ZEV Program that enables automobile manufacturers to exceed compliance in one state in the Northeast and transfer that over-compliance to another state in the Northeast. Unlike the travel provision, the pooling provision does not expire and requires manufacturers to opt into the provision. Regardless of the impact of these provisions on EV sales in New York State, the market will change in the near future.

The State's EV policies are generally borne out of the aforementioned SEP, which specifically calls out EVs as a key element of the overarching strategy to reduce GHG emissions. EV deployment can result in significant GHG emission reductions; for instance, the Union of Concerned Scientists (UCS) reports that electricity in Upstate New York has one of the lowest GHG emissions intensities in the country.[18] The low GHG emitting electricity translates into the equivalent fuel efficiency (as reported in miles per gallon of gasoline equivalent, mpg) of up to 160 mpg. Furthermore, the potential to reduce GHG emissions from electricity as a transportation fuel is not linked to a static emissions factor; rather, as electricity generation increasingly relies on renewable resources, the GHG emissions intensity of electricity *decreases*. For instance, between the original estimates (in 2012) and a more recent updated analysis,[19] UCS reports that the equivalent fuel efficiency of EVs operating in Upstate New York and Long Island have increased from 115 mpg and 41 mpg to 160 mpg and 50 mpg, respectively.

Governor Andrew M. Cuomo's Charge NY program is one of the key elements of the SEP. Charge NY is a collaboration between the New York State Energy Research and Development Authority (NYSERDA), New York Power Authority (NYPA), and the Department of Environmental Conservation (DEC). These agencies are tasked with implementing the Multi-State ZEV Action Plan and aim to support the installation of 3,000 EV charging stations by 2018 (to support an anticipated 30,000 to 40,000 EVs) and 10,000 charging stations by 2021.[20] The initiative also developed best practices for municipal EVSE regulations, provides vehicle incentives such as reduced bridge tolls, and removed regulatory obstacles for installing EVSE at public parking lots.

NYSERDA also administers the Drive Clean Rebate program as part of Charge NY, a $70 million EV rebate and outreach initiative to encourage the deployment of EVs. The majority of the funds ($55 million) is dedicated to rebates for the purchase or lease of a new EV—up to $2,000 per vehicle. In the first year of the program (March 2017 through March 2018), more than 5,750 rebates were issued to New York drivers, totaling more than $7.5 million in funding disbursed. The remaining $15 million will support consumer awareness initiatives by installing more charging stations and developing and demonstrating new technologies as well as other efforts to put more EVs on the road.

New York State has also targeted EVs in municipal fleets. In 2016 the State allocated $2 million in funding for municipalities—$750,000 of the funding was dedicated to vehicle rebates valued at up to $5,000 per vehicle and another $1.25 million was allocated to EV infrastructure projects. The infrastructure funding covered the costs up to $250,000 per facility for installation of EVSE, up to $8,000 per Level 2 charging port, or $32,000 per Direct Current Fast Charging (DCFC) port. Another $3 million was allocated to municipal fleets and rural electricity cooperatives in early 2017 to help deploy EVs in fleets.

NYPA has committed up to $250 million through 2025 via EVolve NY. The initial phase of funding directs $40 million into three new initiatives through the end of 2019, including 200 interstate DC fast chargers, airport charging hubs, and EV model communities.

1.2 Utility Participation in the EV Market

Utilities in NYS have had varying levels of engagement in the EV market. EVs present a significant opportunity for utilities because EV charging can increase asset utilization through increased electricity use and has the potential to reduce electricity rates for all ratepayers. Further, EVs have the potential to provide valuable grid services, like load management and frequency regulation; EV battery storage could also be aggregated and bid into the wholesale marketplace for energy and capacity markets.

In the development of the Joint Utilities (JU) of New York's EV Readiness Framework, the utilities provided a summary of pilot projects—including those that have been completed, those that are ongoing, or those that are planned. The pilot projects are presented across multiple aspects of the EV market, including rate design, vehicle deployment, charging infrastructure deployment, vehicle-to-grid research, and consumer education. The following list provides examples of completed, ongoing, and proposed pilot projects of the investor owned utilities (IOUs) as reported in the JU's EV Readiness Framework.[21]

- Central Hudson has a Residential Electric Vehicle Incentive Program proposed as part of its general rate case. Central Hudson customers that purchase an EV will receive a rebate of $1,250 after proof of vehicle purchase.
- Consolidated Edison's SmartCharge New York program rewards off-peak charging behavior without a tariff change.
- National Grid currently operates more than 65 public Level 2 charging stations in Upstate New York, installed in partnership with ChargePoint, using NYSERDA grant funds. The stations are owned and maintained by National Grid but operated by customers (site hosts) on their own meters, with most site hosts providing free charging to drivers.

- New York State Electric and Gas and Rochester Gas & Electric have proposed an EV Deferrable Demand Rate. This was filed as part of the Smart Home Rate Pilot in Q2 2018 and includes an EV rate that will vary depending on the flexibility to defer charging to a later time if and/or when needed.

The utility's role in the State's EV market is currently under consideration by the New York State Public Service Commission (PSC). In April 2018, the PSC instituted a proceeding (18-E-0138) to encourage increased EV adoption and charging infrastructure deployment. More specifically, the commission instituted the proceeding to consider the following:

> …the role of electric utilities in providing infrastructure and rate design to accommodate the needs and electricity demand of EVs and EVSE. The proceeding will explore cost-effective ways to build such infrastructure and equipment and determine whether utility tariff changes will be needed in addition to those already being considered for residential customers to accommodate and promote the deployment of EVs. The proceeding will also investigate the characteristics of EV charging systems and how those systems may facilitate EV participation as a distributed energy resource (DER) in a manner not yet captured by the Reforming the Energy Vision (REV) Initiative.[22]

1.3 Why Conduct a Benefit-Cost Analysis?

A rigorous benefit-cost analysis is a critical contribution towards developing innovative policy and regulatory initiatives to encourage EV adoption. This benefit-cost analysis was designed to provide the level of detail required to develop policy interventions by either public or private market actors. The benefit-cost analysis presented here was also designed to gain market acceptance by engaging with stakeholders (e.g., utilities) and developing robust modeling assumptions.

The benefit-cost analysis can also help direct investments to improve the cost-effectiveness of transportation electrification programs. For instance, regulators have developed cost-effectiveness tests to allocate funding and resources to the most beneficial programs. The PSC, for instance, has developed a framework to determine when the utility and societal costs of energy production avoided by load reductions from energy efficiency, demand response, and distributed generation (collectively distributed energy resources or DER) are greater than the costs of programs promoting them.[23] For this report, the team has used an avoided cost framework to illustrate the impacts of EV deployment, including the associated costs and infrastructure needed to support them.

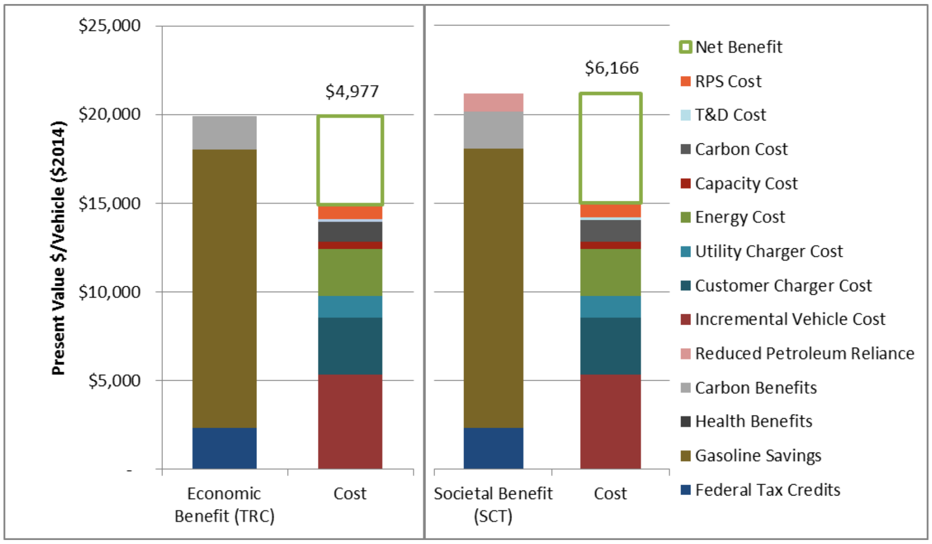
1.4 Differences from Prior Studies

1.4.1 Prior Work

1.4.1.1 California Transportation Electrification Assessment

In 2014, E3 and ICF published a two-phase study performed for the California Electric Transportation Coalition (CalETC), a nonprofit group that represents California's IOUs and other stakeholders engaged in transportation electrification. The study documents the crucial role that transportation electrification will have in meeting GHG and ambient air quality goals in California. The first phase of the study[24] describes the market size, environmental, and societal benefits of 20 market segments of transportation electrification, focusing on four segments in particular: plug-in electric vehicles, forklifts, truck stop electrification, and transport refrigeration units. The second phase of the project provides an in-depth analysis of electric utility costs that will be incurred to support EV charging, with an emphasis on utility distribution systems. E3 and ICF compared the *monetized* costs and benefits that represent actual cash transfers into or out of the state to determine whether California achieves net economic benefits with additional EV adoption (i.e., the Total Resources Cost Test or TRC from the California Public Utility Commission, CPUC). The benefits included the federal tax credit for EVs, gasoline savings, and reduced cap-and-trade GHG allowance costs, which total about $20,000 per vehicle over its lifetime under the time-of-use (TOU) rate/load shape scenario (see Figure 1).[25] The costs include incremental costs of the vehicle, charging infrastructure costs, distribution system upgrades and the avoided costs for delivered energy. Total costs are just under $15,000 per vehicle over its lifetime, for a net benefit of approximately $5,000 over the life of each EV.

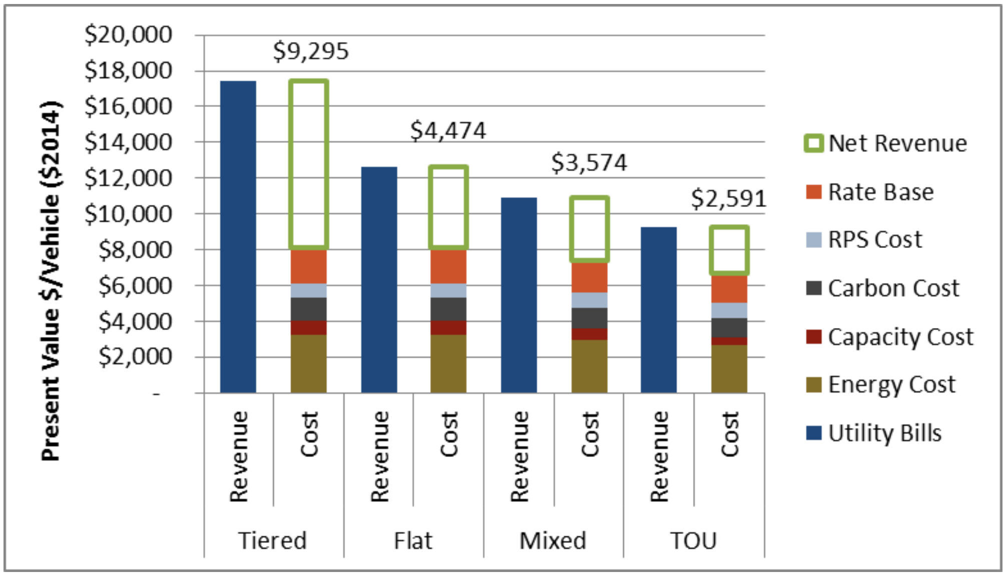
Figure 1. Regional Monetized and Societal Benefits from the California TEA



The evaluation was expanded to include environmental and societal benefits that are not monetized in actual cash transactions, but still provide direct and quantifiable benefits to California. This Societal Cost Test (SCT) includes benefits for health and reduced reliance on petroleum—benefits that are included in the CARB cost-effectiveness method and described as benefits in the interest of utility ratepayers in California's Public Utilities Code (PUC) 740.3 and 740.8.[26] Further, cap-and-trade GHG allowance costs were replaced with a higher estimate of the Social Cost of Carbon (SCC). This increases the net benefit to about $6,600 per vehicle, $1,200 (22%) higher than the net benefit under the TRC.

The CPUC's Ratepayer Impact Measure (RIM) was used to show that EVs can also benefit all utility customers and not just EV owners. That analysis indicated that the utility bills EV owners pay more than offset the costs incurred by the utility to deliver the electricity to charge the vehicles. From the utility customer perspective, revenues from EV charging are a benefit and the resources expended to deliver electricity for charging are costs. Under each of four rates and charging load shape scenarios studied, additional revenue from EV charging was found to exceed the marginal costs to deliver electricity to the customer, providing positive net revenues that can put downward pressure on rates, as shown in Figure 2.

Figure 2. Utility Customer Benefits from the TEA Study in California: Present Value of Revenue and Costs per Vehicle (Ratepayer Impact Measure Cost-Test)



1.4.1.2 Electric Vehicle Cost-Benefit Analysis

MJB&A led a series of 14 State-level, cost-benefit analyses for the Natural Resource Defense Council (NRDC).[27] They estimated the costs and benefits of increased penetration of EVs in New York for two different scenarios: Scenario 1 is based on the State's short-term goal to have 850,000 EVs on the roads of New York by 2025 (8-state ZEV MOU)[28] and Scenario 2 is based on the EV penetration that would be required to achieve the State's long-term goals for economy wide GHG reduction of 80% from 1990 levels by 2050 (80 x 50). Compared to a business-as-usual baseline of continued gasoline car use, the study estimated the total reductions in GHG emissions that could be achieved by turning the light duty fleet (cars and light trucks) over to EVs, and the value of these GHG reductions to society.

The study estimated the benefits that would accrue to all electric utility customers in New York State due to increased utility revenues from EV charging, with the assumption that this revenue could be used to support operation and maintenance of the existing distribution infrastructure, thus reducing the need for future electricity rate increases. These benefits were estimated for a baseline scenario in which EV owners plug in and start to charge their vehicles as soon as they arrive at home or work. The study also evaluated the additional benefits that could be achieved by providing EV owners with price signals or incentives to delay the start of charging until after the daily peak in electricity demand (i.e., off-peak charging). Off-peak EV charging can provide net benefits to all utility customers when vehicles are charged during the time the grid is underutilized, and the cost of electricity is low. The study also estimated the annual financial benefits to New York's EV owners from fuel and maintenance cost savings compared to owning gasoline vehicles.

Figure 3. Net Present Value Utility Costs and Net Revenue from EV Charging (via Baseline Scenario) in Millions of Dollars

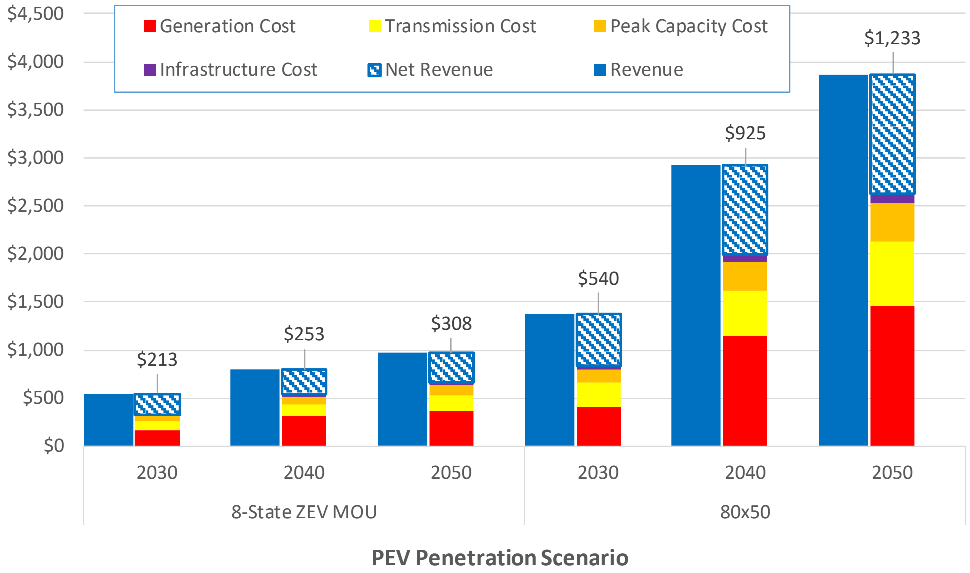
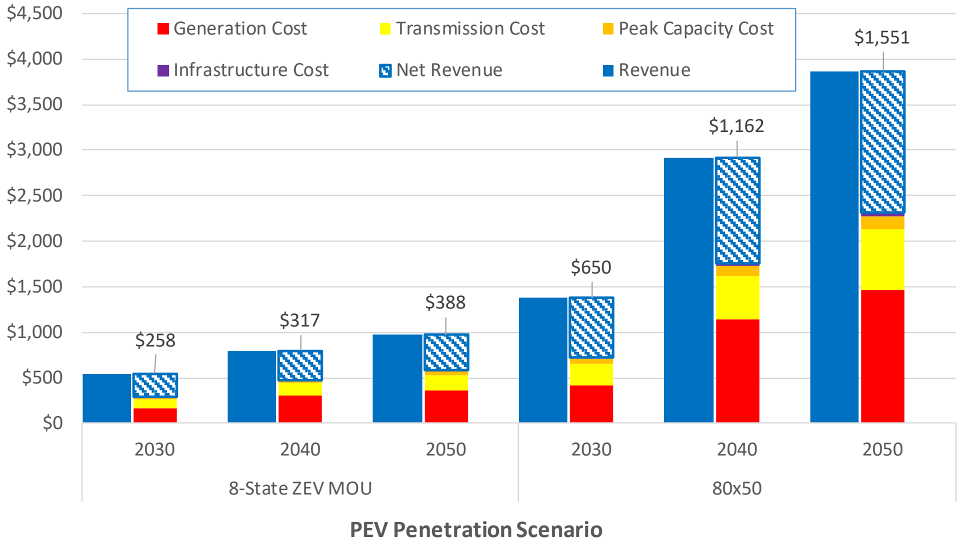


Figure 4. Net Present Value Utility Costs and Net Revenue from EV Charging (via Off-Peak Scenario) in Millions of Dollars



According to the MJB&A analysis, if New York State meets its short-term (2025) goals for EV penetration (in line with the 8-state ZEV MOU penetration scenario) and the increase in EV penetration then continues at the same annual rate in later years, the net present value of cumulative net benefits from greater EV use in the State will exceed $17.8 billion statewide by 2050. By comparison, if the State meets its long-term goals to reduce light-duty fleet GHG emissions by 80% from 1990 levels by 2050, which requires even greater EV penetration, the net present value of cumulative net benefits from greater EV use in New York could exceed $75 billion statewide by 2050.

1.4.2 What Is New in This Study?

The benefit-cost analysis presented here provided a unique opportunity to update the modeling assumptions, methodology, and key inputs compared to the work previously completed in California and New York State. The present study benefits from nearly five years of additional market data—including information such as, but not limited to, EV purchasing habits, consumer charging behavior, charging infrastructure costs (including hardware and installation costs), charging infrastructure requirements (e.g., Level 2 versus DC fast charging equipment), and updated fuel pricing (including electricity and gasoline). The following summarizes the key aspects of the benefit-cost analysis that have been added and/or updated for this study of New York EV adoption.

1.4.2.1 More Granular Results

The work presented here is considered across three distinct regions of New York State. In previous studies analyzing the potential impacts of EV adoption, the work was focused on the State as a whole. In this study, the team presents the results for the New York Metropolitan Area (Metro New York), Long Island, and the Upstate New York region.

1.4.2.2 Review of Incremental EV Pricing

Batteries are the biggest contributor to EV costs. Bloomberg New Energy Finance (BNEF), for instance, reports that battery packs make up 48% of light-duty EV prices.[29] The National Renewable Energy Laboratory (NREL) cites other resources that batteries account for anywhere from 13 to 61% of the total EV price.[30] An updated literature review regarding battery costs indicates that they are decreasing rapidly and will continue to come down in future years, even as energy capacity improves. According to BNEF and other sources, the recent drop in battery prices is due to battery oversupply, reduced material costs, improved technology that can be used across vehicle applications, increased production, manufacturing improvements, and more competition in the market. In addition, vehicle manufacturers are beginning to see the benefit of launching their own battery products, rather than engaging with a supplier, in order to eliminate up-charges. The modeling performed for this analysis relied on updated vehicle pricing estimates from analyses such as BNEF and NREL.

1.4.2.3 Nuanced Consideration of Vehicle Incentives

The federal tax credit and state-level rebates for EVs play an important role in deployment. Most importantly, these purchase incentives lower the price of EVs and help attract EV buyers through more attractive purchase and leasing options. In the California Transportation Electrification Assessment, the project team assumed that both the state rebate and the federal tax credit would be available through 2030. For this study, the team worked with NYSERDA to develop a more nuanced view of the availability of purchase incentives—and assumed that the federal tax credit would be phased out in 2025 and that the New York State Drive Clean Rebate would be phased out in 2024. The rationale behind these decisions are discussed in more detail in section 2.1.

1.4.2.4 EV Charging Infrastructure: Higher Deployment and Higher Installation Costs

The California Transportation Electrification Assessment was initiated in 2012, during the early stages of EV adoption, when there was less information available regarding charging infrastructure requirements and charging infrastructure costs. This study benefits from a more detailed understanding of how much charging infrastructure might be required to support EV deployment, and the different levels of EV charging. For instance, the California study contemplated a slower decrease in EV pricing, which translated to fewer long range (e.g., 200 miles) BEVs, and less demand for DC fast charging infrastructure. This study contemplates a future with EVs that have larger batteries, more electric range, and different charging infrastructure requirements. This study also benefits from multiple years of cost data collected across multiple jurisdictions; more specifically, NYSERDA provided the project team detailed cost data collected as part of the deployment of nearly 700 charging ports across New York State. This level of charging infrastructure cost data helps characterize more accurately the costs that the market will face as EV deployment increases.

1.4.2.5 Consumer Charging Behavior

The project team's assumptions regarding charging behavior had two new elements for this study. Firstly, the project team was able to obtain more information about how and when people actually charge their cars based on data obtained from ChargePoint and Ford, which helped us design more accurate baseline charging scenarios. Secondly, the study had a more detailed consideration of consumer access to charging at homes. More specifically, socioeconomic and Census-based indicators were used to determine the percentage of EV drivers in a given region that would have access to home charging. In previous studies, for instance, a constant ratio of consumers with access to home charging was used in the analysis. The consideration regarding potential access to home charging in this analysis ultimately led to assuming that fewer drivers had access to home charging than has been assumed in other studies, thereby increasing the demand for charging away from home.

2 Data and Assumptions

The goal of the benefit-cost analysis (BCA) exercise is to evaluate impacts at the State level; however, the project team explicitly recognizes that the distribution of costs and benefits related to EV adoption will not be uniform across the entire State. In many cases, the assumptions do not vary across regions; for instance, the team assumes that EV pricing and purchase incentives are uniform. However, in other examples, cost inputs do vary, such as electricity costs to charge EVs or the gasoline costs, which are used for comparative purposes in the analysis. As a result, and where appropriate, the data and assumptions incorporated into the analysis were differentiated by the three regions considered: Metro New York, Long Island, and Upstate New York.

The following sub-sections highlight the key data and assumptions that underpin the analysis:

- **Electric Vehicles** includes discussion of vehicle pricing assumptions, the availability of purchase incentives, the costs of operating and maintaining the vehicle, and the rate of adoption assumed in the analysis.
- **Fuel Pricing** reviews the assumptions regarding electric rates for EV charging in different locations—at home, at workplaces, and in public. The sub-section also reviews gasoline pricing assumptions in each of the three study regions.
- **EV Charging Infrastructure** outlines expected costs associated with EV charging infrastructure deployment, as well as the amount of charging infrastructure that is expected to be needed to support the EV adoption scenarios.
- **Emission Factors and Monetized Externalities** reviews the emission factors used to calculate the environmental impacts of using electricity or gasoline. The sub-section also includes the monetized values of pollutants that are used to incorporate them into the BCA framework.

2.1 Electric Vehicles

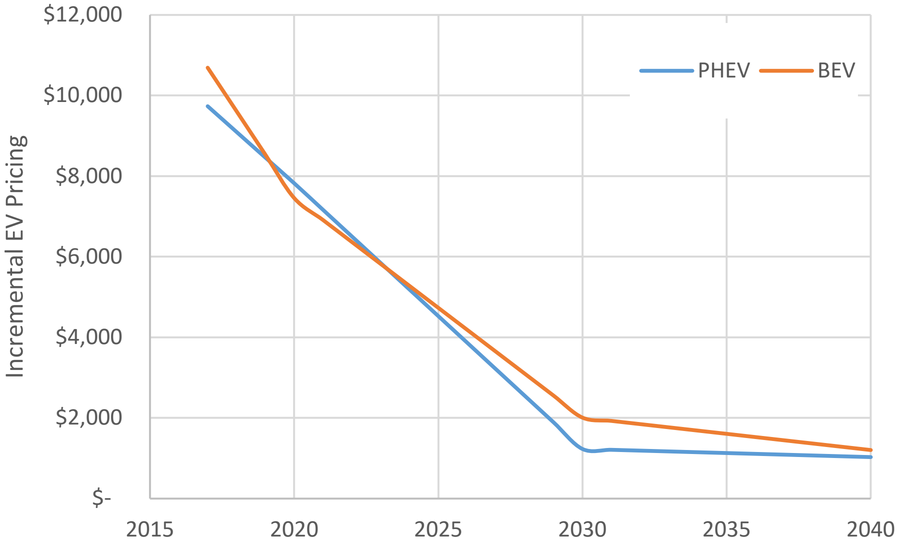
2.1.1 EV Pricing

Electric vehicle pricing has become a subject of considerable debate, particularly because of recent research by market analysts like Bloomberg New Energy Finance (BNEF) focused on rapidly declining battery prices. The decreases in EV pricing predicted by studies like BNEF contract sharply with more conservative estimates from the Energy Information Administration (EIA), as outlined in the Annual Energy Outlook. The range of EV pricing assumptions makes for difficult choices in benefit-cost analyses. Ideally, a benefit-cost analysis should vary EV pricing as a critical parameter across multiple scenarios; however, given cost and resource constraints, the project team made the decision to include a single EV price trajectory in the modeling.

The project team modeled PHEV and BEV incremental pricing based on the cost of the "glider" (a simple vehicle chassis and body) and the cost of batteries ($/kWh), electric drive train ($/kW), and gasoline drivetrain (for PHEVs, in units of $/kW). The incremental vehicle pricing of the Ford Fusion was used as a baseline. In terms of projected future EV prices the most important parameter is projected future battery costs, though drivetrain costs are also relevant. The team assumed that after 2030 electric drivetrain costs would be $41/kW, which was DOE's technical goal included as part of the EV Everywhere program.[31] For battery cost projections the team used BNEF's 2016 estimate,[32] with battery prices falling below $100/kWh (2015$) by 2030. The team used values of $99/kWh in 2030 and $90/kWh in 2050.

The EV pricing was estimated for a PHEV with 50 miles of all-electric range (i.e., a PHEV50) and a BEV with 200 miles of range (i.e., BEV200). The team assumed battery sizes of 16 kWh for the PHEV50 and 65 kWh for the BEV200. These estimates assume an efficiency of about 0.275 kWh per mile for the vehicle (which is consistent with the reported efficiency for the Chevrolet Bolt and the Volkswagen e-Golf), 90% depth of discharge, and 5% degradation of the battery over the life of the vehicle. Lastly, the cost of the gasoline powertrain for PHEVs was assumed to be 80% of the cost of a conventional vehicle's powertrain. Figure 5 shows the incremental EV pricing (relative to a conventional vehicle with an internal combustion engine).

Figure 5. Incremental EV Pricing ($2017) Used in BCA Modeling for NYS



2.1.2 EV Purchase Incentives

The project team accounted for both the federal tax credit (i.e., the Qualified Plug-in Electric Drive Motor Vehicle Credit) and the NYS rebate for electric vehicles. The federal tax credit has a nuanced sunset provision—the tax credit is phased out for each manufacturer based on total vehicle sales. The phase out is described is as follows:

> The qualified plug-in electric drive motor vehicle credit phases out for a manufacturer's vehicles over the one-year period beginning with the second calendar quarter after the calendar quarter in which at least 200,000 qualifying vehicles manufactured by that manufacturer have been sold for use in the United States (determined on a cumulative basis for sales after December 31, 2009) ("phase-out period"). Qualifying vehicles manufactured by that manufacturer are eligible for 50 percent of the credit if acquired in the first two quarters of the phase-out period and 25 percent of the credit if acquired in the third or fourth quarter of the phase-out period. Vehicles manufactured by that manufacturer are not eligible for a credit if acquired after the phase-out period.[33]

Tesla has already passed the 200,000-vehicle threshold[34] and General Motors will surpass the threshold by the end of this year.[35] Given that there is no specific date for a phase out of the federal tax credit, the team assumed that it would available through 2025. The modeling assumed that the tax credit is valued at $7,500 for both the PHEV50 and the BEV200, given the size of the two batteries (reported as 16 kWh and 65 kWh, respectively).

With input from NYSERDA, the project team assumed that the State rebate would be available through 2024. The current structure of the State's Drive Clean Rebate is tied to the all-electric range of the car, with the maximum rebate of $2,000 available to vehicles with more than 120 miles of all-electric range. The rebate's assumed value in the modeling is $1,200 per PHEV and $1,700 per BEV—this is based on the average rebate issued today and anticipates potential changes to the program in the future.

2.1.3 EV Operations and Maintenance Costs

Most market research indicates that EVs should have lower operations and maintenance (O&M) costs than conventional vehicles because of fewer oil changes, less wear and tear on brakes, and other factors. For the purposes of this analysis, the team used a variety of data sources to estimate avoided O&M costs for EVs compared to conventional vehicles.

The O&M costs per region were varied based on two considerations. One set of cost data was extracted from the NAPA Auto Parts cost estimator.[36] The estimator reports parts and labor costs by zip code for different types of automotive work. The project team used a common vehicle (2015 Chevrolet Malibu) and a common maintenance type (front brake pad replacement) to obtain a relative comparison based on the same amount and type of work. The project team also used a statewide average labor cost based on CarMD's 2017 State Repair Cost Rankings. Table 1 includes the labor estimates from the NAPA Auto Parts cost estimator and the CarMD State rankings—the italicized values are used in the analysis and are shown in Table 2 along with other O&M costs.

Table 1. Labor Estimates for Vehicle Maintenance in New York

City	Zip code	Labor Estimates	Relative to Statewide Avg
New York	10036	$159-203	115%
Westchester	10514	$159-203	115%
Long Island	11788	$159-203	115%
Albany	12203	$135-172	97%
Syracuse	13201	$123-157	89%
Buffalo	14201	$129-164	93%
Rochester	14602	$123-157	89%
Upstate, Aggregated		$145	92%
Statewide Avg		$158	--

Table 2. Estimated Avoided O&M Costs for EVs

Parameter	Source	Conventional Sedan	Electric	Hybrid[37]
O&M Cost (¢/mile)	AAA	7.94	6.55	6.99
Difference from Sedan (¢/mile)	Calculation		1.39	0.95
Annual VMT	Model Assumption		12,487	12,487
10-Year NPV at 3% Discount Rate	Calculation		$1,481	$1,012
Regional Adjustment	NAPA, CarMD			
Upstate New York			92%	92%
Metro New York			115%	115%
Long Island			115%	115%
10-Year NPV at 3% Discount Rate	Calculation			
Upstate New York			$1,363	$932
Metro New York			$1,701	$1,163
Long Island			$1,701	$1,163

2.1.4 EV Adoption

EV adoption is known for recent history; however, the analysis requires estimates of year-by-year adoption out to 2030. To establish EV adoption beyond 2017, the analysis used county-by-county, non-commercial BEV and PHEV vehicle registration data.[38] The county-level data was allocated to each analysis region (Upstate New York, Metro New York, Long Island) based on utility service areas for each county and population data.[39] The result was an allocation of BEV and PHEV by analysis area as of January 1, 2017 as shown in Table 3.

Table 3. Estimated Population of EV as of January 1, 2017

Vehicle Type	Upstate New York	Metro New York	Long Island
BEV	1,550	2,123	1,524
PHEV	5,233	2,446	3,688
Total EV	6,783	4,569	5,212

Year-by-year BEV and PHEV values were then established by applying a percentage of total statewide new light-duty vehicles sales. The total vehicle population by year was estimated by applying a growth factor that assumes vehicle miles traveled (VMT) per vehicle remains constant and VMT growth is consistent with assumptions reported by the EIA for the Annual Energy Outlook's Reference Case in 2017, with a focus on the Mid-Atlantic region.[40] The percentage of new light-duty vehicle sales was established in an ramped fashion to acknowledge moderate initial sales growth (2017-2020) and then increasing by 2025 to meet the ZEV MOU target. Beyond 2025, the annual EV percentage of new LDV sales was held constant as a conservative estimate of new EV sales (see Figure 6).

Figure 6. EV Percentage of New LDV Sales

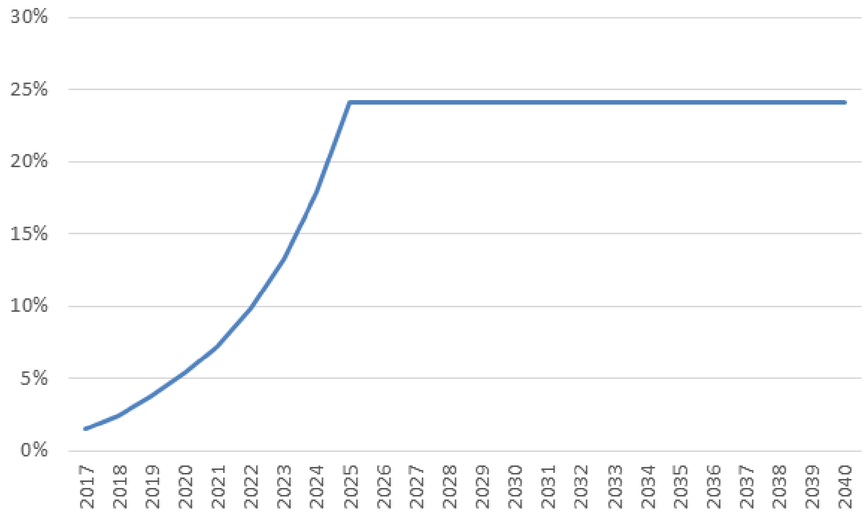


Table 4. Annual and Cumulative EV Sales Projected for New York State, 2017 to 2030

Region		Sales						
		2017	2018	2019	2020	2021	2022	2023
Long Island	Annual	4,000	7,543	11,497	16,379	22,176	30,034	40,604
	Cumulative	9,747	17,290	28,787	45,166	67,342	97,376	137,980
NY Metro	Annual	3,000	6,613	10,079	14,359	19,441	26,330	35,598
	Cumulative	8,545	15,158	25,237	39,596	59,037	85,367	120,965
Upstate	Annual	6,000	9,816	14,967	21,319	28,865	39,092	52,854
	Cumulative	12,691	22,507	37,474	58,793	87,658	126,750	179,604
Total	**Annual**	**13,000**	**23,972**	**36,543**	**52,057**	**70,482**	**95,456**	**129,056**
	Cumulative	**30,983**	**54,955**	**91,498**	**143,555**	**214,037**	**309,493**	**438,549**

Region		Sales						
		2024	2025	2026	2027	2028	2029	2030
Long Island	Annual	54,917	74,265	74,805	75,233	73,427	73,103	72,157
	Cumulative	192,897	267,162	341,967	417,200	490,627	563,730	635,887
NY Metro	Annual	48,144	65,107	65,580	65,955	64,372	64,088	63,259
	Cumulative	169,109	234,216	299,796	365,751	430,123	494,211	557,470
Upstate	Annual	71,480	96,665	97,369	97,925	95,573	95,153	93,922
	Cumulative	251,084	347,749	445,118	543,043	638,616	733,769	827,691
Total	**Annual**	**174,541**	**236,037**	**237,754**	**239,113**	**233,372**	**232,344**	**229,338**
	Cumulative	**613,090**	**849,127**	**1,086,881**	**1,325,994**	**1,559,366**	**1,791,710**	**2,021,048**

Once the EV analysis territory was determined and EV populations were established by year, an estimate of how these populations were split between BEV and PHEV was necessary. For the initial year, actual NYS registration data was used, which indicated that about 67% of all EVs are BEVs and 33% are PHEVs. In subsequent years, the team assumed a transition towards 58% of all new EVs being sold as BEVs by 2030.[41] For the interim years, the percentage of BEV was interpolated between the two and PHEVs represented the balance. Figure 7 summarizes the year-by-year BEV and PHEV population assumptions used for the modeling exercise by region and Figure 8 shows the BEV, PHEV, and total EV populations for New York State out to 2030.

Figure 7. EVs (PHEVs and BEVs) Deployed in Three Study Regions: Long Island, Metro New York, and Upstate New York

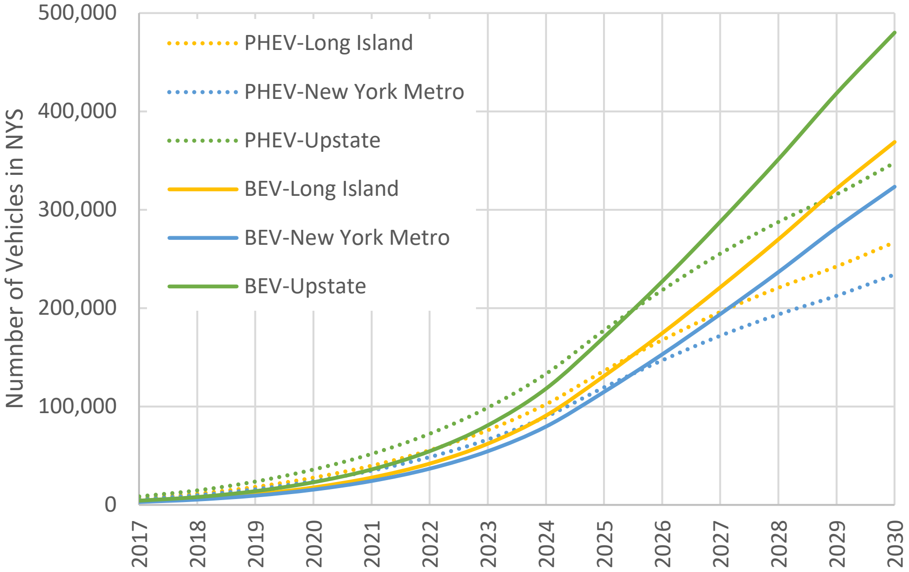
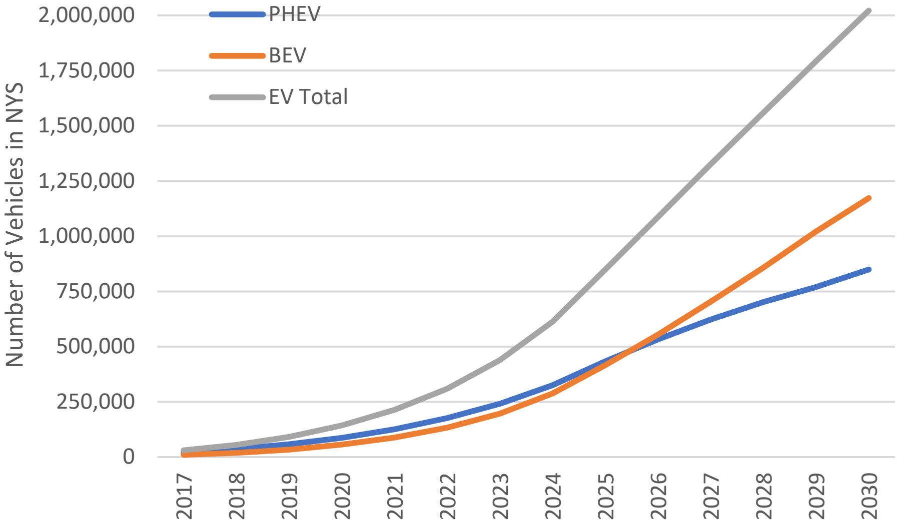


Figure 8. EVs (PHEVs and BEVs) Deployed in New York State



2.2 Fuel Pricing

2.2.1 Electric Rates for EV Charging

For this analysis, rate information was captured for three utilities meant to serve as surrogates for the three analysis regions—Consolidated Edison (ConEd) for New York City and Westchester, Public Service Electric & Gas Long Island (PSEG LI) for Long Island, and National Grid for Upstate New York. For each utility, the team developed several separate rates structures to correspond with the three different functions that rates serve in this study:

- Optimizing charging load profiles
- Calculating cost of charging to the driver for the Participant Cost Test (PCT)
- Calculating utility revenue for the Ratepayer Impact Measure (RIM)

The EV Grid Impacts Model uses one set of rates to optimize load profiles to minimize the driver's electric bill, subject to vehicle and behavioral constraints. Once the load profiles are calculated, the other two rate structures are applied to the load to quantify the driver bill and utility revenue for the PCT and RIM, respectively. These three rate structures are often similar but have a few important distinctions. The PCT and RIM rates differ for public charging because the driver faces a price that not only includes the utility electric rate but also the charging provider's operations costs and profit. The rates used in charging optimization differ from the others in the Behavior Modification Cases for Long Island and Upstate New York only. In these cases, the charging optimization responds to the utility's hourly marginal costs, which produces a best-case scenario load shape for minimizing cost to the electric grid.

Vehicles are assumed to make one morning trip and one evening trip per day—based on average weekday and weekend driving behavior data from Ford, ChargePoint, and national surveys. These trips categorize each 15-minute interval of the year into weekday daytime, weekday nighttime, and weekend daytime periods. Each region's EV population is broken out into twelve segments based on vehicle type and charging access (see section 3.2). The period and population segmentation define what type of charging is available to the vehicle throughout the year, as shown in Table 5.

Table 5. Charging Access by Time and Population Segment

Population Segment			Charging Access		
Vehicle Type	**Work Charging?**	**Home Charger**	**Weekday Night**	**Weekday Day**	**Weekend Day**
BEV	No	None	Public L2	Public L2	Public DCFC
BEV	No	L1	Home L1	Public L2	Public DCFC
BEV	No	L2	Home L2	Public L2	Public DCFC
BEV	Yes	None	Public L2	Work L2	Public DCFC
BEV	Yes	L1	Home L1	Work L2	Public DCFC
BEV	Yes	L2	Home L2	Work L2	Public DCFC
PHEV	No	None	Public L2	Public L2	Public L2
PHEV	No	L1	Home L1	Public L2	Public L2
PHEV	No	L2	Home L2	Public L2	Public L2
PHEV	Yes	None	Public L2	Work L2	Public L2
PHEV	Yes	L1	Home L1	Work L2	Public L2
PHEV	Yes	L2	Home L2	Work L2	Public L2

Because different types of charging locations have different rate structures, most population segments will be subject to varying rates throughout the year. Aside from the marginal cost rates used in the optimization exercise included in the Behavior Modification (BeMod) Cases, data were collected for three general rate types based on charging location: residential, workplace, and public. These rates are pieced together by population segment and time. The following sections describe the sources and structure of those rate types and how they vary by region and scenario.

2.2.1.1 Residential Rates—Base and High-Infrastructure Cases

Rate information was captured from each utility's public website for each rate type. Each utility provides rate schedules as well as approved surcharges for customers to review. The project team extracted individual charges for each rate structure. To aid in the extraction, the project team reviewed sample bills to confirm that all rate charges and surcharges were captured.

The Base and High-Infrastructure (Hi-Infra) Cases for each region assume residential customers have standard flat rate structures (i.e., not TOU or other EV rate). This enables the Behavior Modification Case to isolate the impacts of managed charging, when compared to the baseline flat rate structures.

ConEd and PSEG LI separate their standard residential rates into multiple categories based on kWh usage as well as time of year (see Table 6 and Table 7). Both utilities provide a two-tier approach to energy usage for residential customers requiring higher rates on any electricity consumption exceeding 250 kWh in a given month. Because the model spreads charging load across different locations and because there is a wide range of consumption among customers, the average customer load for the rate class was used to weight the tiers. This total rate was then applied to the model, which is broken up into 15-minute increments for the entire year. Since the model is developed over all time periods for the whole year, the rates were entered based upon the specific time period (e.g., summer rate was used for the months of June, July, August, and September).

Table 6. ConEd Residential Rate

ConEd SC1 - Rate I ($/kWh)	Summer	Non-summer
Monthly adjustment charge (MAC)	$0.006	$0.006
Total merchant function charge	$0.004	$0.004
Market Supply Charge - Capacity	$0.042	$0.042
Revenue Decoupling Mechanism Adjustment	$0.002	$0.002
Energy Efficiency Tracker Surcharge	$0.002	$0.002
Clean Energy Fund Surcharge	$0.005	$0.005
Supply Charge	$0.067	$0.067
Delivery Charges	$0.111	$0.096
Total Rate	$0.238	$0.224

Table 7. PSEG LI Residential Rate

PSEG LI Rate 180	Summer	Non-summer
Delivery and System	$0.084	$0.071
Power Supply Charge	$0.105	$0.101
Shoreham Property Tax Factor	$0.002	$0.002
PILOT	$0.004	$0.004
DER Cost Recovery ($/kWh)	$0.003	$0.003
Revenue Decoupling Mechanism	$0.007	$0.006
Delivery Service Adjustment	$0.002	$0.001
NYS Assessment Factor	$0.001	$0.001
Total	$0.208	$0.189

Unlike ConEd and PSEG LI, National Grid's residential rate only has a single tier and does not vary by season (see Table 8).

Table 8. National Grid Residential Rate

National Grid SC1 ($/kWh)	All Months
Electricity Supply Cost*	$0.038
Delivery	$0.048
Electricity Supply Reconciliation Mechanism*	$0.013
Transmission Revenue Adjustment	($0.003)
System Benefits Charge	$0.008
Dynamic Load Mgmt Surcharge	$0.000
Revenue Decoupling Mechanism	$0.001
Merchant Function Charge	$0.001
Clean Energy Standard Surcharge	$0.003
Total Rate	$0.108

* Average across all National Grid Regions

2.2.1.2 Residential Rates—Behavior Modification Case

For the Behavior Modification scenario, TOU rate information was also captured from each utility's website. Unlike standard residential service, TOU rates are broken down into time blocks typically with higher rates during the morning and afternoon, and lower rates during the evening and overnight.

For PSEG LI and National Grid, voluntary whole-house TOU rates were used. As shown in Table 9, Table 10, and Table 11, both utilities stipulate Peak and Off-Peak time blocks where different rates are charged. For National Grid, the rates also include a Super-Peak time period during the summer where customers are charged a Capacity charge per kW, but because this study assumes vehicles are not at home during this time, it is not used.

Table 9. TOU Time Periods

Period	PSEG LI	National Grid
Peak	10 a.m. to 8 p.m.	7 a.m. to 11 p.m.
Off-Peak	8 p.m. to 10 a.m.	11 p.m. to 7 a.m.
Super Peak		2 p.m. to 6 p.m. (weekdays, June-August)

Table 10. PSEG LI Residential TOU Rate

PSEG LI Rate 184 TOU	Peak		Off-peak	
	Summer	Non-summer	Summer	Non-summer
Delivery and System	$0.191	$0.068	$0.022	$0.022
Power Supply Charge	$0.105	$0.101	$0.105	$0.101
Shoreham Property Tax Factor	$0.004	$0.002	$0.002	$0.002
PILOT	$0.008	$0.003	$0.002	$0.002
DER Cost Recovery ($/kWh)	$0.003	$0.003	$0.003	$0.003
Revenue Decoupling Mechanism	$0.015	$0.005	$0.002	$0.002
Delivery Service Adjustment	$0.004	$0.001	$0.000	$0.000
NYS Assessment Factor	$0.001	$0.001	$0.000	$0.000
Total	$0.330	$0.185	$0.137	$0.132

Table 11. National Grid Residential TOU Rate

National Grid SC1 VTOU Rate ($/kWh)	Summer		Non-Summer	
	Off Peak	On-Peak	Off Peak	On-Peak
Electricity Supply Cost*	$0.038	$0.038	$0.038	$0.038
Delivery	$0.010	$0.061	$0.010	$0.061
Electricity Supply Reconciliation Mechanism	$0.006	$0.006	$0.006	$0.006
Transmission Revenue Adjustment	($0.003)	($0.003)	($0.003)	($0.003)
System Benefits Charge	$0.008	$0.008	$0.008	$0.008
Dynamic Load Mgmt Surcharge	$0.000	$0.000	$0.000	$0.000
Revenue Decoupling Mechanism	$0.001	$0.001	$0.001	$0.001
Merchant Function Charge	$0.001	$0.001	$0.001	$0.001
Clean Energy Standard Surcharge	$0.003	$0.003	$0.003	$0.003
Electricity Supply Uncollectible Expense Factor	$0.001	$0.001	$0.001	$0.001
Working Capital on Purchased Power Costs Factor	$0.000	$0.000	$0.000	$0.000
Total Rate	$0.065	$0.116	$0.065	$0.116

* Average across all National Grid Regions

ConEd offers an EV-specific program called SmartCharge New York that incentivizes charging during off-peak periods by giving a cash rebate for participating and a rebate to reduce the effective rate if participants follow the program rules. The program gives participants $5 per month for keeping a FleetCarma device plugged into the vehicle, which tracks the location and time of day when charging. During the months of June to September, ConEd will also provide customers a $20 rebate when they refrain from charging their vehicle between 2 p.m. and 6 p.m. on weekdays for the entire month. Because the Behavior Modification Case is a bookend scenario designed to show the full potential of such a program, and therefore, 100% compliance is enforced by the deterrence of charging during those intervals. Consequently, this scenario credits the driver each year with $80 for avoiding the summer weekday peak hours and $60 for participation. In addition, customers can receive a $0.10 per kWh rebate for any electricity used for charging their cars in ConEd service territory between midnight and 8 a.m. on any day of the year.

The SmartCharge New York program's off-peak discount is very similar to the PSEG Long Island and National Grid TOU rates with one key difference. While the TOU off-peak rate discounts are tied to the driver's home electric meter, the SmartCharge program provides the rate rebate when charging during off-peak hours at any charger in ConEd service territory. This is especially useful in New York City, where access to charging at home may be more difficult for EV drivers.

2.2.1.3 Workplace Charging Rates

Workplace EV charging programs and rates can range from being free to partially subsidized to full third-party retail price. To account for this variation, workplace charging rates are modeled to recover only the marginal cost to the employer's electric bill, that is, maintenance, infrastructure, and programmatic costs are not passed through to the employee's workplace charging rate.

For workplace charging rates, the project team extracted general commercial rates from utility websites. Similar to residential customers, commercial customers pay for supply and delivery of electricity. However, they are subject to additional charges. These added charges are applied to the maximum kilowatts of demand in a given window (kW), rather than sum of kWh, since commercial installations can require high electrical loads (kW), which can increase costs to the utility for adding capacity to the grid. To recover these costs, the utility charges commercial customers Demand and Capacity charges based on the peak capacity (demand) that the customer needs during a certain month. These kW charges can significantly affect the price a customer pays each month, especially during high-load periods (e.g., summer air conditioning season). While demand charges can be significant for commercial customers, commercial volumetric rates ($/kWh) are generally much lower than the volumetric portion of residential rates. If EV charging can be avoided at times that would increase a commercial building's demand peak and the associated charges, then the charging could occur at a time during which only a low volumetric rate would need to be paid.

Demand charge rates for workplace charging are adjusted so that each driver pays for their share of the incremental bill. This allocation occurs in two steps. First, workplace EV charging is assumed to contribute only 20% of its demand to the existing commercial building's peak. Then, because each workplace charger is assumed to be shared by four vehicles, the remaining 20% of the original demand charge is split among four drivers. The resulting workplace charging rate is modeled with the commercial volumetric rate and about 5% of the commercial demand charge rate (see Table 12 through Table 17).

Table 12. ConEd Commercial Rate—Volumetric Portion

ConEd SC9 - Rate I Low Tension ($/kWh)	Summer	Non-Summer
Monthly adjustment charge (MAC)	$0.006	$0.006
Total merchant function charge	$0.002	$0.002
Revenue Decoupling Mechanism Adjustment	$0.001	$0.001
Energy Efficiency Tracker Surcharge	$0.002	$0.002
Clean Energy Fund Surcharge	$0.005	$0.005
Supply Charge	$0.038	$0.038
Delivery Charges	$0.022	$0.022
Total Rate	$0.076	$0.076

Table 13. ConEd Commercial Rate—Demand Charge with Workplace Adjustment

ConEd SC9 - Rate I Low Tension ($/kW)	Summer	Non-Summer
Market Supply Charge - Capacity	$12.66	$12.66
Delivery Charges	$23.24	$18.36
Total Rate	$35.90	$31.02
Workplace Rate	$1.78	$1.54

Table 14. PSEG LI Commercial Rate—Volumetric Portion

PSEG-LI Rate 281 Secondary ($/kWh)	Summer	Non-summer
Delivery and System	$0.025	$0.010
Power Supply Charge	$0.105	$0.101
Shoreham Property Tax Factor	$0.002	$0.001
PILOT	$0.002	$0.001
DER Cost Recovery	$0.003	$0.003
Revenue Decoupling Mechanism	$0.001	$0.000
Delivery Service Adjustment	$0.000	$0.000
NYS Assessment Factor	$0.000	$0.000
Total Rate	$0.138	$0.118

Table 15. PSEG LI Commercial Rate—Demand Charge with Workplace Adjustment

PSEG-LI Rate 281 Secondary ($/kW)	Summer	Non-summer
Delivery and System	$14.54	$13.33
Shoreham Property Tax Factor	$0.19	$0.17
PILOT	$0.17	$0.15
Revenue Decoupling Mechanism	$0.45	$0.41
Delivery Service Adjustment	$0.29	$0.27
NYS Assessment Factor	$0.04	$0.04
Total Rate	$15.68	$14.37
Workplace Rate	$0.78	$0.71

Table 16. National Grid Commercial Rate—Volumetric Portion

National Grid SC3 Rate ($/kWh)	All Months
Market Supply Charge	$0.035
Electricity Supply Reconciliation Mechanism	$0.006
System Benefits Charge	$0.008
Transmission Revenue Adjustment	($0.002)
Legacy Transition Charge	$0.002
Working Capital on Purchased Power Costs Factor	$0.000
Electricity Supply Uncollectible Expense Factor	$0.000
Total Rate	$0.049

Table 17. National Grid Commercial Rate—Demand Charge with Workplace Adjustment

National Grid SC3 Rate ($/kW)	All Months
Total Rate	$10.24
Workplace Rate	$0.51

2.2.1.4 Public Charging Rates

While some vehicles in the model only have access to public chargers, all vehicles have access to public Level 2 or DC fast chargers at some point in the week. Business models for public charging stations and what they charge their customers vary substantially from charger to charger. Examples of cost structures include low-cost or free charging, memberships, or subscription services that bundle charging on a monthly basis, fixed fees per session, and billing based on electricity consumption or time using the station. The costs of owning and operating public charging stations are similarly diverse—upfront investments, leases, maintenance, utility bills, etc. depend on many factors related to location and use case. Given the variation of current payment models and their uncertainty going forward, the model used a proxy for public charging rates as 150% of the utility's volumetric residential rate. The use of utility-specific rates preserves the regional differences in costs of electric service that would be passed through from the utility to the station owner to the driver. Because many of the factors that account for regional differences in utility rates apply to other charging station costs (e.g., for real estate and labor, the utility rates were scaled up by 50%). The resulting figures were validated against approximated volumetric charges from historical New York charging session data provided by ChargePoint.

2.2.1.5 Summary of Electric Rates

Table 18 gives an overview of how the rates described above fit into the analysis for each scenario.

Table 18. Underlying Rates of Each Scenario by Purpose and Charging Location

Region	Case	Load Optimization			PCT			RIM		
		Home	Work	Public	Home	Work	Public	Home	Work	Public
Metro NY	Base	ConEd SC1	ConEd SC9	Public	ConEd SC1	ConEd SC9	Public	ConEd SC1	ConEd SC9	ConEd SC9
	BeMod	ConEd SC1 w/ SmrtChrg NY	ConEd SC9 w/ SmrtChrg NY	Public w/ SmrtChrg NY	ConEd SC1 w/ SmrtChrg NY	ConEd SC9 w/ SmrtChrg NY	Public w/ SmrtChrg NY	ConEd SC1 w/ SmrtChrg NY	ConEd SC9 w/ SmrtChrg NY	ConEd SC9 w/ SmrtChrg NY
	Hi-Infra	ConEd SC1	ConEd SC9	Public	ConEd SC1	ConEd SC9	Public	ConEd SC1	ConEd SC9	ConEd SC9 + higher demand charge share
Long Island	Base	PSEG LI 180	PSEG LI 281 Sec	Public	PSEG LI 180	PSEG LI 281 Sec	Public	PSEG LI 180	PSEG LI 281 Sec	PSEG LI 281 Sec
	BeMod	Utility Marginal Cost			PSEG LI 184 TOU	PSEG LI 281 Sec	Public	PSEG LI 184 TOU	PSEG LI 281 Sec	PSEG LI 281 Sec
	Hi-Infra	PSEG LI 180	PSEG LI 281 Sec	Public	PSEG LI 180	PSEG LI 281 Sec	Public	PSEG LI 180	PSEG LI 281 Sec	PSEG LI 281 Sec + higher demand charge share
Upstate	Base	NGRID SC1	NGRID SC3	Public	NGRID SC1	NGRID SC3	Public	NGRID SC1	NGRID SC3	NGRID SC3
	BeMod	Utility Marginal Cost			NGRID SC1 VTOU	NGRID SC3	Public	NGRID SC1 VTOU	NGRID SC3	NGRID SC3
	Hi-Infra	NGRID SC1	NGRID SC3	Public	NGRID SC1	NGRID SC3	Public	NGRID SC1	NGRID SC3	NGRID SC3 + higher demand charge share

2.2.2 Utility Marginal Electricity Costs

To calculate the incremental dollar costs to society and the utility ratepayer resulting from the changes in hourly electric loads, an hourly set of marginal utility costs was created using costs incurred by the utility for serving marginally more electric load. Similar to the selection of tariffs, marginal electricity costs from three utilities were used to approximate this study's three regions: ConEd for New York City and Westchester, PSEG LI for Long Island, and National Grid for Upstate New York. Table 19 lists the marginal cost components considered, along with a description of the calculation methodology and source data.

Table 19. Description and Sources of Utility Marginal Electricity Costs

Component	General Description	Input Assumption
Energy	Increase in costs due to change in production from the marginal conventional wholesale generating resource associated with incremental EV load	The value of energy for each utility is derived from a forecast based on production simulation modeling per the NYISO's Congestion Assessment and Resource Integration Study (CARIS). This includes generation energy losses and compliance costs for criteria pollutants but does not include any financial CO_2 emission costs.
Energy Losses	Increase in electricity losses from the points of generation to the points of delivery associated with incremental EV load	Utility transmission and distribution loss factors, i.e., expansion factors, as reported in their respective approved Tariffs. Generation losses are already accounted for in the energy costs.
Generation Capacity	Increase in the fixed costs of building and maintaining new conventional generation resources associated with incremental EV load	The most recent DPS installed capacity (ICAP) model was used to forecast future ICAP prices appropriate under a load modification approach applicable to each utility. These capacity costs are also adjusted for the appropriate energy transmission and distribution (T&D) losses as well as adjusted by the expected system peak-load reduction value.
Ancillary Services	Increase in the costs of services like operating reserves, voltage control, reactive power, and frequency regulation needed for grid stability associated with incremental EV load	A proxy value of 1% assigned. The New York Independent System Operator (NYISO) procures ancillary services on a fixed rather than load-following basis based on a largest single contingency measure. This means that the amount of ancillary services procured would not likely increase in any appreciable way due to the adoption of EVs.
Transmission Capacity	Increase in costs associated with expanding/replacing/upgrading transmission capacity attributable to incremental EV load	The value of transmission capacity is captured in the NYISO CARIS zonal production simulation modeling results and is represented as congestion (i.e., energy price differentials, between the NYISO modeled zones). It is also likely captured to some extent in the various zonal NYISO capacity prices (i.e., more transmission and generation constrained capacity zones would likely have a higher zonal capacity price all else being equal).
Sub-Transmission Capacity	Increase in costs associated with expanding/replacing/upgrading sub-transmission capacity such as substations, lines, transformers, etc. attributable to incremental EV load	Costs based on existing estimates for marginal sub-transmission capacity costs as provided by each utility in their Marginal Cost of Service Studies as updated in the Value of Distributed Energy Resources (DER) proceeding (Case 15-E-0751). These costs are adjusted by the expected sub-transmission system peak-load contribution from EVs based on NYISO zonal load data.
Distribution Capacity	Increase in costs associated with expanding/replacing/upgrading distribution capacity such as lines, transformers, etc. attributable to incremental EV load	Costs based on existing estimates for marginal distribution capacity costs as provided by each utility in their Marginal Cost of Service Studies as updated in the Value of DER proceeding (Case 15-E-0751). These costs are adjusted by the expected distribution system peak-load contribution from EVs based on utility sample substation load data.

2.2.3 Gasoline Pricing

Gasoline pricing was developed for each geographic study area. The fuel price was disaggregated into multiple parts: the wholesale price of gasoline, the federal excise tax, State gasoline taxes, and distribution/marketing costs. Table 20 summarizes the gasoline pricing projections included in the modeling.

Table 20. Gasoline Pricing Components Used in BCA

Parameter	Description
Wholesale price of gasoline	Used 2017 national average for wholesale gasoline prices and forecasted based on energy prices reported for the transportation sector from the Annual Energy Outlook 2017 Reference Case.
Federal excise tax	Held constant at 18.4 ¢/gallon.
State gasoline taxes	Held constant at 43.65 ¢/gallon.
Distribution and marketing costs	Estimated for three study regions based on analysis of weekly fuel reports from NYSERDA for 2017—which includes statewide averages and fuel reports for eight regions. Metro NY: Used New York City pricing, which is about 5% higher than statewide pricing. Long Island: Used the statewide average fuel price. Upstate: Used median percent difference between upstate regions: Albany, Buffalo, Rochester, Syracuse, and Utica-Rome—and the statewide average. This amounted to a 3% discount from the statewide average.

Note that the distribution and marketing costs were estimated by calculating the difference between the retail pricing reported in the NYSERDA fuel reports and the sum of the wholesale gasoline price (by week—reported for New York Harbor) and fuel taxes (federal and state). The project team assumed this value represented the distribution and marketing costs. The distribution and market costs were held constant throughout the analysis years by region—and were valued at $0.42 per gallon for Metro New York, $0.29 per gallon for Long Island, and $0.21 per gallon for Upstate New York.

2.3 EV Charging Infrastructure

2.3.1 Charging Infrastructure Costs

Charging infrastructure costs for Level 1, Level 2, and DCFC equipment were developed based on the following.

For Level 1 charging, the project team assumed a total cost of $50 at residences and no Level 1 installations would occur in nonresidential applications.

For Level 2 charging infrastructure, the team distinguished between residential installations and nonresidential installations. Furthermore, members of the team characterized total costs and the so-called "make ready" costs. The make-ready costs represent the investments required up to, but not including, the charging hardware, or electric vehicle supply equipment. The project team notes that some utilities in other states have received approval from public service commissions to pay for these "make ready" costs and recover the investment through traditional cost recovery and via capitalization of assets.

- For residential installations, the team assumes a total cost of $1,200, including $500 for the charger and a make-ready cost of $700 per Level 2 installation. In the Behavior Modification Case, the team assumed a 10% price premium for Level 2 equipment to account for more sophisticated chargers that would enable price signals to be sent to EV drivers to influence charging behavior.
- For nonresidential installations, the project team used data provided by NYSERDA gathered from deployment initiatives that it supported between 2013 and 2017. NYSERDA reports that for the nearly 700 ports for which it has data, the average per-port cost for Level 2 installations was around $9,000. Of that, $5,000 was for the make-ready aspect of the installation. Similar to residential installations, the team assumed a 10% price premium for nonresidential Level 2 equipment that would enable price signals to be sent to EV drivers to impact charging behavior.

For DC fast charging equipment, the project team assumed that equipment would be able to deliver up to 50 kW, with a total cost of $75,000 and a make-ready cost of $50,000. Because make-ready costs in dense urban areas can be much more expensive than other areas, the team adjusted make-ready costs by region. The baseline make-ready costs described above are used for the Upstate New York region, which were adjusted for Long Island and Metro New York with factors comparing E3's forecasted distribution costs of National Grid to those of PSEG LI and ConEd, respectively. The resulting make-ready costs are presented in Table 21.

Table 21. Make-Ready Charger Costs by Region and Charger Type

Region	DCFC	Nonresidential L2	Residential L2	Residential L1
Upstate	$50,000	$5,000	$700	$0
Long Island	$63,325	$6,332	$887	$0
Metro New York	$90,970	$9,097	$1,274	$0

2.3.2 Charging Infrastructure Deployment

The project team developed assumptions for the amount of charging infrastructure that is required to support EV adoption. These varied by level of charging (Level 1, Level 2, and DCFC) and by charging location (residential and nonresidential).

- For residential charging, the team used survey data to determine Level 1 and Level 2 charger deployment for each region. See section 3.2 for more details.
- For nonresidential Level 2 charging, the team assumed 4 EVs per EVSE, totaling approximately 5000,000 by 2030.
- For DC fast charging, the team assumed 3 DC fast chargers would be deployed for every 1,000 BEVs in the Base Case and Behavior Modification Case, for a total of about 3,500 deployed by 2030. In the High-Infrastructure Case, the team assumed the Base Case deployment of DC fast chargers would increase from three DC fast chargers installed per 1,000 BEVs sold in 2017 to twelve DC fast chargers installed per 1,000 BEVs in 2030. This resulted in approximately 10,500 DC fast chargers deployed by 2030 in the High-Infrastructure Case.

2.4 Emission Factors and Monetized Externalities

Apart from the traditional financial metrics associated with EVs, the project team quantified several environmental and energy security externalities in the context of EV deployment: (1) reduced GHG emissions, (2) reduced criteria air pollutants, and (3) displaced petroleum. These externalities were monetized based on recent research corresponding to each externality.

2.4.1 GHG Emissions

The project team developed an approach to estimate the emissions attributable to the following:

- A decrease in emissions from reduced combustion of gasoline in vehicles
- An increase in emissions from incremental electricity usage

The impact of gross emissions equals the magnitude of the decrease in petroleum-related emissions less the magnitude of the increase in electricity-related emissions.

The project team used tailpipe GHG emission factors for gasoline consumption, taken from the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model (2017 release).[42] The electricity GHG emissions factor was derived from New York State data in the EPA's Emissions and Generation Resource Integrated Database (eGRID).[43] The emissions rates were employed as a constant across all years in this study and are representative of what is assumed to be the marginal unit of electricity generation (i.e., a newer combined cycle, natural gas fired turbine) to account for the marginal EV load. The project team notes that because the electricity generation sector operates under a cap-and-trade system, electricity sector GHG emissions are unlikely to rise substantially. It is anticipated that the cap-and-trade system will put downward pressure on the GHG emission factor for marginal load in the future. However, given that there are many possible assumptions and methodologies that can be employed to calculate long-term marginal GHG emissions, the project team opted to use a constant GHG emissions factor for electricity over time.

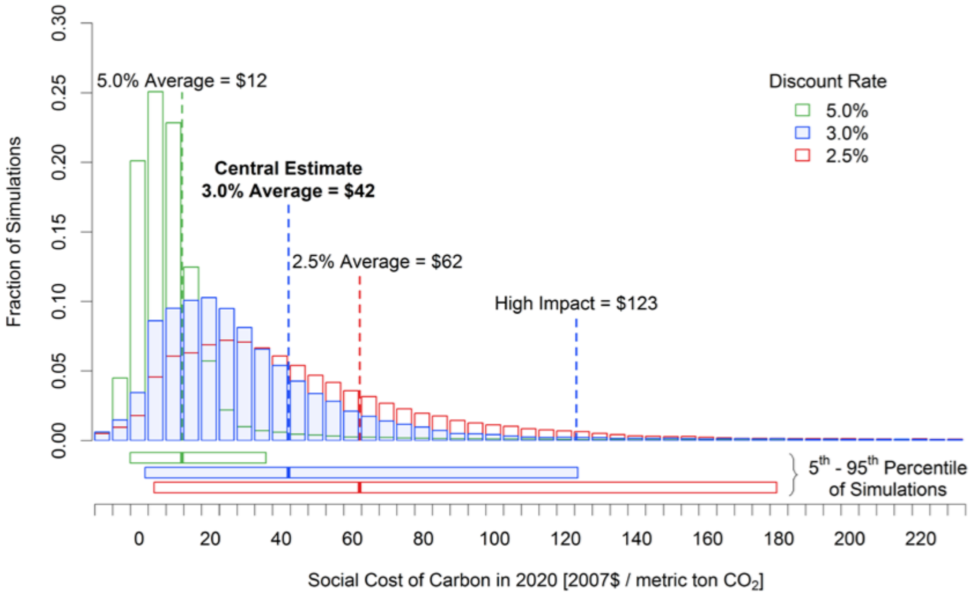
The monetized value of damages avoided as a result of CO_2 reductions, including changes in net agricultural productivity, human health and flooding, is referred to as the social cost of carbon (SCC). In 2010, the U.S. government's Interagency Working Group on Social Cost of Carbon released a report outlining the range of estimated values for the social cost of carbon. That work was most recently updated via a Technical Support Document in August 2016.[44] The SCC is based on the results of various integrated assessment models (IAMs) that the interagency group reviewed. These models include the following:[45]

- The Dynamic Integrated Climate-Economy (DICE) model was primarily developed by William Nordhaus, an economics professor at Yale University. DICE is a modified Ramsey-style optimal economic growth model whereby additional so-called unnatural capital (e.g., increased GHG emissions) have a negative effect on economic output. The model was recently updated for changes reflecting modifications to the carbon cycle, improved representation of sea-level rise dynamics, and a re-calibrated damage function (largely as a result of modifications to sea-level rise).
- The Climate Framework for Uncertainty, Negotiation and Distribution (FUND) model is co-developed by David Anthoff and Richard Tol. According to FUND's developers, the model "links scenarios and simple models of population, technology, economics, emissions, atmospheric chemistry, climate, sea level, and impact." The most recent version of the model includes changes that impacted space heating, sea-level rise and corresponding land loss, an updated function impacting damages in the agricultural sector, an updated transient temperature response function, and includes the indirect effects of methane emissions.

- The Policy Analysis of the Greenhouse Effect (PAGE) model simulates the economic and environmental impact of climate change policies and is developed by Chris Hope with John Anderson, Paul Wenman and Erica Plambeck. PAGE is a stochastic model meaning that it generates results based on multiple model runs (generally 1,000 runs per scenario) and reports the results as a probability distribution, rather than as a single value. The most recent version of the PAGE model has several notable changes. The developers (1) added a third category of damages from sea-level rise, (2) revised the damage function that accounts for saturation of benefits from increased temperatures, (3) modified regional scaling factors that are in line with studies used by the IPCC's third assessment report, (4) improvements to how the model manages nonlinear extreme events (e.g., the melting of the Greenland ice sheet), (5) increased vulnerability to climate change and increased timeframes to minimize vulnerability via adaptation, and (6) changes to carbon absorption accounting and how global average temperatures are modified for use in regional damage functions.

The working group reports the SCC modeling results for five scenarios using three discount rates (5%, 3%, and 2.5%) in each of the three models. Figure 9 highlights the results of the interagency group's analysis in 2020. The distribution shown for each discount rate accounts for 150,000 estimates of the social cost of carbon across the three models employed. Using a lower discount rate extends the tail of the probability distribution because the costs are not discounted as steeply, thereby increasing the negative impact of an additional ton of carbon emitted.

Figure 9. Social Cost of Carbon in 2020 ($2007)[46]



The project team used the SCC with a 3% discount rate, consistent with the Commission's BCA Order indicating that this value should be used until a REC Tier 1 price is determined.

2.4.2 Criteria Pollutant Emissions

Criteria air pollutants such as nitrogen oxides (NO_x), particulate matter (PM), volatile organic compounds (VOC), and sulfur dioxide (SO_2) are considered negative externalities and researchers have attempted to capture the value of avoided emissions in the form of health and environmental benefits. NO_x and VOC are precursors to photochemical ozone formation, and PM is linked to an array of respiratory problems. Various regulatory agencies, including the PSC and the EPA have developed cost per ton estimates quantifying the avoided costs of reduced criteria air pollutant emissions. The health benefits of reducing transportation-related emissions will depend on several local factors, including the overall levels of pollution in the area and the number of individuals especially sensitive to air pollution, among others. Further, the unit risk factors, that is, the estimated avoided health damage per unit of emissions, for several of the emissions vary as state and federal agencies differ on their values.

It is important to note that there are two key aspects for consideration in the review of the estimated criteria air pollutant estimates:

- Firstly, the project team only considered tailpipe criteria air pollutant emission reductions. It is possible–and in many cases likely–that the criteria pollutant emissions reductions would be larger if our analysis considered lifecycle emission reductions. Quantifying lifecycle criteria pollutant emissions is a challenging exercise and was considered beyond the scope of this analysis. Generally speaking, the determination of criteria pollutant emission reductions requires an understanding of the marginal unit of production (e.g., of electricity or crude oil). Incorporating lifecycle criteria pollutant emissions is also difficult because the avoided damage costs are linked to the geographic location of emissions. In other words, the damage costs are linked to exposure. Again, in this case, the location of the emissions for the activities associated with EV deployment is uncertain.
- Secondly, the EPA has developed several programs to reduce criteria pollutant emissions from light-duty and heavy-duty vehicles. The avoided costs reported here are incremental to the benefits of existing vehicle emission programs.

The project team used tailpipe emission factors for gasoline derived from the GREET model. PHEVs using electricity and BEVs had zero tailpipe criteria pollutant emissions. Electricity emission factors for SO_2 and NO_x were also derived from EPA's eGRID database. For VOCs, the team used the emission factor from a modern gas turbine with emissions controls.[47]

For the societal cost of criteria emissions, damage costs used by the PSC and by EPA in rulemakings were used.[48] More specifically, NO_x and SO_2 rates are from the NYISO's 2016 CARIS. The project team notes that these values were provided by NY Department of Public Service (DPS) staff, with the recognition that the social costs of NO_x and SO_2 are *higher* than the compliance cost of the cap- and trade-system; however, these values are what the PSC recognizes. Further, the PSC does not recognize damage costs from PM and VOC. The magnitude of damage costs (on a dollar per ton basis) for $PM_{2.5}$ is dependent on the location of emission reductions.[49] Areas with higher population density, for instance, tend to have higher damage costs than less populated areas. The project team developed a population-weighted average for the damage cost of $PM_{2.5}$ in New York State. For VOC, the project team used values from the EPA.

2.4.3 Petroleum Displacement

Petroleum based fuels—gasoline and diesel—account for about 95% of the energy consumed in the transportation sector today. Refineries in Petroleum Administration for Defense District (PADD) 1, the region where New York State gets its gasoline, import 50 to 65% of the crude oil processed at these facilities.[50] In addition to the environmental benefits noted previously, petroleum displacement by electricity as part of EV deployment will lead to improved energy security. As outlined in detail by a report from Oak Ridge National Laboratory regarding energy security benefits,[51] energy security concerns arise from three problems: (1) concentrated crude oil supply in an historically unstable region, (2) the sustained exercise of market power by oil exporting countries, and (3) the vulnerability of the economy to oil supply shocks and price spikes.

Leiby estimates the benefits of energy security, focusing on two components:[52]

- Monopsony Component: This component reflects the effect of U.S. import demand on the long-run world oil price. The U.S. remains a sufficiently large purchaser of foreign oil supplies, which in turn, affects global oil pricing. This demand is characterized as monopsony power. In other words, increases or decreases in U.S. petroleum demand can increase or decrease the price of crude oil globally. Leiby estimates the extent of U.S. monopsony using a complex set of factors, such as the relative demand for imported oil in the U.S., OPEC behavior, and the sensitivity of petroleum supply/demand by other market participants.
- Macroeconomic Disruption/Adjustment Costs: The second component of Leiby's analysis focuses on the effect of oil imports on disruptions such as a sudden increase in oil prices. These price spikes increase the costs of imports in the short run and can lead to macroeconomic contraction, dislocation, and gross domestic product loss.

Leiby estimates the incremental benefits to society in units of dollars per barrel by reducing U.S. imports. These costs are not reflected in the market price of oil and are considered externalities. Leiby notes that his analysis does not include other “non-economic or unquantifiable effects such as effects on foreign policy flexibility or military policy.”

The most recently available results from Leiby’s analysis regarding the monetized benefits of decreasing oil imports are shown in Table 22 for the years 2013 and 2022.

Table 22. Energy Security Premium for 2013 and 2022 ($2010/Barrel)[53]

Component	2013		2022	
	Mean	Range	Mean	Range
Monopsony	11.40	3.83 to 19.40	9.82	3.27 to 16.77
Disruption Costs	7.13	3.41 to 10.35	7.84	3.80 to 11.30
Total	18.53	10.03 to 26.74	17.66	9.88 to 24.99

The project team used a value for petroleum displacement using a 7% discount rate, assuming 50% of the gasoline used in New York State is refined from imported crude oil.

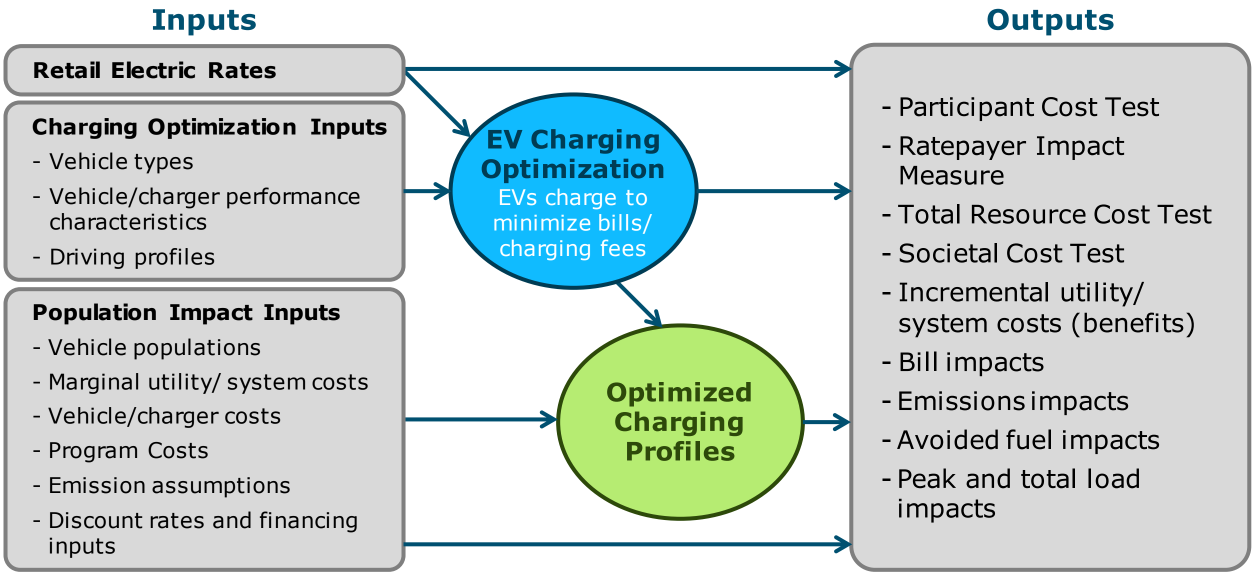
3 Modeling Methodology

3.1 Overview

The E3 EV Grid Impacts Model takes an EV adoption scenario and calculates several physical and economic impacts. An EV adoption scenario is defined by many assumptions that reflect a particular state-of-the-world and, if applicable, a specific EV program. Each scenario evaluates the impacts of one EV adoption trajectory relative to identical levels of internal combustion engine (ICE) vehicle use. The model optimizes EV charging to minimize costs from the utility grid or driver perspective given vehicle specifications, end use driving demand, and charging availability.

Figure 10 provides an overview of the model logic, including the key inputs and outputs. Model inputs include tariffs, vehicle characteristics, driving patterns, incremental costs of EVs above ICE vehicles, vehicle and charger population forecasts, and emissions assumptions. The assumptions and data used for these inputs were described in section 2.

Figure 10: E3 EV Grid Impacts Model Logic Progression



The E3 EV Grid Impacts model calculates charging usage patterns for each vehicle type and rate combination under the assumption that customers will meet their driving needs while minimizing their fueling cost. The model determines only the EV charging behavior, and it does not alter the usage pattern for the customer's other home or business load. The model optimizes charging profiles for each customer segment based on vehicle type, charging level, and the total charging load based on a driver's so-called electric vehicle miles traveled (eVMT), which represents the miles that a vehicle travels while in all-electric mode. After calculating optimized charging profiles, the E3 EV Grid Impacts Model uses marginal cost estimates to calculate the incremental cost of distribution upgrades triggered or accelerated by EV charging.

3.2 Driver Populations

For the first step in modeling EV charging profiles, E3 developed estimates of driver populations in each of the three regions: Metro New York, Long Island, and Upstate New York. The team used information on population and housing type from the American Community Survey (ACS) to estimate the number of households for each of three categories: Single-Family Dwelling (SFD), Single-Family Attached (SFA) and Apartment Building (Apt).[54] Using data from the ACS, the team estimated the number of households by type, the percentage of each household type that owns a car, and the percentage of car owners that drive to work. The team then used a report from University of California, Davis to estimate the availability of home charging at each type of housing and the percentage of vehicles that would charge at home, at work, and on public chargers.[55]

Table 23 shows the resulting breakdown of primary and secondary charging levels and location by region. In Metro New York, which has a higher percentage of apartment dwellers, 43% of vehicles do not have access to home charging, as compared to 14% and 18%, respectively, for Long Island and Upstate New York. Furthermore, in Metro New York, a total of 24% of vehicles can potentially charge at work, which is much lower than the 42% and 45% with potential access to workplace charging in Long Island and Upstate New York, respectively.

Table 23. Summary of Primary and Secondary Charging Locations by Region

Work Charging	Home Charging	Primary Charging	Secondary Charging	Metro New York	Long Island	Upstate NY
Yes	None	Work	Public	10%	6%	8%
	L1	Home	Work	8%	16%	17%
	L2	Home	Work	6%	20%	20%
	Total Workplace Charging			24%	42%	45%
No	None	Public		33%	8%	10%
	L1	Home	Public	25%	22%	20%
	L2	Home	Public	17%	28%	24%

3.3 EV Grid Impacts Model Optimization

3.3.1 Charging Profile Optimization

E3's EV Grid Impacts Model uses a 15-minute interval, linear optimization program designed to produce load profiles that reflect what would result if EV operators were to minimize their bills under a given tariff structure. The optimization model determines the quarter-hourly charging profile that minimizes customer charging costs on a monthly basis, co-optimizing volumetric charges and demand charges when applicable. This analysis includes vehicles with fast charging that can complete charging in less than one hour. E3 accounts for the impact of sub-hourly charging on the peak demand of these customers. Tariff charges that are not associated with the monthly load profile of a customer (e.g., monthly fixed charges) do not change with charging behavior and thus, while included in revenue calculations, are not included in the optimization.

The optimization model is also subject to the physical and behavioral constraints listed in Table 24. Inputs to the optimization include vehicle characteristics, driving behavior for each vehicle and corresponding eVMT, charging levels, and applicable retail tariffs. The result of the optimization is optimal quarter-hourly electricity charging demand.

Table 24. EV Grid Impacts Model Optimization Constraints

Physical Constraints
State of Charge Limits: The state of charge for each vehicle cannot be less than zero nor greater than the stated vehicle's battery size (kWh).[56]
Charging Rate Limit: The quarter-hourly increase in state of charge for each vehicle cannot exceed the stated vehicle's maximum charging capacity (kW).
Charger Limit: The sum of the demands for each vehicle in a given interval cannot exceed capacity of the charger (kW).
Behavioral Constraints
Beyond the physical constraints of an EV battery and charger, further behavioral constraints are implemented to capture the daily driving needs of an EV operator.
Availability: EVs may only charge when not in use and parked at a site with available charging. Each vehicle modeled has a weekday and weekend availability profile; in intervals when charging is unavailable, the corresponding vehicle cannot charge.
Driving Profile: Each vehicle modeled has a weekday and weekend driving profile with a corresponding charging load based on required eVMT. EVs must charge sufficiently so that they have enough stored energy to complete all scheduled drives.

3.3.2 Range Anxiety Minimization

Using historical New York State trip data provided by Ford, E3 constructed 15-minute interval weekday and weekend probabilities that an EV might take an impromptu drive. In addition, E3 also used national trip survey data to estimate the distribution of lengths of these impromptu drives. With this distribution, E3 developed a piecewise linear probability density function representing the likelihood that a percent state of charge (state of charge divided by battery storage capacity) would be insufficient for an impromptu trip. For example, a fully-charged battery would have a probability of insufficient energy of 0, whereas a fully-depleted battery would have a probability of insufficient energy of 1.

The product of these two probabilities, the probability that a driver takes an impromptu drive in a given 15-minute interval and the probability that there is insufficient energy for an impromptu drive given the state of charge in said interval, provides the probability that a driver takes an impromptu drive in a given interval with insufficient energy. This probability is then multiplied by a cost scalar (representing how "bad" it is for a driver to have insufficient energy for an impromptu drive) to produce the customer anxiety component of the objective function. When the customer anxiety is above a threshold, they will seek a charge at the next possible time.

3.4 Cost Test Approach and Overview

Using the BCA methodology and inputs described in section 2, E3 calculated the costs and benefits of EV adoption from the societal, participant, and ratepayer perspectives.

The benefits from the societal perspective include the direct, monetary benefits that will flow to New York State as a result of the transition from ICE vehicles to EVs, as well as the indirect benefits of reduced carbon and criteria pollutant emissions and energy security benefits associated with a reliance on local electricity rather than imported oil. These benefits are compared to the incremental cost of purchasing EVs and chargers and serving the new utility load. The participant perspective compares the cost of buying, operating, and maintaining an EV to the costs of buying, operating, and maintaining a comparable ICE vehicle (taking into account monetary incentives for EVs). The ratepayer perspective shows the effects of EV adoption on non-EV drivers and is a comparison of the increased costs to utilities in serving new load from EVs versus the revenue collected from EV drivers as they purchase electricity at current rates.

Table 25. Cost Test Categories for Transportation Electrification

Category	Societal Perspective	Participant Perspective	Ratepayer Perspective
Electricity Supply Costs			
Energy Supply	Cost		Cost
Generation Capacity	Cost		Cost
T&D Capacity	Cost		Cost
Losses	Cost		Cost
Ancillary Services	Cost		Cost
Electricity CO_2	Cost		
Electricity Criteria Pollutants	Cost		
Retail Utility Bills			
Retail Bills for EV Charging		Cost	Benefit
EV Costs and Benefits			
Incremental Vehicle Cost	Cost	Cost	
Vehicle O&M Savings	Benefit	Benefit	
Federal Tax Credit	Benefit	Benefit	
State Tax Credit		Benefit	
Gasoline Cost	Benefit	Benefit	
Gasoline State Tax		Benefit	
Gasoline CO_2	Benefit		
Gasoline Criteria Pollutants	Benefit		
Gasoline Security Value	Benefit		
Charging Infrastructure Costs			
Customer Charger & Installation Cost	Cost	Cost	
Utility Charger & Installation Cost	Cost		Cost

4 Results

This analysis focuses on quantifying the costs and benefits associated with EVs sold between 2017 and 2030 in New York State. Because these EVs have an assumed 10-year lifetime, benefits and costs are accrued through 2039. Each cost and benefit produced by the EV Grid Impacts Model is aggregated by year into a stream of nominal values from 2017 to 2039. The present value of the costs and benefits over the period of analysis are calculated using a 3% annual discount rate. The present value costs and benefits in the following passages are levelized to provide results on an annual dollar per-vehicle basis.

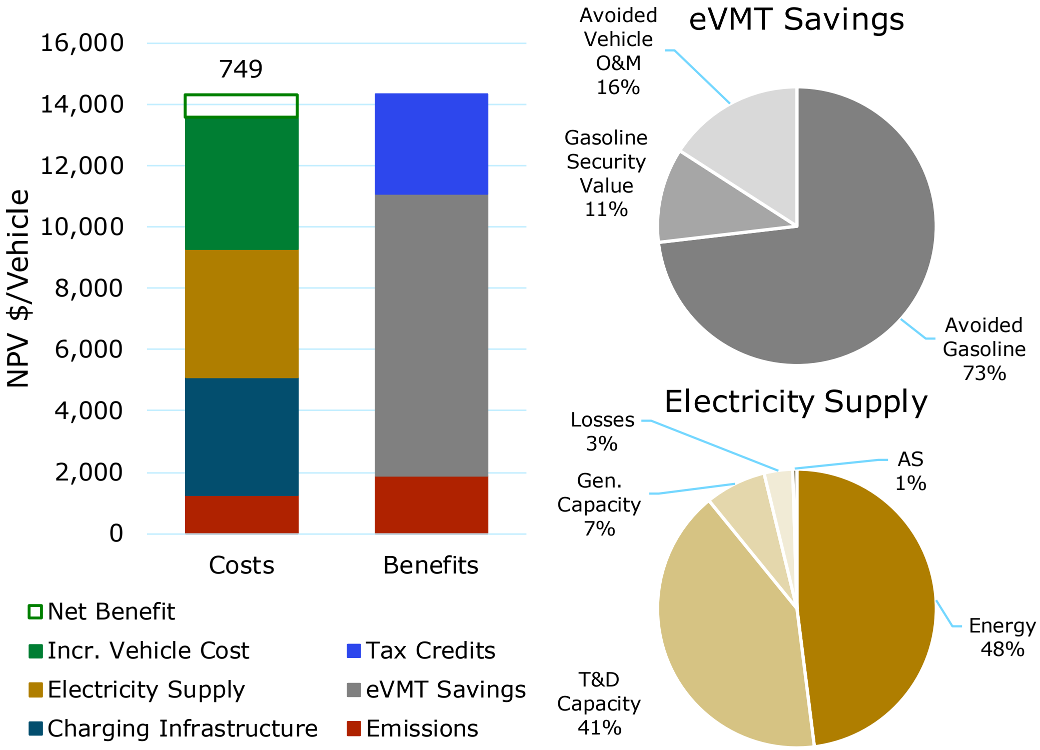
4.1 Metro New York

4.1.1 Societal Perspective Results

4.1.1.1 Base Case

Under Base Case conditions, the EVs adopted in the Metro New York area, which consists of ConEd's service territory, from 2017 to 2030 accrue a net societal benefit of $749 per vehicle over the lifetime of the vehicle. Figure 11 shows the cost and benefit components that produces this result.[57] The current value vehicle cost presented here represents the premium one would pay relative to an internal ICE vehicle. About one third of the costs are made up of this incremental vehicle cost, which emphasizes the importance of EV cost reduction in order to reach adoption goals. The relatively high cost of transmission and distribution (T&D) upgrades in ConEd's service territory contributes to significant portions of the electricity supply and charging infrastructure costs. On the benefits side, the avoided costs of gasoline and O&M, along with the Federal Tax Credit are the main elements that counterbalance the aforementioned costs. The remaining component, emissions, are generated by both electric and gasoline vehicle use, but are a net benefit for EVs in New York State. EVs' incremental electric load increases CO_2 and criteria pollutant emissions costs, but these emissions are more than offset by the avoided emissions costs from lower gasoline consumption.

Figure 11. Societal Perspective Benefits and Costs per EV—Metro New York, Base Case



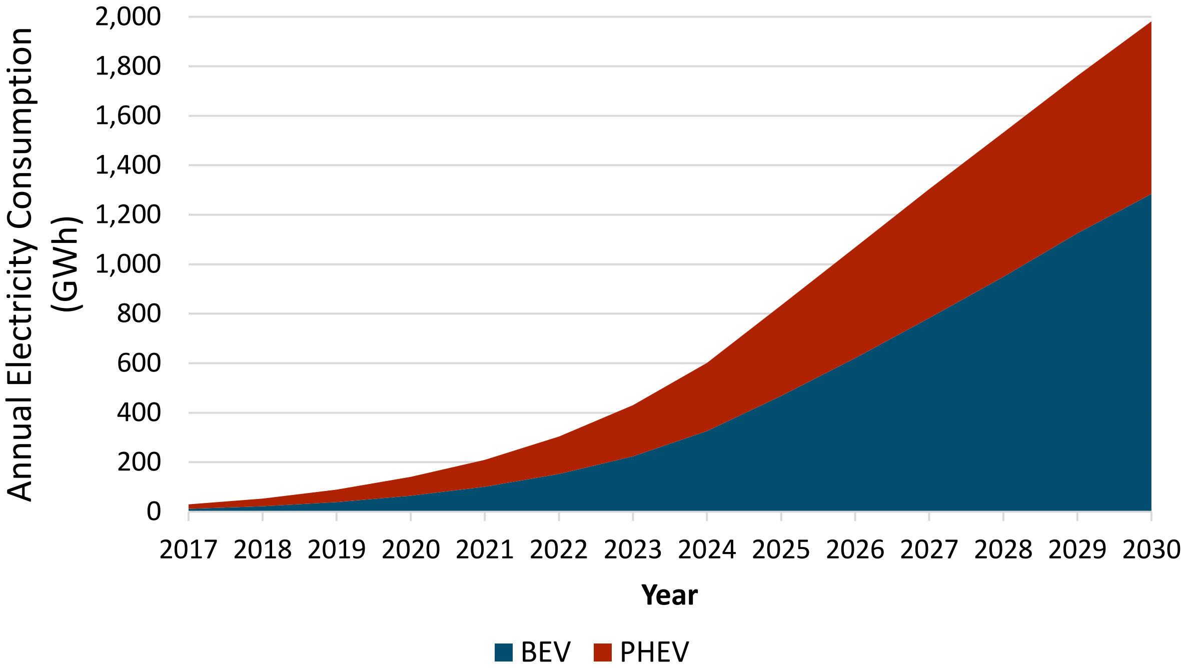
While the replacement of ICE vehicles with EVs decreases emissions from gasoline, electric sector emissions may grow due to the additional load. Table 26 shows the expected net emissions changes over the lifetime of all EVs adopted in Metro New York from 2017 to 2030. Replacing ICEs with EVs in this period avoids the consumption of more than 1.6 billion gallons of gasoline cumulatively, which would have emitted 14.6 million metric tons (MMT) of CO_2 into the atmosphere. Although the additional EV load accounts for the emission of 11.4 MMT of CO_2, the net result is an abatement of 3.2 MMT CO_2. Criteria pollutants more associated with gasoline, such as PM and VOCs, also see a net abatement, but pollutants more endemic to electricity generation, like NO_x and SO_x, may increase on net, depending on the generation mix.

Table 26. Calculated Total Emission Impacts of EV Deployment in Metro New York Region

Pollutant (Metric Tons)	Avoided Gasoline Emissions	Incremental Electric Emissions	Abated Emissions
CO_2	14,620,216	11,370,483	3,249,733
NO_x	3,560	5,811	-2,251
PM	694	292	402
SO_x	148	5,998	-5,850
VOC	7,085	620	6,464

With a forecasted Metro New York population of 2,820 BEVs and 5,725 PHEVs in 2017 growing to 323,333 BEVs and 234,137 PHEVs in 2030, the annual energy consumption of EVs in this region would grow from 30 GWh in 2017 to nearly 2,000 GWh in 2030 (Figure 12). The stacked layers show the annual electricity consumption segmented by BEV and PHEV. Annual EV load shifts from majority PHEV to majority BEV in 2023, reaching 65% BEV by 2030. This is due to both a higher forecasted relative growth in BEV sales compared to PHEV sales as well as the higher per-vehicle annual electricity consumption assumed for BEVs.

Figure 12. Annual Energy Consumption of EVs in Metro New York Region

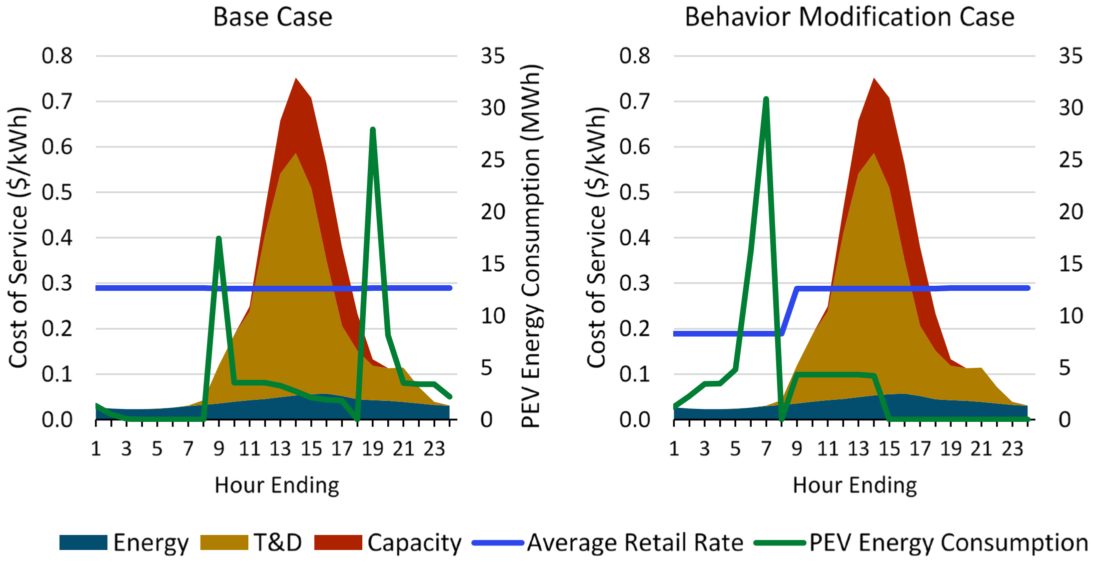


4.1.1.2 Behavior Modification Case

The large load increase described previously has the potential to put immense strains on the electric grid if EVs mainly charge during hours in which the grid is already constrained. To ease this pressure, utilities can develop rate structures or incentive programs that shift this load to off-peak hours. In order to test the cost-benefit impacts of such a program, the team modeled ConEd's SmartCharge New York program, which uses a FleetCarma device to track the time and charging of EVs when in ConEd territory. The program gives rebates to participants when charging during off-peak hours, which is similar to a TOU rate.

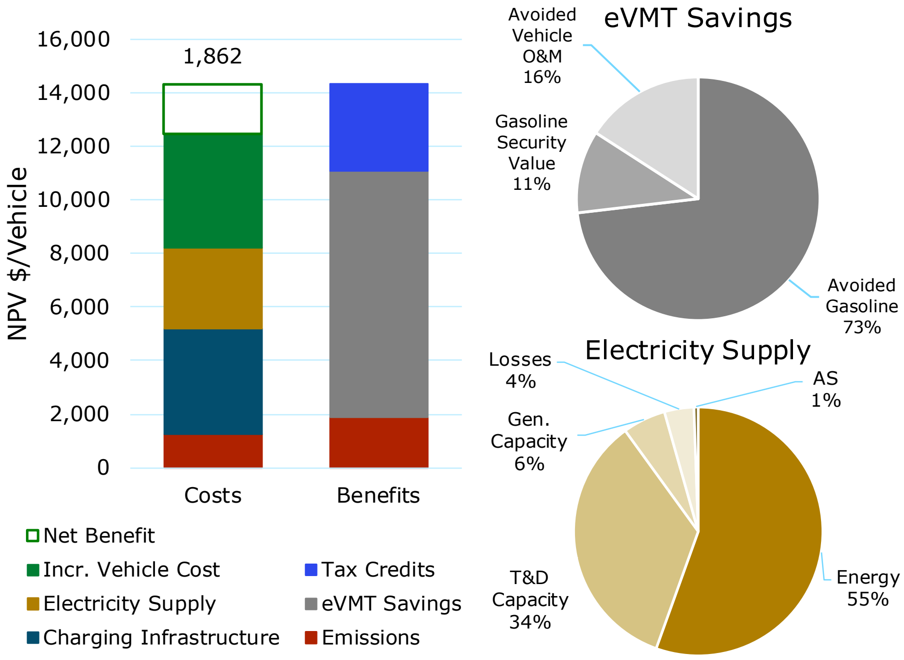
The EV Grid Impacts Model optimizes EV charging to minimize a customer's bill, subject to behavioral and customer preference constraints. Figure 13 presents optimization and billing components of an average summer weekday in the Base and Behavior Modification Cases. The model seeks to shift the load profile to the hours with the lowest cost of charging. In the Base Case, the retail rate is fairly flat, so with no opportunity to charge cheaply, the vehicles charge when most convenient. That is, because rates remain constant all day, the driver opts to recharge the battery immediately after the morning and evening commutes. However, the SmartCharge New York program modeled in the Behavior Modification Case, offers a \$0.10/kWh rebate for charging between midnight and 8 a.m. Much of the shift to charging during these hours is due this offer. ConEd's electricity supply costs are also shown in these charts to show the impact of this charging behavior shift on grid costs. By responding to the SmartCharge New York rate, much of the energy consumption is shifted from hours with moderately high energy and T&D capacity costs in the Base Case to low-cost hours in the Behavior Modification Case.

Figure 13. Load Profile Comparison between Cases for Metro New York Region



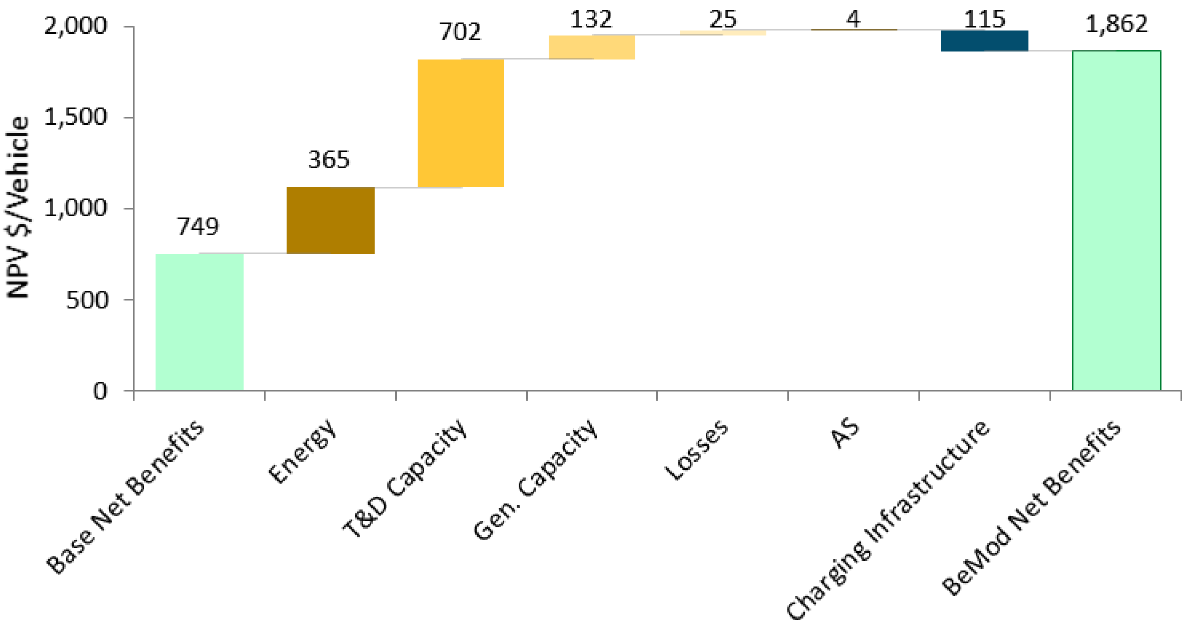
Consequently, electricity supply costs are lowered in the Behavior Modification Case such that present value net societal benefits amount to $1,862 per vehicle—an increase of $1,113 per vehicle over the Base Case.

Figure 14. Societal Perspective Benefits and Costs per EV—Metro New York, Behavior Modification Case



The waterfall chart (Figure 15) shows the differences in net benefit components between the Base and Behavior Modification Cases. Avoided T&D capacity costs provide most of the electricity supply cost savings, followed by energy, generation capacity, losses, and ancillary services. A small net cost reduces these benefits, accounting for technology upgrades to the charging infrastructure to make this smart charging program possible.

Figure 15. Changes in Net Benefit Components between the Base and Behavior Modification Cases

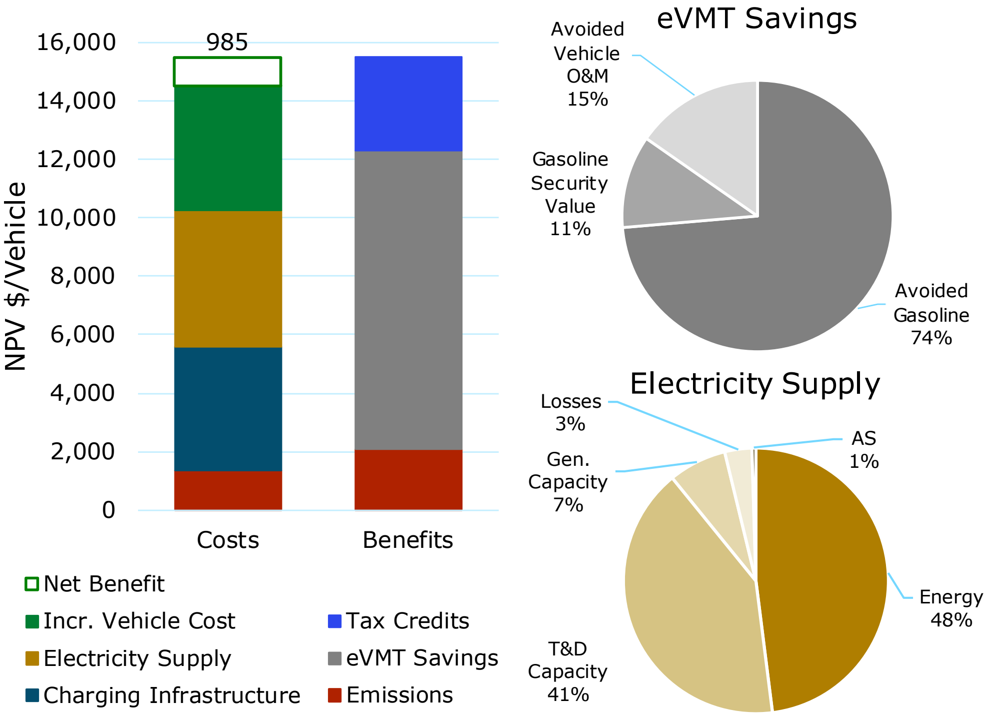


4.1.1.3 High-Infrastructure Case

Stakeholders often cite a lack of charging infrastructure to meet the needs of EV drivers as a potential barrier to EV adoption. Drivers may be deterred from purchasing EVs if they are concerned about running out of charge with no chargers nearby. A higher penetration of DCFCs may help to overcome this barrier to adoption but installing more DCFCs is expensive. The High-Infrastructure (Hi-Infra) Case seeks to gauge whether the net benefits from providing additional charging infrastructure are large enough to offset the added cost of these extra charging stations. To model the benefits of facilitating more EV travel by people without access to home charging and more confidence to drive EVs on trips that may be longer than an EV's electric range, this scenario increased fleetwide eVMT by 10% relative to the Base Case. DCFC penetration in the Base Case scales equally with the vehicle population at 333 BEVs per DCFC. In the High-Infrastructure Case, DCFC penetration starts at the Base Case ratio in 2017 but linearly escalates to 86 BEVs per DCFC by 2030.

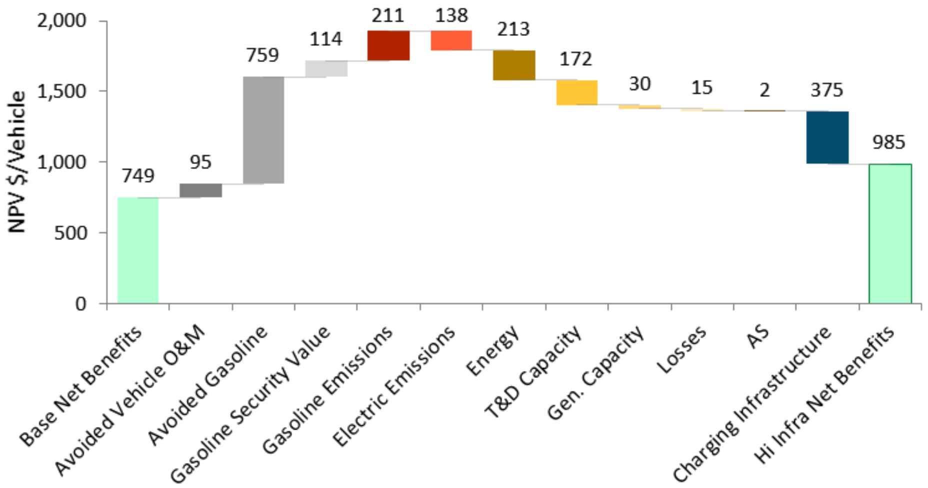
Though there is much interest about the impact DCFC stations can have on EV adoption, the effect is difficult to isolate from other factors and the literature on the subject to date is limited. The team therefore used an assumption of a 10% increase in eVMT to make an illustrative cost-benefit analysis of a high-infrastructure case in which the presence of more DCFC increases EV adoption and eVMT. This approach is somewhat conservative; one study found that a 10% increase in the number of DCFC would lead to an increase in EV adoption of 8.4%.[58] Another found that each additional DCFC station per 100,000 residents would increase its EV market share by 0.12%.[59] Studies also estimate a wide range for the ratio of EVs per DCFC when the market is more mature from as high as 290 EVs per DCFC to as low as 50.[60,61]

Figure 16. Societal Perspective Benefits and Costs per EV—Metro New York, High-Infrastructure Case



The High-Infrastructure Case results in a present value societal net benefit of $985 per vehicle for ConEd. With an increase in eVMT, additional benefits are accrued from avoiding vehicle O&M, gasoline, and gasoline emissions costs, while additional expenses come from electric supply and emissions costs. These eVMT benefits exceed the costs by a significant margin—about $610 per vehicle. With the assumption of a 10% increase in eVMT, the additional benefits are more than large enough to offset the additional costs of the expanded DCFC infrastructure, accumulating a net benefit $235 per vehicle greater than the Base Case.

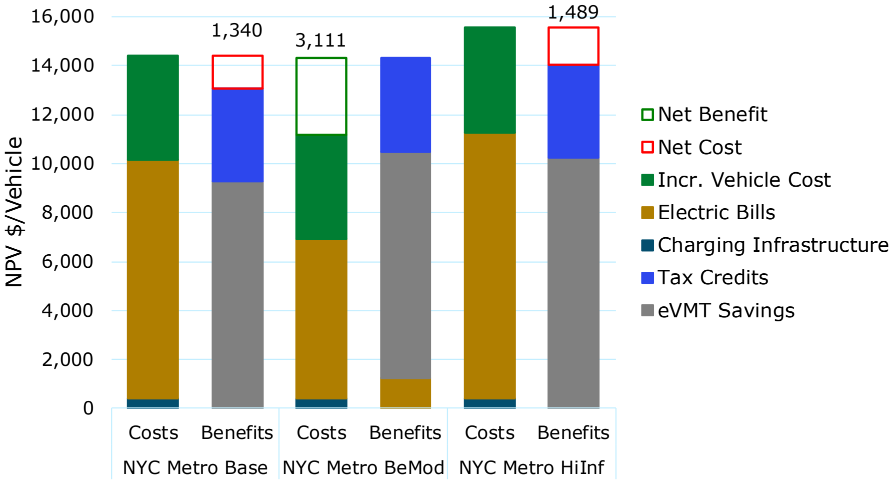
Figure 17. Changes in Net Benefit Components between the Base and High-Infrastructure Cases



4.1.2 Participant Perspective Results

The previous results have shown the benefit-cost calculation from a broad societal perspective, taking into account certain externalities, but the team also quantified net benefits from the perspective of the participant, the EV driver. In addition to the exclusion of emissions and security value externalities in the participant perspective, there are several other key differences. The only charging infrastructure costs borne directly by the participants are for the population segments that have a Level 1 or Level 2 charger at home. Costs of other charging infrastructure are covered to some extent by either public charging or utility retail rates, which make up the electric bill portion of the cost side. On the benefits side, avoided state gasoline taxes are credited to participants, as well as the New York State Drive Clean Rebate, which credits up to $2,000 for the purchase of an EV.

Figure 18. Participant Perspective Benefits and Costs per EV—Metro New York, All Cases



Under the Base Case assumptions, Metro New York EV drivers face a present value net cost of $1,340 per vehicle. The high cost of electricity under non-dynamic retail rates and comparatively inexpensive gasoline costs are the main drivers of this net cost.

However, under ConEd's already implemented SmartCharge New York EV rate program modeled in the Behavior Modification Case, participants face a present value net benefit of $3,111 per vehicle. The program's discounts and rebates shift the default convenience charging behavior to a more grid-friendly load profile that also results in dramatic customer savings. In Figure 18, electric bill components are included on both the costs and benefits sides. The electric bill on the cost side is reduced by $3,233 due to the $0.10/kWh discount for late night charging (midnight to 8 a.m.), while the $1,230 electric bill benefit comes from the program's monthly $5 participation credit and $20 monthly credit for not charging in peak summer hours (weekdays June through September from 2 p.m. to 6 p.m.). After netting out a small increase in smart charging infrastructure costs, the Behavior Modification Case increases present value net benefits by $4,573 per vehicle relative to the Base Case.

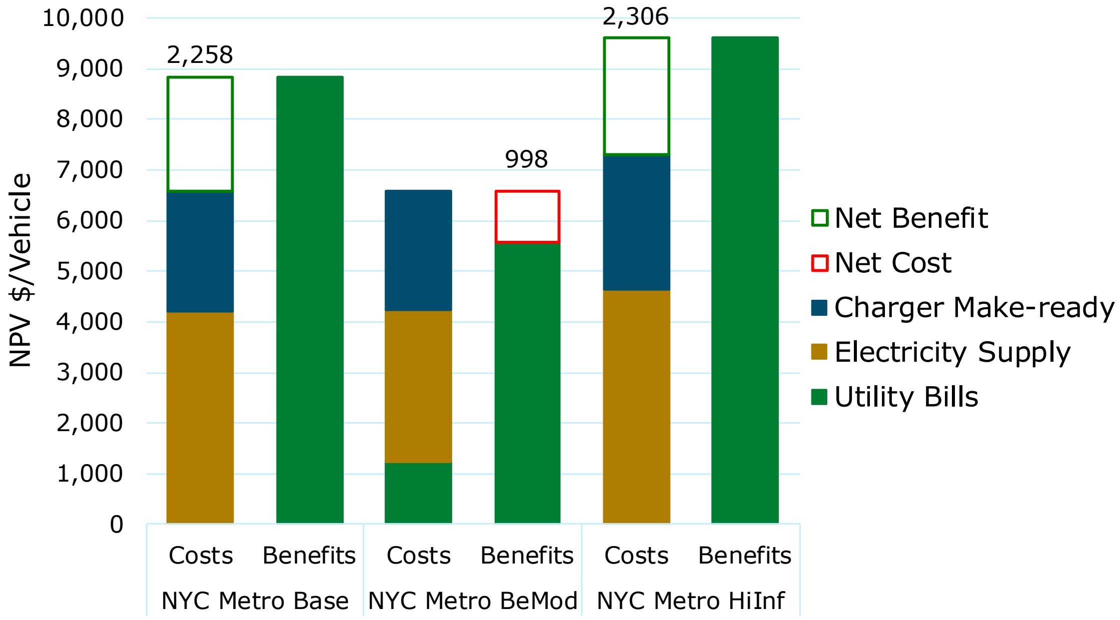
The High-Infrastructure Case faces a present value net cost of $1,489 per vehicle in the Metro New York region. From the participant perspective, changes relative to the Base Case are tied to the increase in eVMT, which consist of higher electric bills, avoided O&M costs, and avoided gasoline costs. Because the incremental avoided O&M and gasoline costs do not offset the incremental electric bills, the per vehicle present value net cost increases by $150 relative to the Base Case.

4.1.3 Ratepayer Perspective Results

The previous results have shown the benefit-cost calculation from a broad societal and participant (or EV driver) perspectives. The ratepayer perspective includes the costs of energy supply (without accounting for the costs from pollutant emissions) and utility infrastructure upgrades that will be required as a result of investments in EV charging infrastructure. Ratepayer perspective also includes the impacts on retail bills (as noted previously) as a function of additional revenue collected from EV charging—and the difference between these costs and revenues is the ratepayer net benefit or cost. For these scenarios, the modeling assumed that the utility would use ratepayer funds to cover the make-ready costs of the charging infrastructure, as discussed above in section 2.3.1. The team reported net benefits in the Base

Case and the High-Infrastructure cases, with a present value net benefit per vehicle exceeding $2,250. In other words, in both the Base Case and High-Infrastructure Case, the increased revenue from EV charging is greater than the costs of accommodating that EV charging and has the potential to put downward pressure on volumetric rates. Similarly, the value could be viewed as the amount that the utility could spend on programs to encourage EV adoption without increasing electric rates.

Figure 19. Ratepayer Perspective Benefits and Costs per EV—Metro New York Region, All Cases



The team reported a net cost to ratepayers in the Behavior Modification Case, with a net present cost of about $1,000 per vehicle. The dramatically different results for this case are reflective of ConEd's existing SmartCharge NY program (described above in section 2.2.1.2). The results reflect an assumption that the parameters of program participation remain unchanged throughout the analysis period, which is likely to not be the case. It is important to note that, despite the fact that the net benefits are negative in the Behavior Modification Case, the behavior modification strategies used in that case are still very successful in reducing electricity supply costs, which are lowest in that case. With small modifications (presumably over time) to the program structure to incentivize behavior modification, the net cost could change to either a net zero cost or a net benefit. Regardless of the net cost, it is noteworthy that the actual electricity supply costs are lowest in this scenario. Note that the costs in this case include a rebate on customers' utility bills, a unique feature of the ConEd program.

One of the main reasons for the reduction in electricity supply costs between the Behavior Modification Case and the other cases is that people with access to workplace charging, which can add load at peak times and trigger expensive upgrades to the electricity system if not controlled, are encouraged to charge overnight instead in the Behavior Modification Case. For those who have access to it, workplace charging is convenient and can be a reasonably priced option for drivers. Because these workplace chargers may be added to the building's existing electric meter, incremental EV load not coincident with the building's peak load would avoid demand charges and be billed at low commercial volumetric rates. While workplace charging is relatively inexpensive for drivers and employers, utility marginal costs of electricity during typical workday hours are considerably higher than other periods. In Metro New York's Base Case, while the incremental utility bills from workplace charging do not cover the marginal electricity costs at that time of day, there are large net benefits from EV drivers charging at other times and locations, generating a net benefit for ratepayers even when the assumption of utility support for make-ready infrastructure is added in. In the BeMod Case, many people choose to charge overnight or before the summer peak period of 2 p.m. to 6 p.m., which helps to reduce the cost of serving EV charging loads. However, the ConEd program achieves these savings by providing both a bill reduction and a further subsidy to EV drivers, which together is larger than the additional cost savings from shifting charging behavior to off-peak hours. It is important to note that different program design choices and other changes to EV charging could substantially improve ratepayer net benefits.

4.2 Long Island

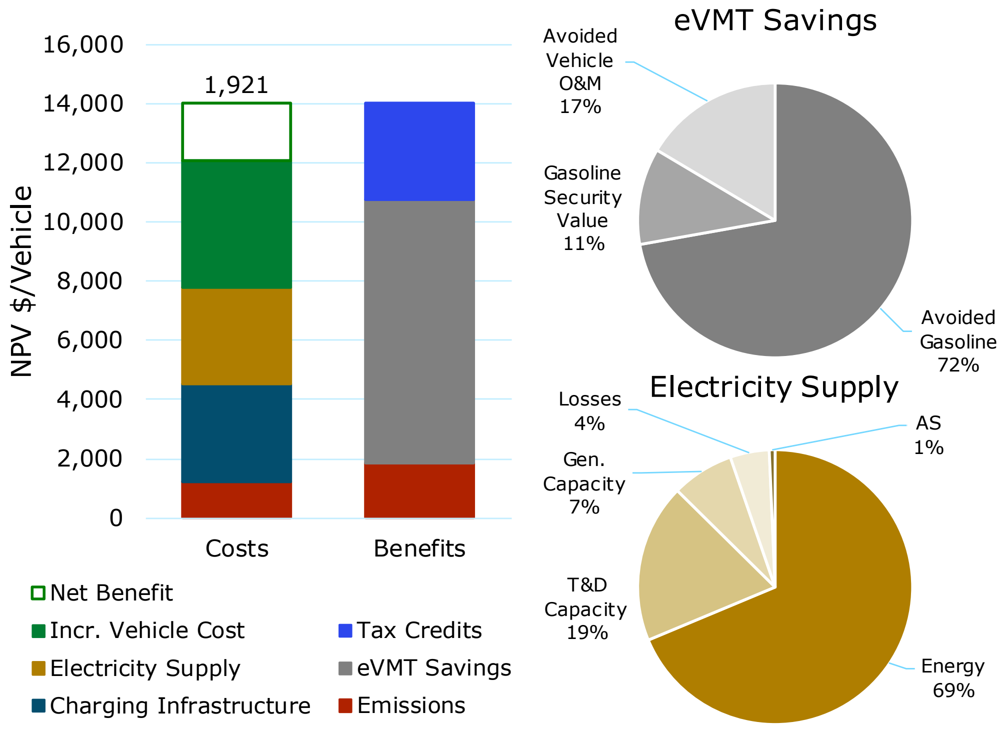
4.2.1 Societal Perspective Results

4.2.1.1 Base Case

Under Base Case conditions, the EVs adopted on Long Island from 2017 to 2030 accrue a net societal benefit of $1,921 per vehicle over the lifetime of the vehicle. Figure 20 shows the cost and benefit components that produce this result. The present value vehicle cost presented here represents the premium one would pay relative to a similar ICE vehicle. About one third of the costs are made up of this incremental vehicle cost, which emphasizes the importance of EV cost reduction in order to reach adoption goals. Energy makes up a majority of Long Island's electricity supply costs. While Long Island's T&D capacity costs are lower than the Metro New York region, this region's constrained island geography and dense population contribute to above average electricity supply and charging infrastructure costs. On the benefits side, the avoided costs of gasoline and O&M are only slightly lower than those in

Metro New York. Because this difference in benefits is exceeded by the difference in electricity supply and charging infrastructure costs, EVs on Long Island see larger societal net benefits per vehicle than Metro New York. The remaining component, emissions, are generated by both electric and gasoline vehicle use, but are a net benefit for EVs. EV charging load increases CO_2 and criteria pollutant emissions costs in the electric sector, but these emissions are more than offset by the avoided emissions costs from lower gasoline consumption.

Figure 20. Societal Perspective Benefits and Costs per EV—Long Island Region, Base Case



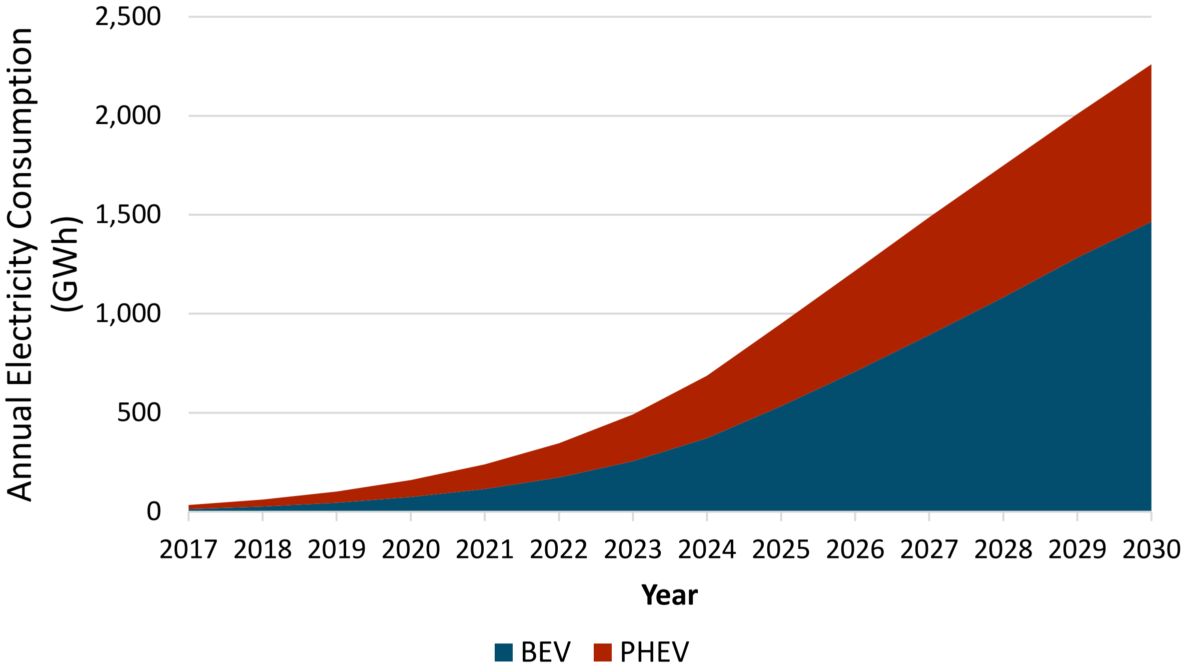
While the replacement of ICE vehicles with EVs decreases emissions from gasoline, electric sector emissions may grow due to the additional load. Table 27 shows the expected changes for net emissions over the lifetime of all EVs adopted in Long Island from 2017 to 2030. Replacing ICEs with EVs in this period avoids the consumption of more than 1.8 billion gallons of gasoline cumulatively, which would have emitted 16.7 MMT of CO_2 into the atmosphere. Although the additional EV load accounts for the emission of 12.9 MMT of CO_2, the net result is an abatement of 3.7 MMT CO_2. Criteria pollutants more associated with gasoline, such as PM and VOCs, also see a net abatement, but pollutants more endemic to electricity generation, like NO_x and SO_x, may increase on net, depending on the generation mix.

Table 27. Calculated Total Emission Impacts of EV Deployment in Long Island Region

Pollutant (Metric Tons)	Avoided Gasoline Emissions	Incremental Electric Emissions	Abated Emissions
CO_2	16,676,779	12,943,227	3,733,551
NO_x	4,061	6,615	-2,554
PM	792	333	459
SO_x	169	6,828	-6,659
VOC	8,081	706	7,375

With a forecasted Long Island population of 3,217 BEVs and 6,530 PHEVs in 2017 growing to 368,814 BEVs and 267,073 PHEVs in 2030, the annual energy consumption of EVs on Long Island would grow from 35 GWh in 2017 to nearly 2,300 GWh in 2030. Figure 21 shows the annual energy consumption of EVs adopted between 2017 and 2030. The stacked layers show the annual electricity consumption segmented by EV type (PHEV/BEV). Annual forecasted EV load shifts from majority PHEV to majority BEV in 2022, reaching 65% BEV by 2030. This is due to both a relative growth in forecasted BEV sales compared to PHEV sales as well as the higher per-vehicle annual electricity consumption inherent to BEVs.

Figure 21. Annual Energy Consumption of EVs in Long Island Region

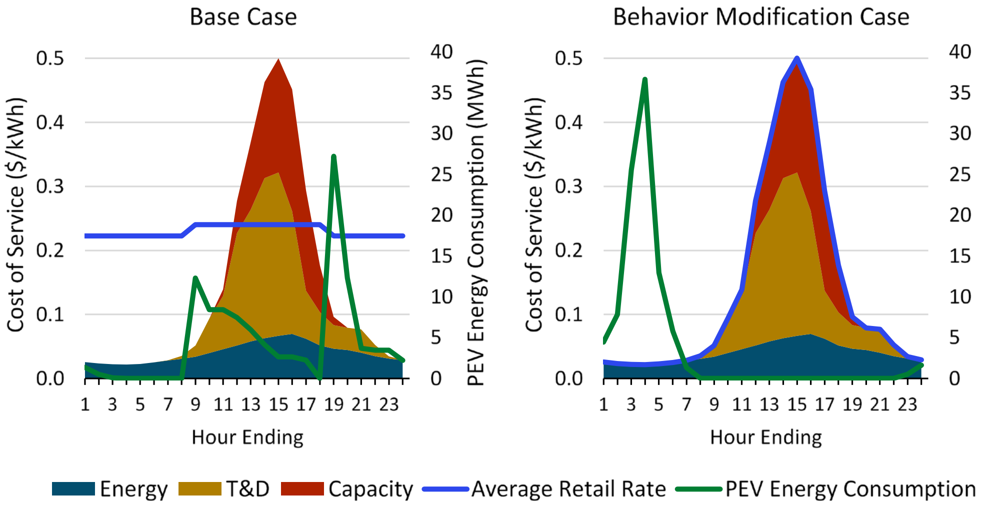


4.2.1.2 Behavior Modification Case

The large load increase described previously has the potential to put immense strains on the electric grid if EVs mainly charge during hours in which the grid is already constrained. To ease this pressure, utilities can develop rate structures or incentive programs that shift this load to off-peak hours. In order to determine the maximum benefits that could result from such a program, the team developed a Behavior Modification Case in which the model optimizes EV charging load according to the utility's marginal electricity costs. This differs from the Metro New York Behavior Modification Case, which optimizes charging load against an existing managed charging program. Instead, the Long Island Behavior Modification Case represents a bookend approach, estimating the potential savings in electricity costs relative to the Base Case.

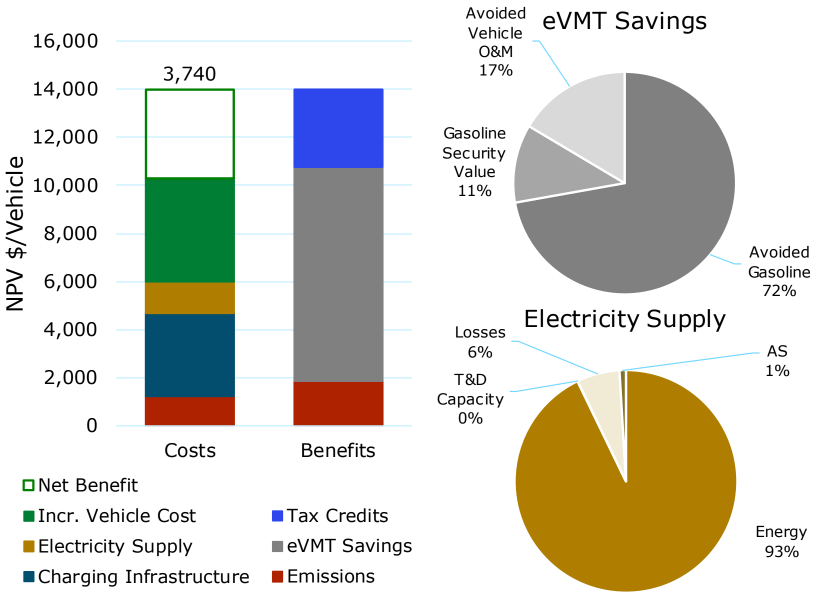
The EV Grid Impacts Model optimizes EV charging to minimize a customer's bill, subject to behavioral and customer preference constraints. Figure 22 presents optimization and billing components of an average summer weekday in the Base and Behavior Modification Cases. Because the Long Island Behavior Modification Case perfectly aligns the electricity costs of the driver and the utility, the retail rate matches the sum of marginal electricity costs. The model seeks to shift the load profile to the hours with both the lowest electricity supply cost and lowest retail rate. In the Base Case, the retail rate is fairly flat, so with little difference in charging costs throughout the day, the vehicles charge when most convenient. That is, because rates remain fairly constant all day, the driver opts to recharge the battery immediately after the morning and evening commutes. However, in the Behavior Modification Case, the rates are set to the marginal electricity costs, which change on an hourly basis throughout the year. These marginal costs can vary significantly over the course of a day, especially during times of the year when generation, transmission, and/or distribution capacities are already constrained by peak-load conditions. In the Behavior Modification Case, the model responds to these cost signals by opting to charge the vehicles during low-cost evening hours and avoiding the midday system peaks whenever possible. The model still shows some midday charging when necessary to reach a driver's next destination, but only when it is essential.

Figure 22. Sample Load Profile Comparison between Cases for Long Island Region



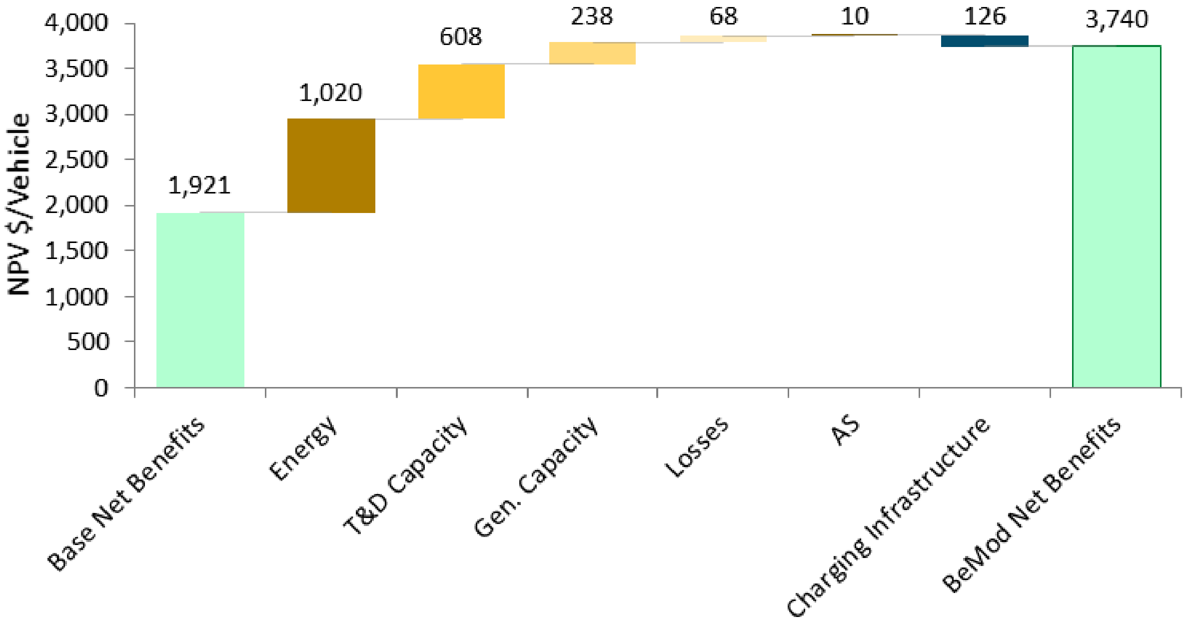
Through this optimal distribution of EV charging load, electricity supply costs are lowered in the Behavior Modification Case such that present value net societal benefits total $3,740 per vehicle—an increase of $1,819 per vehicle over the Base Case. In this scenario, additional T&D capacity costs and generation capacity costs associated with increased EV adoption are dramatically lower than in the Base Case because most charging is not concurrent with peak system demand. This provides a significant opportunity for societal savings compared to the Base Case.

Figure 23. Societal Perspective Benefits and Costs per EV—Long Island Region, Behavior Modification Case



The waterfall chart (Figure 24) shows the differences in net benefit components between the Base and Behavior Modification Cases. Avoided energy costs account for the largest portion of the additional benefits, followed up by T&D capacity, generation capacity, losses, and ancillary services. A small cost associated with technology upgrades to the charging infrastructure reduces net benefits but is necessary to make the smart charging program possible.

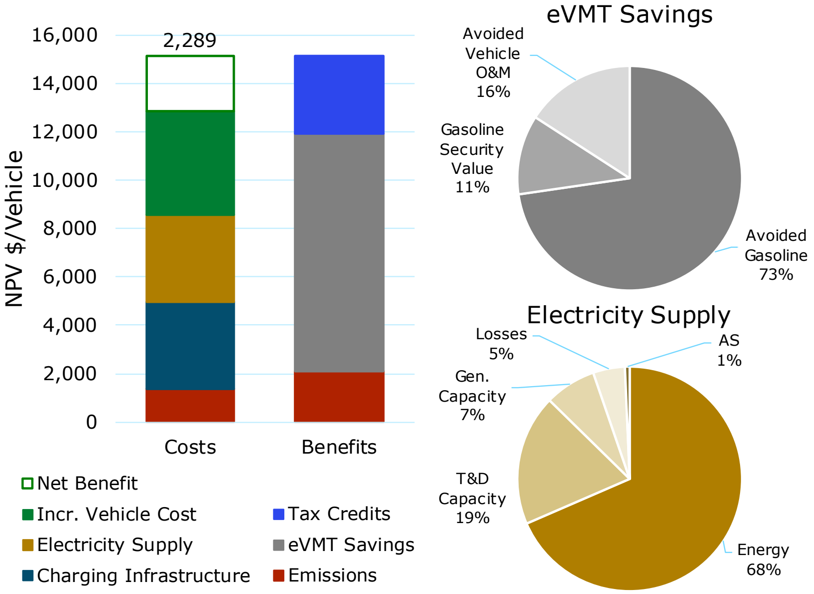
Figure 24. Changes in Net Benefit Components between the Base and Behavior Modification Cases



4.2.1.3 High-Infrastructure Case

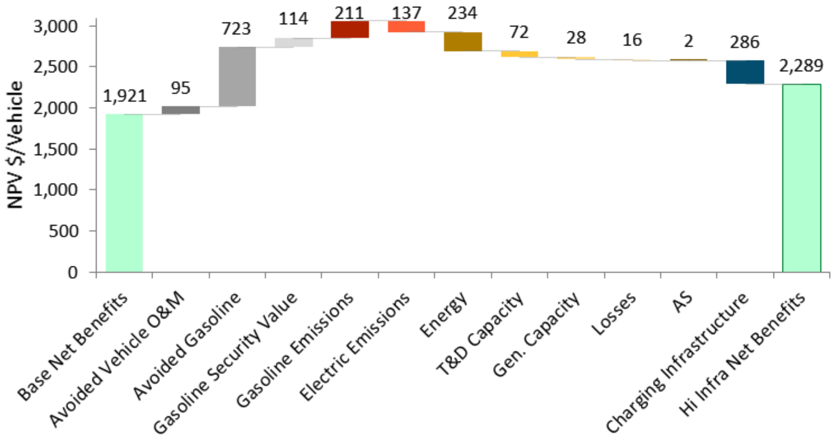
Stakeholders often cite a lack of charging infrastructure to meet the needs of EV drivers as a potential barrier to EV adoption. Drivers may be deterred from purchasing EVs if they are concerned about running out of charge with no chargers nearby. A higher penetration of DCFCs may help to overcome this barrier to adoption but installing more DCFCs is expensive. The High-Infrastructure (Hi-Infra) Case seeks to gauge whether the net benefits from providing additional charging infrastructure are large enough to offset the added cost of these extra charging stations. To model the benefits of facilitating more EV travel by people without access to home charging and more confidence to drive EVs on trips that may be longer than an EV's electric range, this scenario increased fleetwide eVMT by 10% relative to the Base Case. DCFC penetration in the Base Case scales equally with the vehicle population at 333 BEVs per DCFC. In the High-Infrastructure Case, DCFC penetration starts at the Base Case ratio in 2017 but linearly escalates to 86 BEVs per DCFC by 2030.

Figure 25. Societal Perspective Benefits and Costs per EV—Long Island Geography, High-Infrastructure Case



The High-Infrastructure Case results in a present value societal net benefit of $2,289 per vehicle for Long Island. With an increase in eVMT, additional societal benefits are accrued from avoiding vehicle O&M, gasoline, and gasoline emissions costs, while additional costs come from electric supply and emissions costs from increased electricity generation. These eVMT benefits exceed the costs by a significant amount—about $654 per vehicle. The additional benefits are more than large enough to offset the additional costs of the expanded DCFC infrastructure, accumulating a net benefit $368 per vehicle greater than the Base Case.

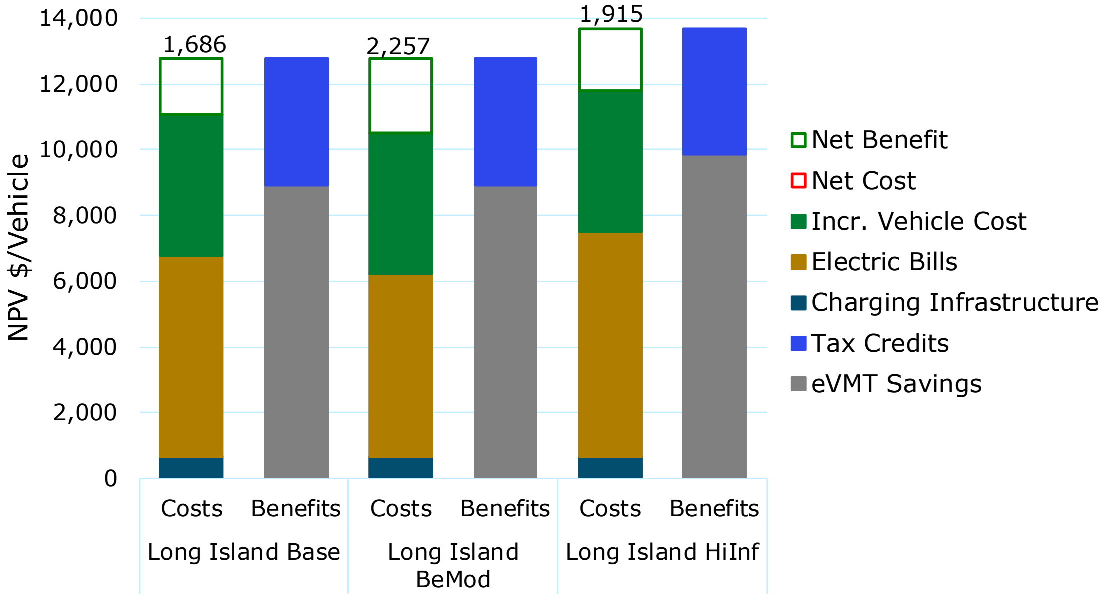
Figure 26. Changes in Net Benefit Components between the Long Island Base and High-Infrastructure Cases



4.2.2 Participant Perspective Results

The previous results have shown the benefit-cost calculation from a broad societal perspective, taking into account certain externalities, but the team also quantified net benefits from the perspective of the participant, the EV driver. In addition to the exclusion of emissions and security value externalities in the participant perspective, there are several other key differences. The only charging infrastructure costs borne directly by the participants are for the population segments that have a Level 1 or Level 2 charger at home. Costs of other charging infrastructure are covered to some extent by either public charging or utility retail rates, which make up the electric bill portion of the cost side. On the benefits side, the participant is credited with avoiding the full pump cost of gasoline—including State taxes, as well as with the New York State Drive Clean Rebate, which gives an incentive of up to $2,000 for the purchase of an EV.

Figure 27. Participant Perspective Benefits and Costs per EV—Long Island Region, All Cases



Under the Base Case assumptions, Long Island EV drivers face a present value net benefit of $1,686 per vehicle. A large portion of the participant benefits come from avoiding paying the a bove-average costs of gasoline and vehicle O&M on Long Island. While static Base Case electric rates may offset driver benefits for some population segments, resulting in a break-even or net cost, drivers with access to workplace charging enjoy larger net benefit margins. Workplace charging may be less expensive for drivers for two reasons. First, the employer may provide charging at discounted, free, or cost-based rates. Second, workplace EV chargers are often co-metered with the existing building load so that incremental EV load would be billed at a low volumetric commercial rate and minimally contribute to the demand charge. To reflect this, workplace charging in this study is modeled with the utility's commercial rate with an 80% reduction to the demand rate. (See section 2.2.1.3 for more information.) Because this workplace charging contingent makes up a sizable portion of Long Island EV drivers (42%), their large net benefits combine with the moderate net benefits of the remaining population—for a sizeable net benefit overall.

This Base Case net benefit is augmented further when charging is optimized against an idealized marginal cost-based electric rate in the Behavior Modification Case. These optimized charging profiles are then subjected to the electricity rates the driver would pay, which differ from the Base Case for residential charging. EVs are billed with PSEG Long Island's TOU rate when charging at home. Because this TOU rate is more aligned with the utility system costs that went into the Behavior Modification Case charging optimization, electric bills are lower than those in the Base Case. That is, optimizing charging to electric system costs shifts load from immediately after the evening commute to off-peak times in the middle of the night, when TOU rates are lowest. This results in a present value net benefit of $2,257 per vehicle in the Behavior Modification Case—an increase of $571 per vehicle relative to the Base Case.

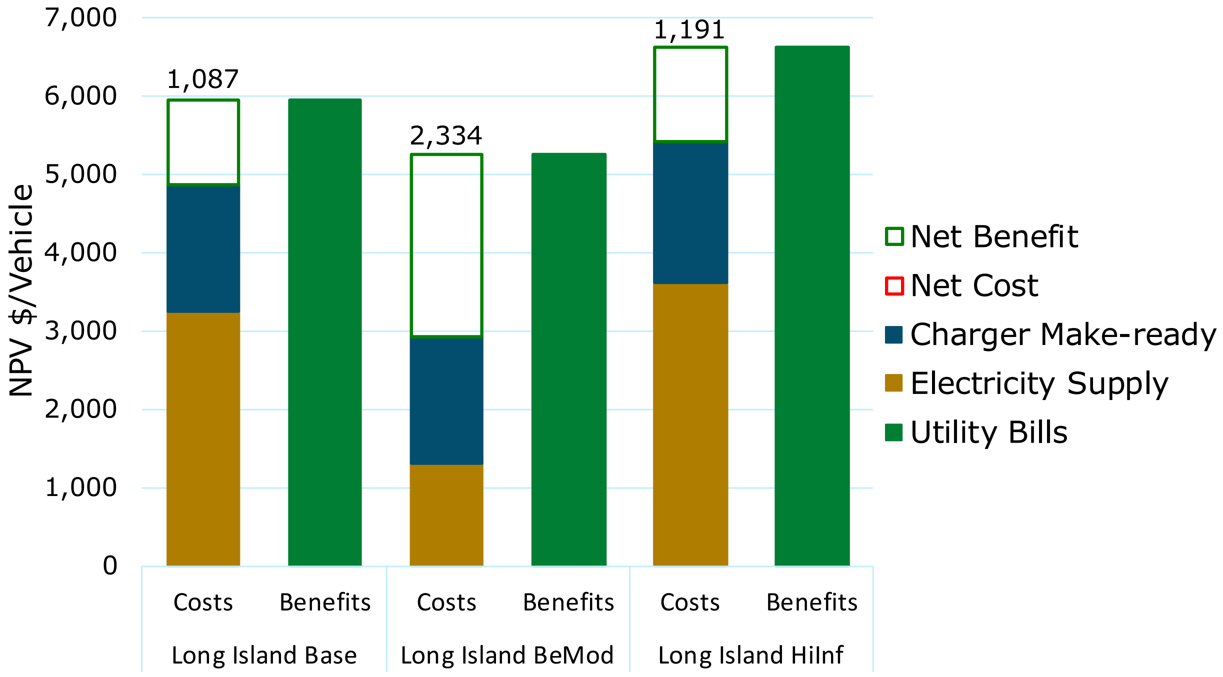
While ConEd's SmartCharge New York program uses a device that provides incentives to charge off peak regardless of location, residential TOU rates can only incentivize smart charging during the hours the vehicle is at home. A location-bound TOU rate may be effective in aligning participant and utility costs for drivers where residential charging is the cheapest or only option but may be insufficient for drivers who lack access to home charging or who have access to workplace charging. In the latter instances, other incentive structures may need to be considered to disincentivize peak-time charging.

The High-Infrastructure Case results in a net present value benefit for the driver of $1,915 per vehicle in Long Island. From the participant perspective, changes relative to the Base Case are tied to the increase in eVMT, which consist of higher electric bills, avoided O&M costs, and avoided gasoline costs. Because the additional avoided O&M and gasoline costs more than offset the additional electric bills, the per vehicle present value net benefit increases by $228 relative to the Base Case.

4.2.3 Ratepayer Perspective Results

The previous results for Long Island have shown the benefit-cost calculation from a broad societal and participant (or EV driver) perspectives. The ratepayer perspective includes the costs of energy supply (without accounting for the costs from pollutant emissions) and utility infrastructure upgrades that will be required as a result of investments in EV charging infrastructure; it also includes the impacts on retail bills (as noted previously) as a function of additional revenue collected from EV charging. And the difference between these costs and revenues is the ratepayer net benefit or cost. For these scenarios, the modeling assumed that the utility would use ratepayer funds to cover the make-ready costs of the charging infrastructure, as discussed above in section 2.3.1. The team reported net benefits across all three cases for Long Island—ranging from $1,100 net present benefit per vehicle in the Base Case up to $2,300 net present benefit per vehicle in the Behavior Modification Case. In other words, in all three cases modeled for Long Island, the increased revenue from EV charging is greater than the costs of accommodating that EV charging and has the potential to put downward pressure on volumetric rates. Similarly, the value could be viewed as the amount that the utility could spend on programs to encourage EV adoption without increasing electric rates.

Figure 28. Ratepayer Perspective Benefits and Costs per EV, Long Island Region—All Cases



The energy supply costs are drastically reduced in the Behavior Modification Case, and without substantive changes to the charger make-ready cost component, the net revenue from additional EV charging yields significant potential benefits to ratepayers. Furthermore, the higher electricity supply costs in the High-Infrastructure Case are offset by higher revenues, thereby maintaining the benefits observed in the Base Case.

One of the main reasons for the difference between the Behavior Modification Case and the other cases is that people with access to workplace charging—which can add load at peak times and trigger expensive upgrades to the electricity system if not controlled—are encouraged to charge overnight instead in the Behavior Modification Case. For those who have access to it, workplace charging is convenient and can be a reasonably priced option for drivers. Because these workplace chargers may be added to the building's existing electric meter, incremental EV load not coincident with the building's peak load would avoid demand charges and be billed at low commercial volumetric rates. While workplace charging is relatively inexpensive for drivers and employers, utility marginal costs of electricity during typical workday hours are considerably higher than other periods. In Long Island's Base Case, incremental utility bills do not cover the marginal electricity costs of workplace charging, but even when the assumption of utility support for make-ready infrastructure is added in, these RIM net costs are more than compensated for by the large net benefits from EV drivers who charge at other locations. Because EVs in the BeMod Case are minimizing charging costs based on a TOU rate that presents very low overnight charging costs, drivers who charged at work during the day in the Base Case mostly switch to charging during low-cost evening hours at home (or public chargers when needed) in the BeMod Case. For this reason, the net ratepayer impacts are even larger in the BeMod Case. While this represents a bookend case, it is important to consider how to design rates to minimize the grid costs of workplace charging without overly inconveniencing a large share of drivers.

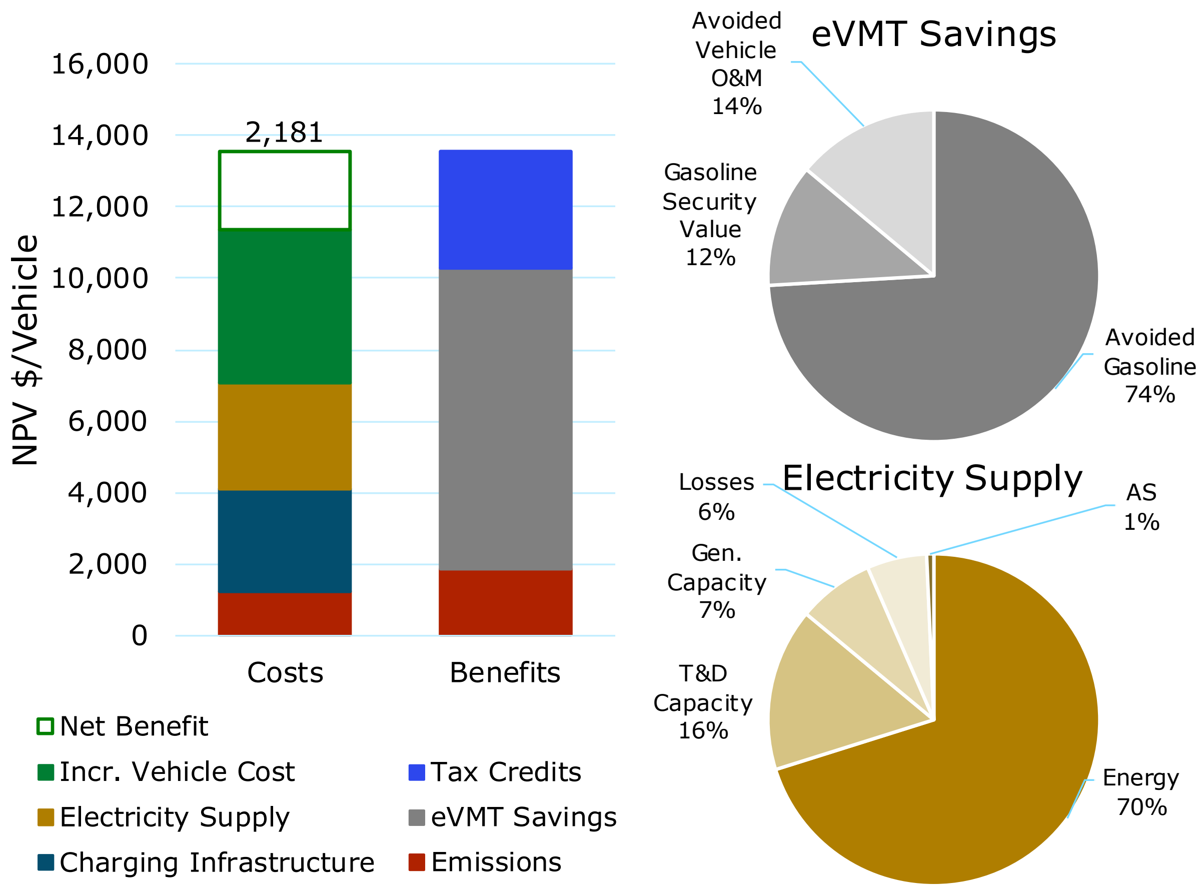
4.3 Upstate New York

4.3.4 Societal Perspective Results

4.3.4.1 Base Case

Under Base Case conditions, the EVs adopted in Upstate New York from 2017 to 2030 accrue a net societal benefit of $2,181 per vehicle over the lifetime of the vehicle. Figure 29 shows the cost and benefit components that produce this result. The present value vehicle cost presented here represents the premium one would pay relative to a similar ICE vehicle. About one third of the costs are made up of this incremental vehicle cost, which emphasizes the importance of EV cost reduction in order to reach adoption goals. Energy makes up a majority of Upstate New York's electricity supply costs. Relative to the other two regions, Upstate New York has lower electricity supply and charging infrastructure costs. On the benefits side, the avoided costs of gasoline and O&M are also lower than those in Metro New York and Long Island. Upstate New York EVs see larger societal net benefits per vehicle than the other two regions because the savings from not driving gasoline cars are close to what they are downstate, but the costs of driving EVs are significantly lower Upstate New York. The remaining component, emissions, are generated by both electric and gasoline vehicle use but are a net benefit for EVs. EV charging load increases CO_2 and criteria pollutant emissions costs, but these emissions are more than offset by the avoided emissions costs from lower gasoline consumption.

Figure 29. Societal Perspective Benefits and Costs per EV—Upstate Region, Base Case



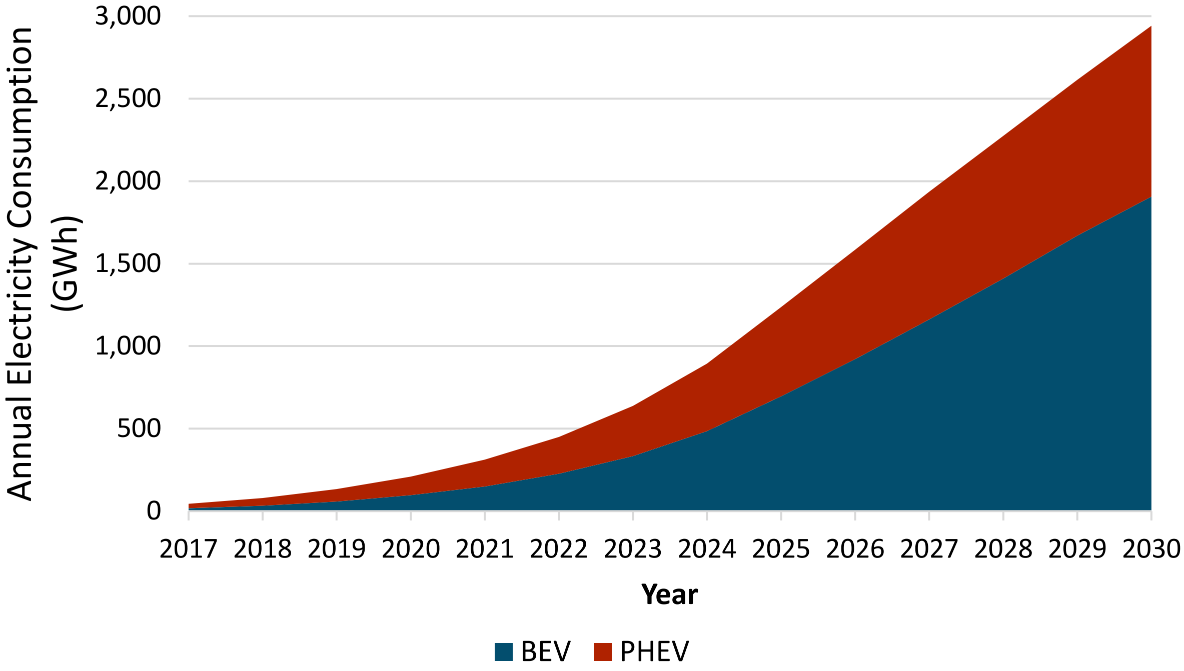
While the replacement of ICE vehicles with EVs decreases emissions from gasoline, electric sector emissions may grow due to the additional load. Table 28 shows the expected net emissions changes over the lifetime of all EVs adopted in Upstate New York from 2017–2030. Replacing ICEs with EVs in this period avoids the consumption of more than 2.4 billion gallons of gasoline cumulatively, which would have emitted 21.7 MMT of CO_2 into the atmosphere. Although the additional EV load accounts for the emission of 17.1 MMT of CO_2, the net result is an abatement of 4.6 MMT CO_2. Criteria pollutants more associated with gasoline, such as PM and VOCs, also see a net abatement, but pollutants more endemic to electricity generation, like NO_x and SO_x, may increase on net, depending on the generation mix.

Table 28. Calculated Total Emission Impacts of EV Deployment in Upstate New York Region

Pollutant (Metric Tons)	Avoided Gasoline Emissions	Incremental Electric Emissions	Abated Emissions
CO_2	21,707,142	17,103,379	4,603,763
NO_x	5,286	8,741	-3,456
PM	1,031	439	591
SO_x	220	9,022	-8,803
VOC	10,519	933	9,586

With a forecasted Upstate New York population of 4,189 BEVs and 8,502 PHEVs in 2017 growing to 480,061 BEVs and 347,630 PHEVs in 2030, the annual electricity consumption of EVs in Upstate New York would grow from 45 GWh in 2017 to 2,942 GWh in 2030. Figure 30 shows the annual electricity consumption of EVs adopted between 2017 and 2030. The stacked layers show the annual electricity consumption segmented by EV type (PHEV/BEV). Annual forecasted EV load shifts from majority PHEV to majority BEV in 2022, reaching 65% BEV by 2030. This is due to both a relative growth in forecasted BEV sales compared to PHEV sales as well as the higher per-vehicle annual electricity consumption inherent to BEVs.

Figure 30. Annual Energy Consumption of EVs in Upstate New York Region

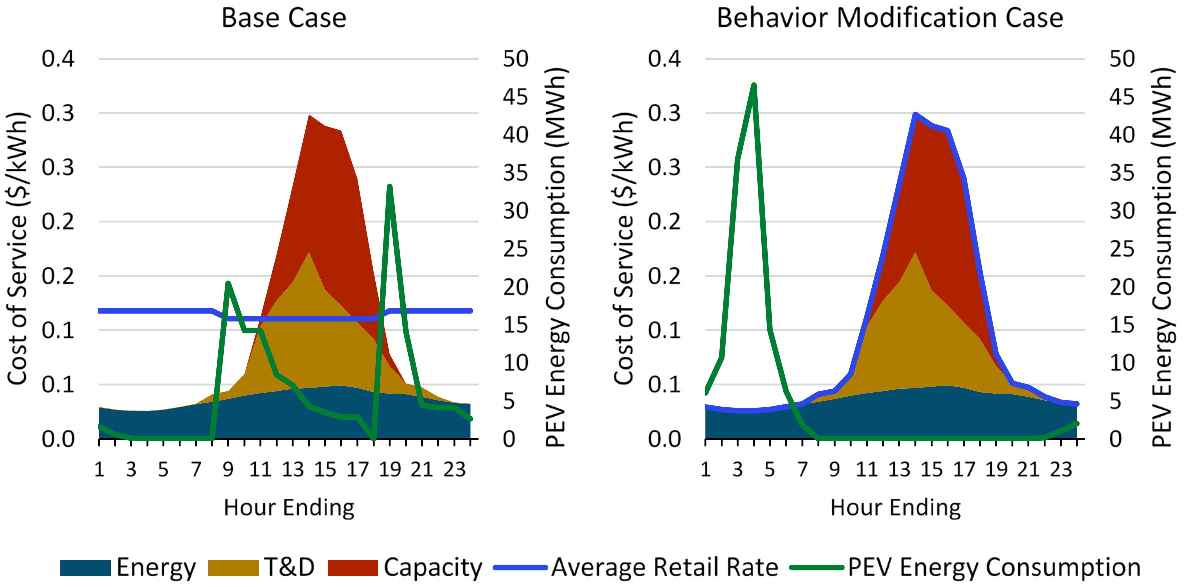


4.3.4.2 Behavior Modification Case

The large load increase described above has the potential to put immense strains on the electric grid if EVs mainly charge during hours in which the grid is already constrained. To ease this pressure, utilities can develop rate structures or incentive programs that shift this load to off-peak hours. In order to determine the maximum benefits that could result from such a program, the team developed a Behavior Modification Case in which the model optimizes EV charging load according to the utility's marginal electricity costs. This differs from the Metro NY Behavior Modification Case, which optimizes charging load against an existing managed charging program. Instead, the Upstate New York Behavior Modification Case (like the Long Island Behavior Modification Case) represents a bookend approach, estimating the potential savings in electricity costs relative to the Base Case.

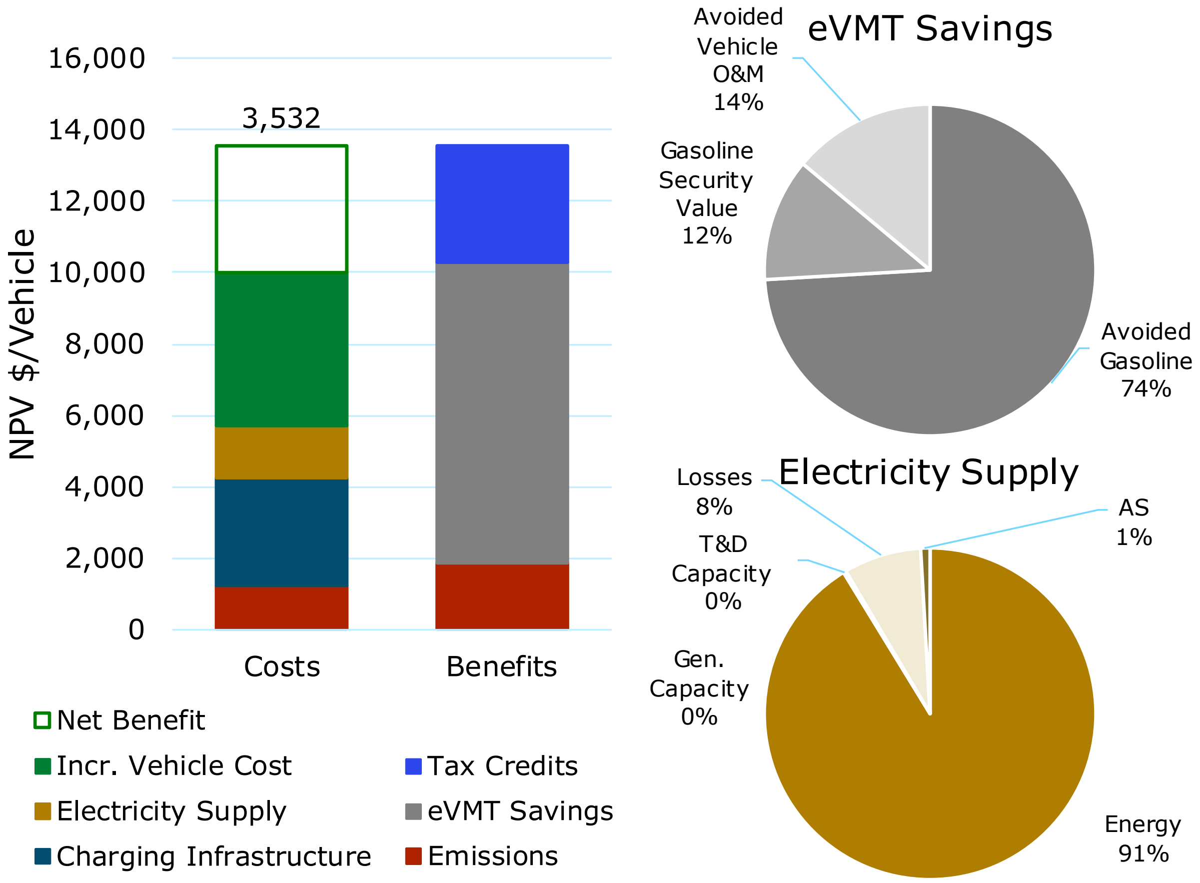
The EV Grid Impacts Model optimizes EV charging to minimize a customer charging cost, subject to behavioral and customer preference constraints. Figure 31 presents optimization and billing components of an average summer weekday in the Base and Behavior Modification Cases. Because the Upstate New York Behavior Modification Case perfectly aligns the electricity costs of the driver and the utility, the retail rate matches the sum of marginal electricity costs. The model seeks to shift the load profile to the hours with both the lowest electricity supply cost and lowest retail rate. In the Base Case, the retail rate is fairly flat, so with little difference in charging costs throughout the day, the vehicles charge when most convenient. That is, because rates remain fairly constant all day, the driver opts to recharge the battery immediately after the morning and evening commutes. However, in the Behavior Modification Case, the rates are set to the marginal electricity costs, which change on an hourly basis throughout the year. These marginal costs can vary significantly over the course of a day, especially during times of the year when generation, transmission, and/or distribution capacities are already constrained by peak-load conditions. In the Behavior Modification Case, the model responds to these cost signals by opting to charge the vehicles during low-cost evening hours and avoid the midday system peaks.

Figure 31. Sample Load Profile Comparison between Cases for Upstate New York Region



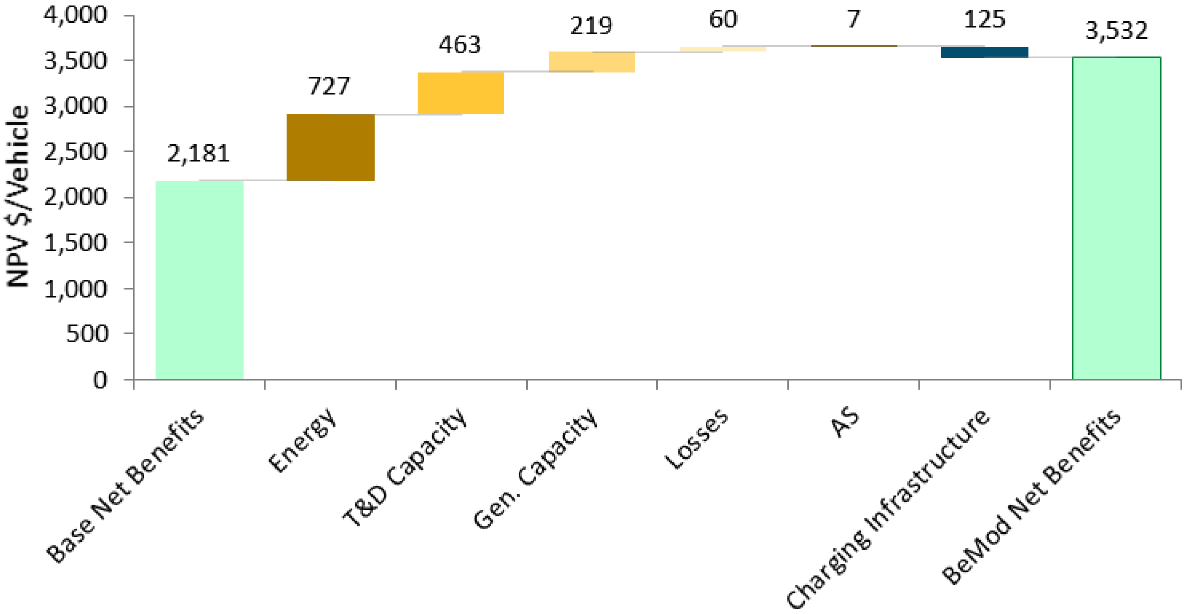
Through this optimal distribution of EV charging load, electricity supply costs are lowered in the Behavior Modification Case such that present value net societal benefits amount to $3,532 per vehicle— an increase of $1,351 per vehicle over the Base Case.

Figure 32. Societal Perspective Benefits and Costs per EV—Upstate New York Region, Behavior Modification Case



The waterfall chart (Figure 33) shows the differences in net benefit components between the Base and Behavior Modification Cases. Avoided energy costs make up most of the additional benefits, followed up by T&D capacity, generation capacity, losses, and ancillary services. A small net cost reduces these benefits, accounting for technology upgrades to the charging infrastructure to make this smart charging program possible.

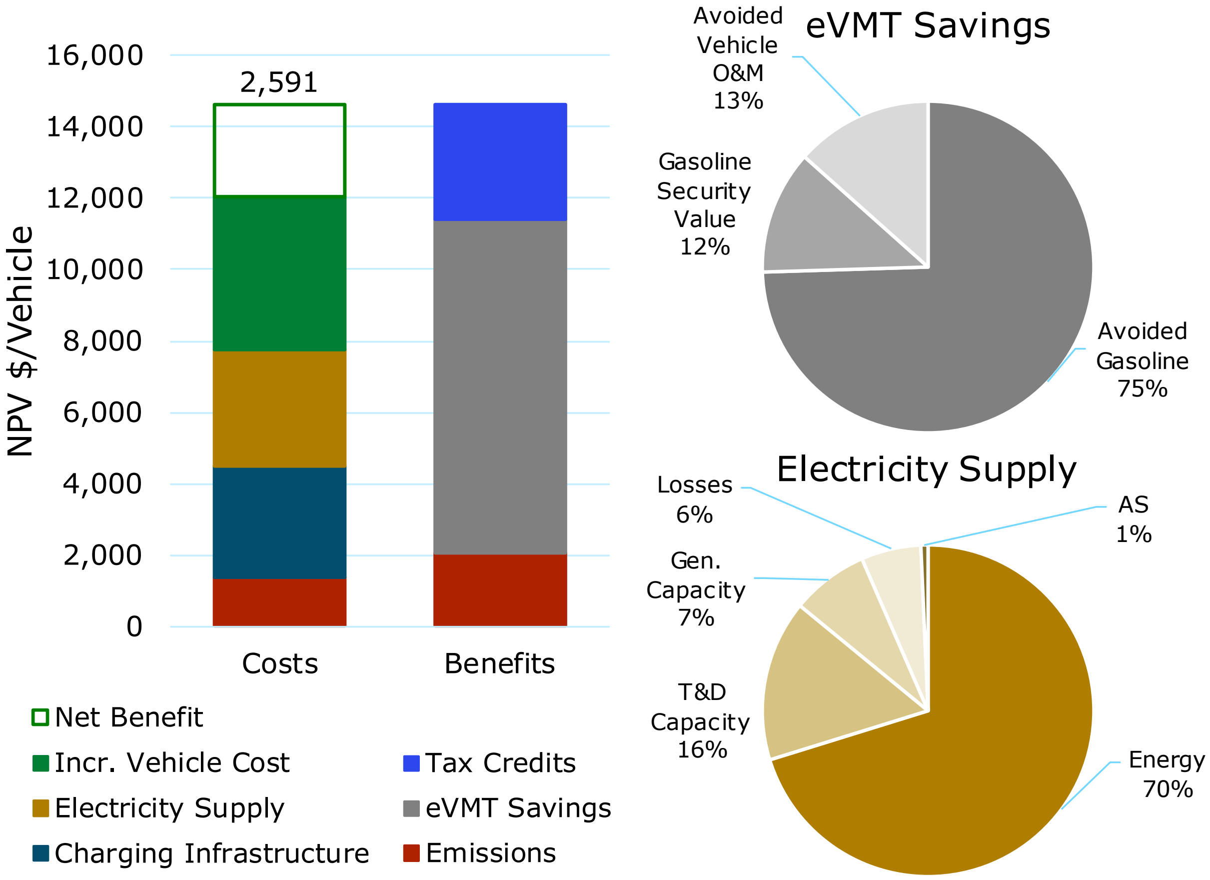
Figure 33. Changes in SCT Net Benefit Components between the Base and Behavior Modification Cases, Upstate New York



4.3.4.3 High-Infrastructure Case

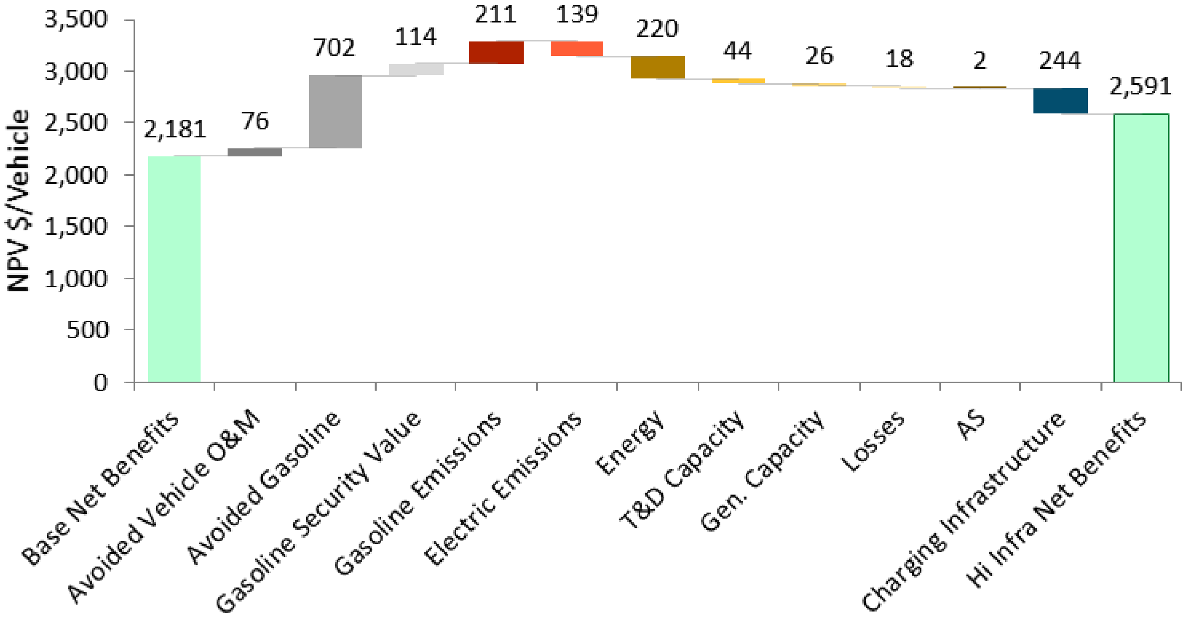
Stakeholders often cite a lack of charging infrastructure to meet the needs of EV drivers as a potential barrier to EV adoption. Drivers may be deterred from purchasing EVs if they are concerned about running out of charge with no chargers nearby. A higher penetration of DCFCs may help to overcome this barrier to adoption but installing more DCFCs is expensive. The High-Infrastructure (Hi-Infra) Case seeks to gauge whether the net benefits from providing additional charging infrastructure are large enough to offset the added cost of these extra charging stations. To model the benefits of facilitating more EV travel by people without access to home charging and more confidence to drive EVs on trips that may be longer than an EV's electric range, this scenario increased fleetwide eVMT by 10% relative to the Base Case. DCFC penetration in the Base Case scales equally with the vehicle population at 333 BEVs per DCFC. In the High-Infrastructure Case, DCFC penetration starts at the Base Case ratio in 2017 but linearly escalates to 86 BEVs per DCFC by 2030.

Figure 34. Societal Perspective Benefits and Costs per EV—Upstate New York Region, High-Infrastructure Case



The High-Infrastructure Case results in a present value societal net benefit of $2,591 per vehicle for Upstate New York. With an increase in eVMT, additional benefits are accrued from avoiding vehicle O&M, gasoline, and gasoline emissions costs, while additional costs come from electric supply and emissions costs. These eVMT benefits exceed the costs by a significant amount—about $653 per vehicle. These benefits are more than large enough to offset the additional costs of the expanded DCFC infrastructure, accumulating a net benefit $410 per vehicle greater than the Base Case.

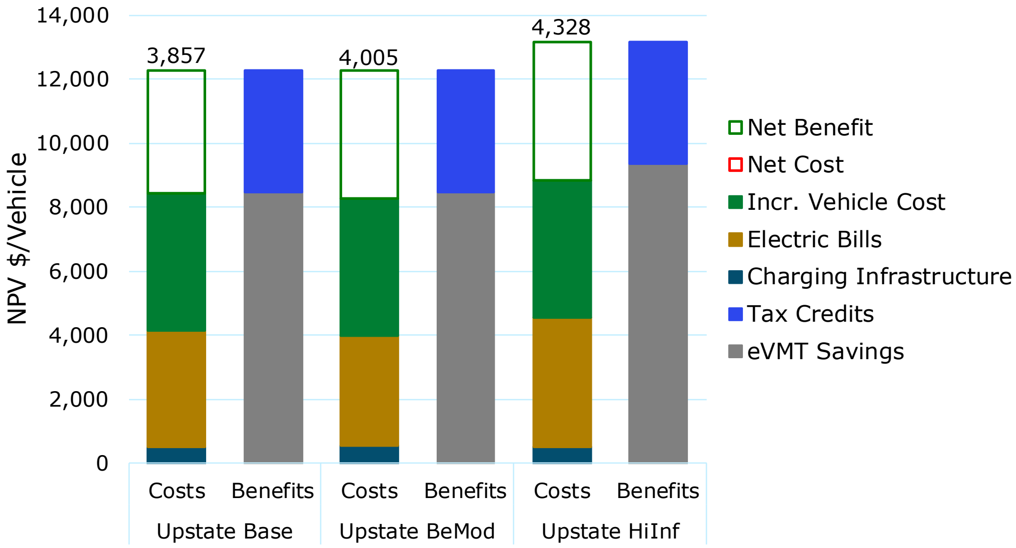
Figure 35. Changes in Net Benefit Components between the Upstate New York Base and High-Infrastructure Cases



4.3.5 Participant Perspective Results

The previous results have shown the benefit-cost calculation from a broad societal perspective, taking into account certain externalities, but the team also quantified net benefits from the perspective of the participant, the EV driver. In addition to the exclusion of emissions and security value externalities in the participant perspective, there are several other key differences. The only charging infrastructure costs borne directly by the participants are for the population segments that have a Level 1 or Level 2 charger at home. Costs of other charging infrastructure are covered to some extent by either public charging or utility retail rates, which make up the electric bill portion of the cost side. On the benefits side, the participant is credited with avoiding the full pump cost of gasoline—including State taxes, as well as with the New York State Drive Clean Rebate, which gives an incentive of up to $2,000 for the purchase of an EV.

Figure 36. Participant Perspective Benefits and Costs per EV—Upstate New York Region, All Cases



Under the Base Case assumptions, Upstate New York EV drivers face a present value net benefit of $3,857 per vehicle. Participant benefits consist of the avoided costs of gasoline and vehicle O&M and low electric rates. This combination of factors in Upstate New York ensures that eVMT savings are more than double the additional cost of electricity associated with driving EVs in this part of the Sstate.

This Base Case net benefit is augmented further when charging is optimized against an idealized marginal cost-based electric rate in the Behavior Modification Case. These optimized charging profiles are then subjected to the electricity rates the driver would pay, which differ from the Base Case for residential charging: EVs are billed with National Grid's TOU rate when charging at home. Because this TOU rate is more aligned with the utility system costs that went into the Behavior Modification Case charging optimization, electric bills are lower than those in the Base Case. That is, optimizing charging to electric system costs shifts load from immediately after the evening commute to off-peak times in the middle of the night, when TOU rates are lowest. This results in a present value net benefit of $4,005 per vehicle in the Behavior Modification Case—an increase of $148 per vehicle relative to the Base Case.

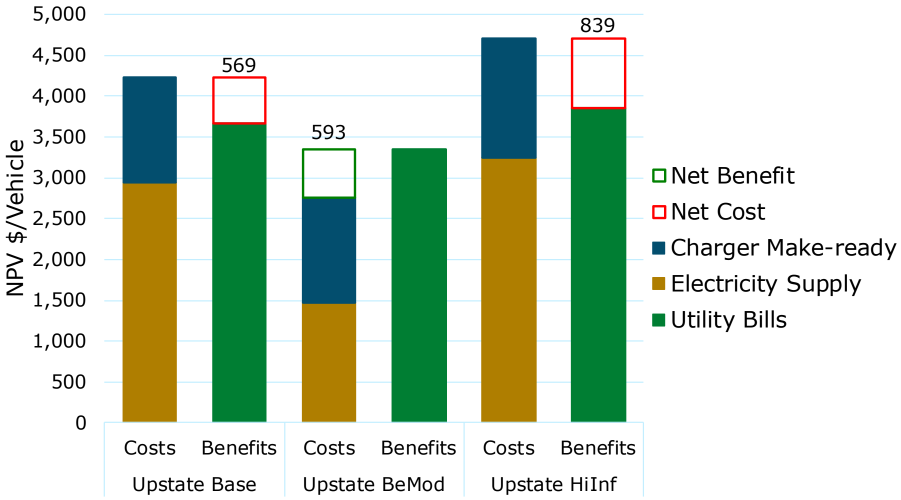
While ConEd's SmartCharge New York program uses a device that provides incentives to charge off peak regardless of location, residential TOU rates can only incentivize smart charging during the hours the vehicle is at home. A location-bound TOU rate may be effective in aligning participant and utility costs for drivers where residential charging is the cheapest or only option but may be insufficient for drivers who lack access to home charging or who have access to workplace charging. In the latter instances, other incentive structures may need to be considered to disincentivize peak-time charging.

The High-Infrastructure Case results in a net present value benefit for the driver of $4,328 per vehicle in Upstate New York. From the participant perspective, changes relative to the Base Case are tied to the increase in eVMT, which would result in higher electric bills that are more than offset by additional avoided gasoline and O&M costs. Because the additional avoided O&M and gasoline costs more than offset the higher electric bills, the per-vehicle present value net benefit increases by $471 relative to the Base Case.

4.3.6 Ratepayer Perspective Results

The previous results for Upstate New York have shown the benefit-cost calculation from a broad societal and participant (or EV driver) perspectives. The ratepayer perspective includes the costs of energy supply (without accounting for the costs from pollutant emissions) and utility infrastructure upgrades that will be required as a result of investments in EV charging infrastructure; it also includes the impacts on retail bills (as noted previously) as a function of additional revenue collected from EV charging. And the difference between these costs and revenues is the ratepayer net benefit or cost. For these scenarios, the modeling assumed that the utility would use ratepayer funds to cover the make-ready costs of the charging infrastructure, as discussed above in section 2.3.1. The team reports net costs for the Base Case and the High-Infrastructure Case in Upstate New York—with net present costs per vehicle of about $570 and $840, respectively. In the Behavior Modification Case, the team reports a net present benefit per vehicle of about $590. The electricity supply costs for both the Base Case and, for instance, High-Infrastructure Case make up a greater share of the total costs than in the Long Island example. In this case, although the actual electricity supply costs are lower than in other regions, the electric rates are also lower, thereby yielding a result in which the additional revenue from EV charging does not cover the additional costs tied to deploying EVs and EV charging infrastructure. This leads to a net cost for both the Base Case and the High-Infrastructure Case. However, the Behavior Modification Case demonstrates that even modest intervention via time-based rates, incentives, or managed charging can help generate a net benefit for ratepayers.

Figure 37. Ratepayer Perspective Benefits and Costs per EV, Upstate New York Region—All Cases

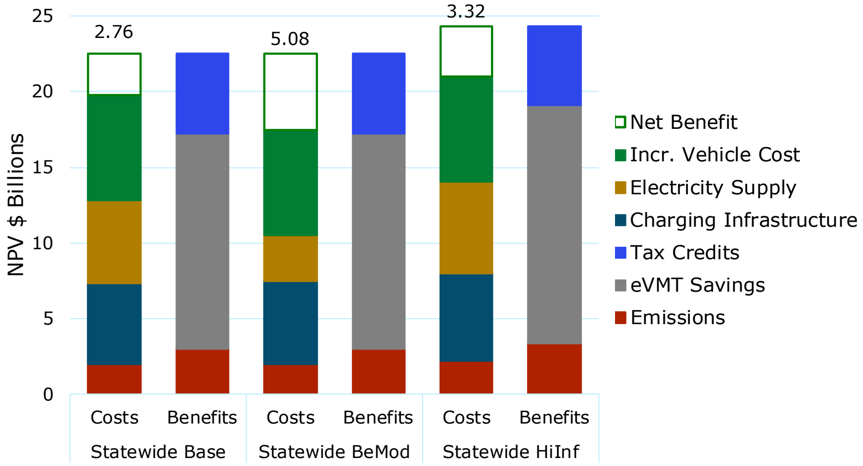


One of the main reasons for the difference between the Behavior Modification Case and the other cases is that people with access to workplace charging—which can add load at peak times and trigger expensive upgrades to the electricity system if not controlled—are encouraged to charge overnight instead in the Behavior Modification Case. For EV drivers who have access to it, workplace charging is convenient and can be a reasonably priced option for drivers. Because these workplace chargers may be added to the building's existing electric meter, incremental EV load not coincident with the building's peak load would avoid demand charges and be billed at low-commercial volumetric rates. While workplace charging is relatively inexpensive for drivers and employers, utility marginal costs of electricity during typical workday hours are considerably higher than other periods. In Upstate New York's Base Case, incremental utility bills do not cover the marginal electricity costs of utilities serving workplace charging loads, resulting in a RIM net cost for vehicles charging at work. When the assumption of utility support for make-ready infrastructure is added in, these added costs outweigh the added ratepayer benefits of higher utility bill collections from all EV charging. Because EVs in the BeMod Case are minimizing charging costs based on a TOU rate that presents very low overnight charging costs, drivers who charged at work during the day in the Base Case mostly switch to charging during low-cost evening hours at home or public chargers in the BeMod Case. For this reason, the net ratepayer impacts are positive in the BeMod Case. While this represents a bookend case, it is important to consider how to design rates to minimize the grid costs of workplace charging without overly inconveniencing a large share of drivers.

4.4 Statewide

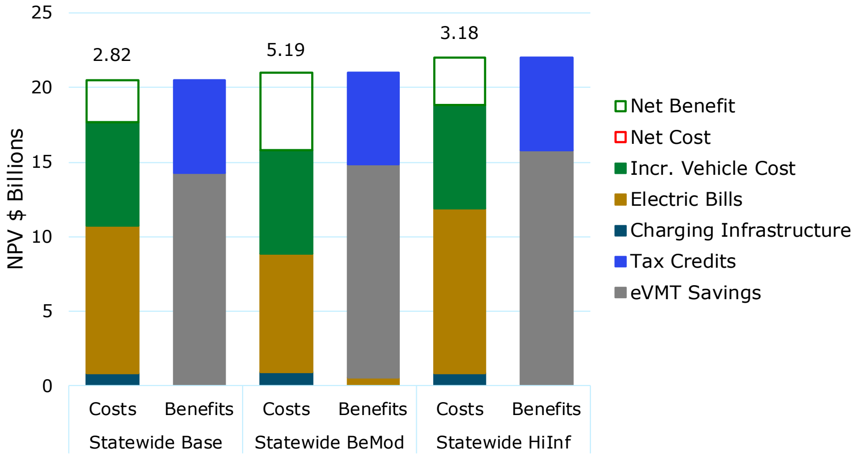
Aggregating the results of the three regions to a statewide level, the net present value of benefits from EV adoption in New York State (from 2017 to 2030) to meet the ZEV MOU target in the Base Case is $2.76 billion from the societal perspective. Smart charging in the Behavior Modification Case nearly doubles the benefits to $5.08 billion. With both higher charging infrastructure costs and higher eVMT in the High-Infrastructure Case the net benefits are $3.32 billion, $560 million higher than in the Base Case.

Figure 38. Net Societal Impact of EV Adoption: Statewide Results



The participant (or driver) benefits at the statewide level are of a similar magnitude to the societal benefits. The net benefits in the Base Case are $2.82 billion. With smart charging in the Behavior Modification Case the net benefits increase to $5.19 billion. The participant benefits for the High-Infrastructure case are $3.18 billion.

Figure 39. Net Participant Impact of EV Adoption: Statewide Results



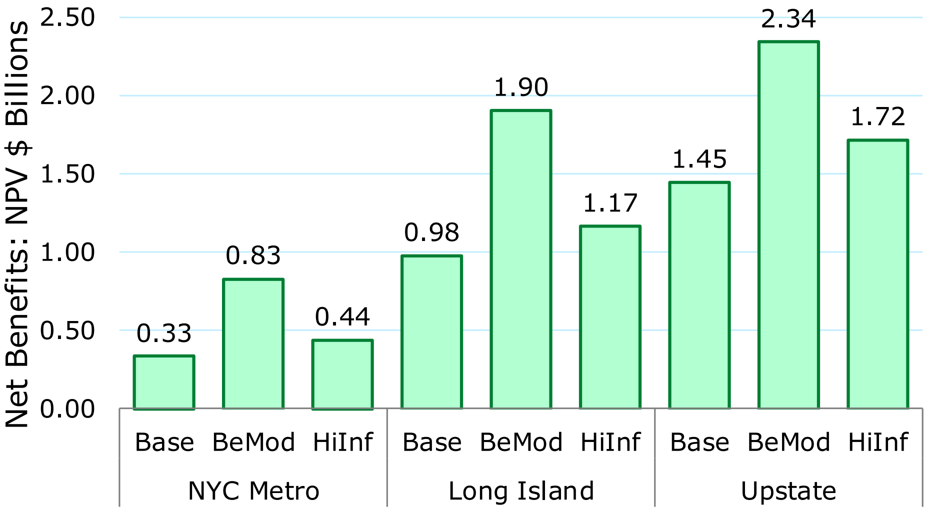
5 Conclusions and Next Steps

5.1 Implications of Results for Utilities, New York State, and Other Stakeholders

5.1.1 Electric Vehicles Provide Significant Societal Benefits across New York State

Net societal benefits are positive for every case and region (Figure 40). The NPV of societal benefits ranges from $2.8 billion to $5.1 billion in aggregate for the State (Figure 38). Avoided gasoline and O&M costs, collectively referred to as eVMT savings, outweigh the cost of charging EVs and account for most of the benefits of EV adoption.

Figure 40. Net Societal Impact of EV Adoption by Region and Case



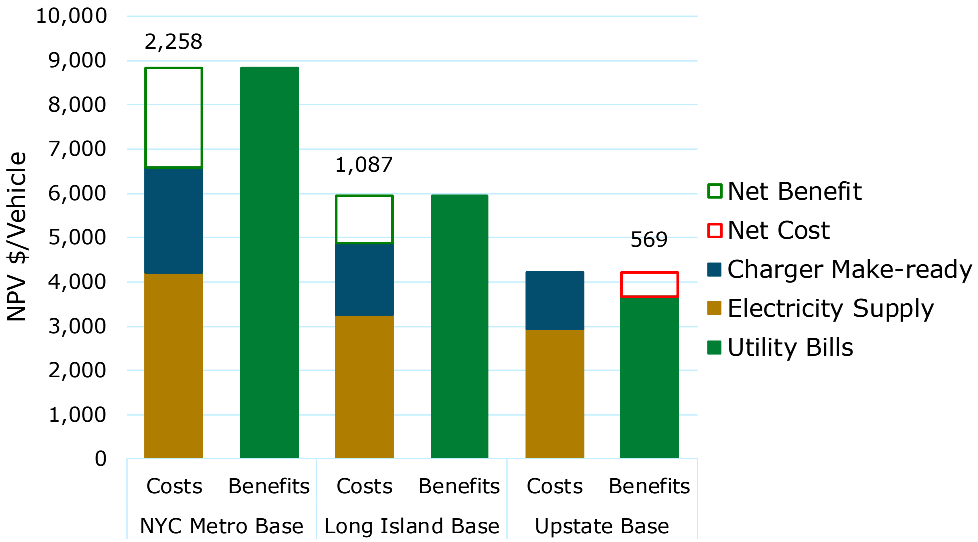
5.1.2 Smart Charging Reduces Grid Upgrade and Energy Costs, Increasing Societal Net Benefits

The statewide and regional Behavior Modification (BeMod) cases show that smart charging can significantly reduce electricity supply costs, further improving the economics of EV adoption (Figures 38 and 40). Savings arise from delaying distribution and system capacity upgrades to accommodate EV charging, as well as from charging vehicles during off-peak hours when energy is less costly. Utilities and regulators have numerous options to implement smart charging, including direct control of charging by utilities or third parties, time-varying electricity rates that encourage off-peak charging, or incentives to charge during periods when the marginal cost of electricity is lowest.

5.1.3 EV Adoption Yields Ratepayer Benefits

In all regions the revenues from EV charging exceed the marginal cost (electricity supply) of serving that load (Figure 41). The difference is much larger in the BeMod Cases than in the Base Cases (Figures 19, 28, and 37). This is because the smart charging approaches modeled almost eliminated entirely the need for capacity upgrades on both the distribution and bulk-power systems through 2030. Unlike some other distributed energy resources, EV adoption *lowers the average cost of service,* which *exerts downward pressure on rates.* New revenue from serving EV load may be used to fund utility programs to enable or promote EV adoption, invest in grid modernization, offset other costs, or reduce rates. For illustrative purposes, this study assumes that the utilities use a portion of the additional revenues generated from EV charging to finance make-ready infrastructure for chargers at workplaces and public locations. This assumption results in net ratepayer costs in the Upstate New York region.

Figure 41. Ratepayer Impact of EV Adoption by Region: Base Case



5.1.4 Ratepayer and Participant Benefits of Smart Charging Depend on Program Design

The magnitude of costs savings from smart charging and its relative impacts on EV drivers and ratepayers depends on the design of utility programs and rates. The study's regional BeMod cases provide bookend values that illustrate alternative smart charging approaches, with disparate implications for cost savings and how they are shared between EV owners and other utility customers.

- The Long Island and Upstate New York BeMod cases highlight the *technical* potential of smart charging by assuming that all EV owners are served on and respond rationally to a real-time rate that reflects their utility's hourly marginal cost of service. The modeled electricity supply cost savings represent an upper bound on what could be realized in an actual program. Current TOU rates from each region were used to calculate EV owners' bills, which resulted in large ratepayer benefits (Figures 28 and 37) and modest savings to EV owners (Figures 27 and 36) in both regions.
- The Metro New York BeMod case illustrates how a smart charging program that yields electricity supply cost savings and societal benefits (Figure 40) and increases benefits to EV owners (Figure 18) can nevertheless raise costs for other utility customers (Figure 19). This case assumes that all EV owners in the region participate in a scaled-up version of ConEd's ongoing SmartCharge NY pilot. It is reasonable to expect that the pilot program's relatively generous incentives would be reduced if it were implemented at scale, which could shift some of the cost savings to non-participating customers but most likely would also reduce participation and compliance.

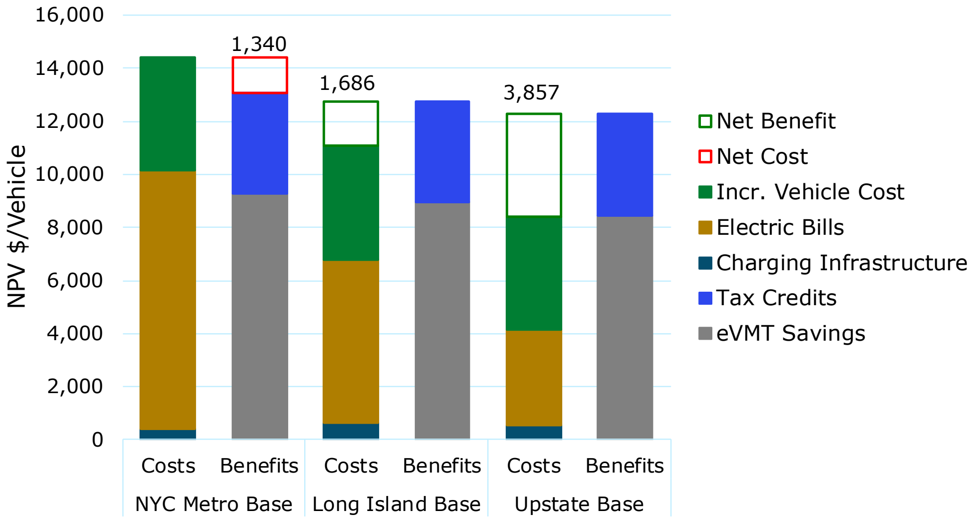
5.1.5 Participant Benefits Vary Regionally

Regional variation in retail electricity rates leads to significant differences in the customer value proposition for EVs across NYS (Figure 32). Most notably, under Base Case conditions, drivers in the Metro New York region face an NPV *cost* of about $1,300 per vehicle, compared to an NPV *benefit* per vehicle of $1,686 on Long Island and $3,857 in Upstate New York. The greater cost to drivers in the Metro New York region results primarily from the area's higher electricity rates. There is comparatively little variation in gasoline prices around the State, so savings from avoided gasoline consumption do not differ much across regions.

5.1.6 EV Purchase Incentives are Crucial to the Value Proposition for Prospective EV Buyers

Even with the forecasted decline in EV prices, their premium relative to comparable gasoline vehicles remains a significant cost component during the timeframe of this analysis, which focuses on vehicles purchased through 2030. Without the State and federal purchase price incentives at the levels assumed, EV purchasers would not realize net benefits in the Base Case in any region (Figure 42). These observations reinforce the need to maintain some level of vehicle purchase incentives for EV drivers for at least the near-term future.[62] It is also important to note that there is an implicit causal linkage between the study's assumptions about the persistence of tax credits and trends in EV sales and prices: the incentives drive sales, which lead to manufacturing economies of scale and, in turn, yield the declining EV price trajectory included in the modeling.

Figure 42. Net Participant Impact of EV Adoption by Region, Base Case



5.1.7 Expanded Public DCFC Networks May Increase Net Societal Benefits

Many stakeholders contend that widespread availability of DCFC, especially along major travel corridors, is essential to meet New York State's EV adoption goal. While survey research supports this argument, empirical evidence from market data is scarce. This is because experience is still limited and there are numerous confounding factors that make it difficult to isolate the effect on EV adoption relating to differences in DCFC access across geographic areas. Weighing the evidence for the induced effect is beyond the scope of this analysis, and instead, the study focused on the relation between availability of DCFC and eVMT: the study posits that expanding the DCFC network will give EV owners the confidence to drive their EVs further and more often, increasing annual eVMT by 10%. Net societal benefits increase relative to the Base Case statewide (Figure 40) and in each region (Figures 17, 26, and 35). This is because operating and fuel cost savings from increased eVMT offset the additional spending on public chargers.

Further implications of the modeling results are presented in the following passages, broken down into several categories—with a focus on reducing charging infrastructure costs, the potential role of managed charging and the challenges to encouraging it with potentially higher retail rates, and making the case for additional DCFC infrastructure.

5.2 Reducing Charging Infrastructure Costs

Charging infrastructure costs, mainly for public Level 2 and DCFC, account for a significant portion of the societal cost of EV adoption. Both the cost and the amount and type of charging infrastructure that will ultimately be needed (and deployed) in NYS are uncertain. If realized costs are lower than the team assumed for either of these reasons, net benefits will rise and vice versa. For this analysis it was assumed that make-ready infrastructure at workplaces and public locations would be provided by the utilities and funded by ratepayers, which still left net ratepayer benefits in the Long Island and Metro New York regions but resulted in net costs in Upstate New York.

Driving down infrastructure costs through innovation, economies of scale, or other means will increase the benefits of EV adoption. Well-targeted utility investments and/or cost-sharing with hosts and others would increase the net ratepayer benefit. One potentially promising avenue to explore is to take advantage of the intelligence and communications capabilities already built into new vehicles. Making use of the telematics data and other features of today's smart and connected cars can avoid duplicating capabilities and expenses. Capturing these savings will require close coordination between utilities, EVSEs and OEMs. Ongoing survey research, customer engagement by utilities and third-party EVSEs, and insights from OEMs' marketing studies are also critical to inform public and ratepayer investment deployment strategies.

5.3 The Growing Importance of Managed Charging

The long-term value proposition of EV charging via vehicle-to-grid (V2G) communications is attractive. V2G includes bidirectional power flow between the EV and the grid and unlocks a variety of services that can be provided by EV and EVSE as distributed energy resources. There are a variety of grid services that EVs can provide, including, but not limited to, load balancing, demand response, congestion relief, frequency regulation, voltage support, ramp rate mitigation, and reductions in peak demand. Most of these considerations are beyond the scope of this BCA; further, these grid services are unlocked at higher rates of EV adoption than assumed in the near-term future of the study. Managed charging, often referred to as V1G or smart charging, allows an entity (e.g., the utility or a third-party provider) to send price signals and influence charging behavior, similar to more traditional demand response programs.

- The Behavior Modification Cases demonstrate the potentially pivotal role of smart charging with respect to societal, participant, and ratepayers. Introducing pricing elements that modified drivers' behavior and encouraged off-peak charging increased the net present benefit on a per vehicle basis by a factor of 2.5, 1.6, and 1.6 for Metro New York, Long Island, and Upstate New York, respectively. These impacts are realized primarily by achieving the same level of transportation electrification while reducing the electricity supply costs by pushing charging to periods when the cost of service is low. The Upstate New York and Long Island BeMod cases demonstrated the *technical potential* of smart charging by analyzing simulated profiles generated using a real-time rate that matched the utilities' hourly marginal cost of service. These estimates represent an *upper bound* on the benefits that can be realized from smart charging. In contrast, the Metro New York case likely *underestimates* the benefits of smart charging in that region. This is because it envisions extending ConEd's current SmartCharge NY pilot to all EV owners in the region. It is reasonable to expect that the pilot program's relatively generous incentives would be reduced if it were implemented at scale.

The BCA modeling suggests there is a high value associated with smart charging, which will require coordinated efforts by stakeholders to ensure that the appropriate technology is deployed and that the proper incentive programs are in place. There is still much to learn with respect to consumer behavior and EV charging, but the relative benefits of managed charging demonstrate the benefits of harnessing information about consumer EV charging behavior and using it to inform specific programs that can help realize the benefits reported here. It also indicates the importance of involving the stakeholders that have the most to benefit from managed charging, primarily the utilities in the EV market, to ensure that the greater societal benefits associated with manage charging can be achieved. Utility smart charging programs should include carefully crafted experimental designs to ensure that they maximize insights into how consumers respond to smart charging incentives.

5.4 Encouraging Smart Charging with Retail Rates

Smart charging has the potential to increase the benefits of EV deployment substantially. The statewide and regional Behavior Modification (BeMod) cases show that smart charging can significantly reduce electricity supply costs, further improving the economics of EV adoption. Savings arise from delaying distribution and system capacity upgrades to accommodate EV charging, as well as from shifting charging to hours when energy is less costly. Utilities and regulators have numerous options to implement smart charging, including direct control of charging by utilities or third parties, time-varying electricity rates that encourage off-peak charging, or incentives to charge during periods when the marginal cost of electricity is lowest. The BeMod cases also illustrate some potential challenges to encouraging smart charging with retail rates alone. Commercial rates are generally lower than residential rates and many workplaces currently offer free charging. This could encourage EV drivers to charge during the day at work irrespective of their retail rate for EV charging at home. The ConEd SmartCharge NY pilot illustrates one way to overcome this issue with a rebate that follows the car irrespective of where it is charging.

5.4.1 Expanded Cost-Benefit Analysis is Necessary to Support High-Infrastructure Case (Including Induced Effect on EV Adoption and eVMT)

The High-Infrastructure Cases found that in most cases and in most regions and from most stakeholder perspectives, investments in additional Level 2 and DCFC infrastructure yield greater net present benefits on a per vehicle and absolute basis than the Base Case. As noted above, these cases test the hypothesis that if EV owners drive their EVs more due to increased access to public DCFC their incremental O&M savings will offset the added cost of deploying more chargers. The HighInf cases simply assume that a more DCFC would result in a 10% increase in eVMT. This “thought experiment” does not take into account the fact that increased availability of DCFC may also stimulate EV adoption.

The conservative approach of the study likely underestimates the increased benefits from expanded availability of charging infrastructure. Accelerated and induced EV adoption beyond the 10% increase in eVMT assumed here would lead to higher benefits than what has been reported. As the market evolves, it is important that stakeholders seek to understand the most effective means to increasing EV adoption, particularly as it relates to EV charging infrastructure, as this will lead to an improved understanding of how best to incentivize charging infrastructure deployment and expand the cost-benefit analysis of EV adoption to support increased charging infrastructure. Future research should take up this question, drawing on the growing body of empirical literature that seeks to measure the extent of an *induced* effect of EV adoption and eVMT from observed market data.

As noted previously, the BCA includes a proxy for make-ready investments, representing the estimated investment required up to, but not including the charging hardware, or electric vehicle supply equipment. This was explicitly included because utilities in other states have received approval from public service commissions to pay for these costs and recover the investment through traditional cost recovery and via capitalization of assets. The results on the High-Infrastructure Case can help provide boundaries for the discussion regarding utility investment in EV charging infrastructure, while also helping to inform and prioritize utility investment decisions regarding EVs in general. In other words, the High-Infrastructure Case demonstrates that without accompanying measures to increase EV adoption (e.g., rebates, outreach and education), the benefits do not outweigh the costs of deploying EV charging infrastructure. This suggests that the State and utilities should investigate carefully how they prioritize complementary investments across transportation electrification—including incentives for vehicles, investment in charging infrastructure, rate design, or other incentives. Furthermore, this case affirms the point that EVs generate a finite benefit to ratepayers, and any use of ratepayer or public monies to invest in transportation electrification should be bound by this concept.

5.5 Areas for Future Investigation/Analysis

Transportation electrification is rapidly evolving as a result of a confluence of technical, regulatory, and economic influences. For instance, battery technology continues to advance, drawing the attention of a wide range of transportation market segments (i.e., other than light-duty vehicles); regulators are increasingly looking to electrification as a core strategy to decarbonize the economy; and rapidly decreasing battery costs are improving the value proposition of transportation electrification for multiple stakeholders. It is increasingly clear that policy makers will need to grapple with electrification of multiple transportation modes, not just light-duty vehicles. More specifically, the project team has identified the following areas for future investigation and analysis to build upon the BCA presented here.

5.5.1 Electrifying Buses and Transportation Network Companies (TNCs)

Mobility is rapidly changing in New York State. There is a concerted effort to reduce vehicle miles traveled in single occupancy vehicles, which will require more and improved mobility options for consumers, including traditional public transportation via transit buses and emerging mobility options like ride-hailing services (e.g., via Uber and Lyft).

Transit buses are well-suited for electrification, as they run the same or similar routes daily, have a high-stop frequency, operate at low speeds, cover short distances, and are commonly centrally fueled at their depot. There are multiple commercially available electric transit bus options from providers like BYD and Proterra. New York City's Metropolitan Transportation Authority (MTA), for instance, is currently testing 10 electric buses, and has plans to purchase another 60 electric buses as part of the 2015-2019 capital program, as updated in April 2018. [63] Further, NYC Transit, an operating unit of the MTA, has plans to convert the entire public bus system to an all-electric fleet by 2040.[64]

Ridership for ride-hailing services like Uber and Lyft has been increasing rapidly over the last five years, especially in urban areas like New York City. In congested urban areas, ride-hailing services are putting upward pressure on VMT at prodigious rates.[65] Ride-hailing services are an ideal application for electrification for a number of reasons. Service vehicles tend to be driven intensively; their relatively high VMT enhances the life cycle benefits of electrification by strengthening the tradeoff between purchase price premium and lifetime fuel and maintenance cost savings. Also, while electrification *per se* does not solve concerns regarding congestion, electrifying these fleets can help mitigate the negative environmental impacts (e.g., air pollution and increased GHG emissions) of increased VMT. Policy makers and private stakeholders alike will need to work together to plan for the deployment of services that support mobility providers like Uber and Lyft, while also coordinating with EV service providers and utilities to ensure that charging infrastructure is deployed strategically.

5.5.2 Electrifying Last Mile Delivery

Fully electrified medium duty trucks and vans are increasingly available and are currently being piloted or demonstrated in select markets including New York City. Especially in urban cores these vehicles contribute to congestion and air pollution, as well as emitting GHGS. Medium duty vehicles have a wide variety of vocations and duty cycles, so electrification will proceed gradually. Large fleets of last mile parcel vehicles are strong candidates for early electrification. Smaller fleet operators are more likely to be dissuaded by the upfront purchase premium and costs of chargers, but in some instances could benefit from favorable polices. Energy regulators will need to collaborate with fleet operators, city governments and other stakeholders to advance and capture societal benefits of electrifying delivery fleets.

5.5.3 Utilization of Municipal Property for Charging Infrastructure

Although most EV charging is expected to happen at home, the role of nonresidential EV charging is likely to increase moving forward. This will include workplace, fleet, and destination or opportunity charging—with a mix of Level 2 and DCFC equipment deployed. More specifically, moving forward, it will be important to clarify the role of municipal property for use as a site host for EV charging infrastructure. In the early stages of the market, municipalities have sought to deploy EV charging infrastructure at highly visible locations like city halls or libraries, with the intent of demonstrating support for electrification. And in many cases, municipalities do not charge to access the EV charging infrastructure. This can present multiple challenges for municipalities because they are (1) giving up valuable parking assets and (2) often responsible for paying ongoing expenses like the electricity dispensed to vehicles, the maintenance of the charging equipment, and in some cases, a network access fee.

The BCA includes the costs of deploying EV charging infrastructure but does not explicitly contemplate the utilization of municipal assets as a site host for EV charging infrastructure. Moving forward, it is important that there are basic rules of engagement and administration in place as NYSERDA and other agencies continue to coordinate with municipalities to ensure that they are able to participate in incentive programs and broader EV charging infrastructure deployments. For instance, EV charging equipment at municipal properties, unless they are being utilized exclusively by municipal employees or fleets, should be publicly accessible and meet all State ADA requirements. Broadly speaking, however, more strategic considerations and the anticipated role of municipal property in a broader statewide rollout should be considered by NYSERDA and other stakeholders.

5.5.4 Understanding and Influencing Charging Behavior

This BCA makes a variety of assumptions about market developments, including regarding consumer charging behavior. In order to improve the accuracy of the BCA of light-duty EVs, there is a clear need to understand three critical aspects of EV charging behavior: (1) when vehicles are charging, (2) where vehicles are charging, and (3) how much power is being delivered to the vehicle. These additional data about how EV drivers are using and charging their vehicles will help stakeholders understand trends and develop programs and interventions to influence charging behavior. This will be a critical aspect of the market moving forward to help clarify the appropriate incentives and policies to maximize the value proposition of EV charging in different locations and with different equipment. This additional data will also help to inform rate design and smart charging programs, which in turn will need to be tested. Implementing rigorously designed smart charging pilots with careful attention to experimental design will provide essential insights for understanding and improving managed charging initiatives. Broad stakeholder engagement in program development will help to ensure that appropriate technology is deployed and that the proper incentive programs are in place to shift charging accordingly.

5.5.5 State and Local Initiatives to Reduce EV Cost if Federal Tax Credit Phases Out Rapidly

Congress' overhaul of the federal tax code last year showed that the EV tax credit very likely will remain available until each automobile manufacturer reaches the 200,000-vehicle phase-out cap. The House of Representatives' version of the tax bill that ultimately became Public Law 115-97 would have repealed the tax credit, but the Senate declined to follow suit and managed to prevail in the conference committee that reconciled the two chambers' bills. This was so even though the bill, as a budget reconciliation measure, could not be subjected to a Senate filibuster. The measure's passage in the Senate by a simple majority vote therefore suggests two things: (1) the EV tax credit had support from Senators on both sides of the aisle and (2) even with a Republican-controlled Congress and a Republican Administration, the credit cannot easily be eliminated.

Despite the room for optimism, it is conceivable that the federal tax credit is phased out sooner than contemplated in this study. As noted previously, two automobile manufacturers, Tesla and GM have surpassed the threshold of 200,000 EVs, thereby triggering the phase out of the availability of the federal tax credit for EVs sold by those manufacturers. Furthermore, Nissan and Ford have surpassed 125,000 and 110,000 EVs sold, respectively; and Toyota is not far behind with more than 90,000 EVs sold.

If the federal tax credit is not extended, it is conceivable that State and local governments will have to consider the extent to which they want to provide incentives to replace completely or partially the vehicle incentive. Other jurisdictions will have to grapple with this challenge as well. For instance, in California, the state will look to the Low Carbon Fuel Standard (LCFS) program to begin funding a statewide point of purchase rebate based on percentage contributions from utilities participating in the program.[66] The BCA framework presented here can serve as the foundation for a more detailed analysis into the importance of vehicle incentives and the associated impact on the market.

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