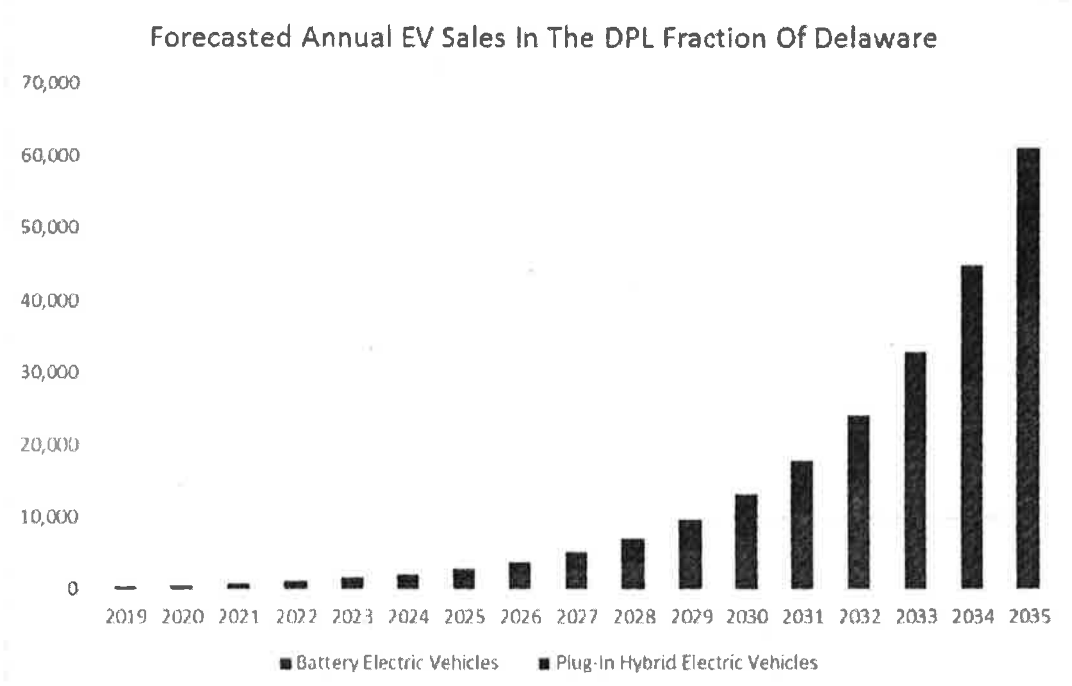
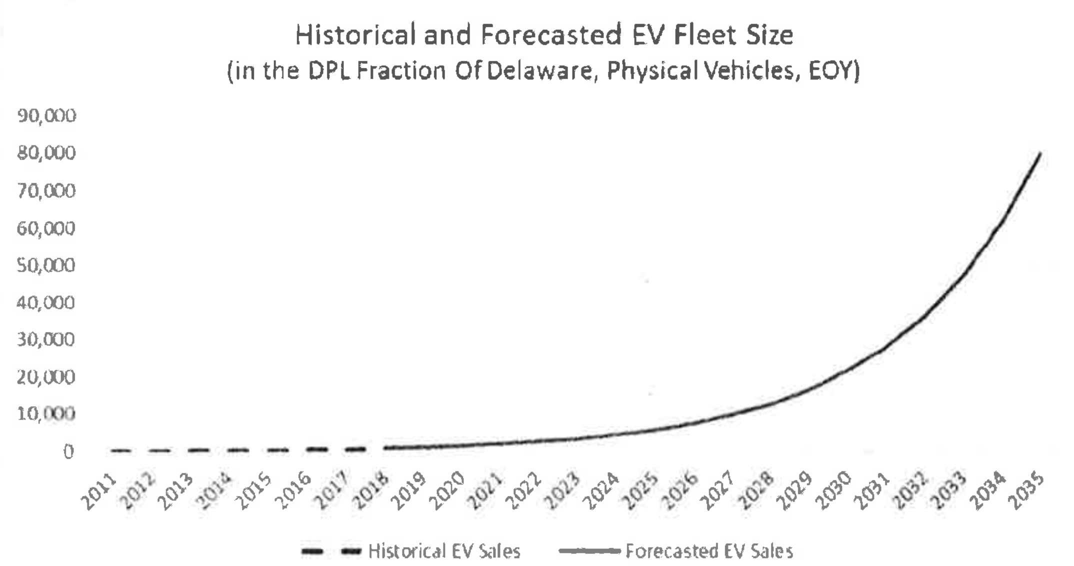
The following charts summarize the forecasted EV sales for the DPL-DE territory and the resulting EV fleet size over the analysis period (after accounting for vehicle retirements)[c].




[c] If BEVs are a larger fraction of the vehicle mix, many of the benefits quantified in the following section will be slightly higher through elimination of occasional gasoline use by PHEVs.

# 4 Methodology For Measuring Impacts

Many of the impacts from EV use result from how vehicle charging impacts both electricity markets and utility infrastructure. These impacts have physical, economic, and environmental dimensions that can be quantified, in addition to broader strategic implications. The benefit-cost analysis is therefore based primarily on quantifying the net impact of displacing gasoline consumption with electricity use. The analysis is based on the following scope, methods, and assumptions:

1. **Analysis Period:** The study computes annual impacts for the years from 2019 to 2035.

2. **Territory**: The analysis is based on a forecast of EV adoption within the DPL-DE territory over the analysis period, building on a) historical sales of EVs in the territory, and b) expected sales growth as already evident, as reinforced by a variety of positive market developments that are expected to encourage EV adoption growth, including the utility programs being proposed. Section 3 provides details on the EV forecast that is the foundation of the study.

3. **Delaware Market Conditions:** The EV forecast is translated into a variety of statistical models that quantify vehicle use and energy impacts. These models are based on market research for the DPL-DE territory, and reflect customer behaviors and market conditions specific to that territory, including vehicle characteristics (energy efficiency), travel patterns (average miles per day, etc.), charging schedules (where EV drivers charge, and when), baseline electricity consumption patterns, cost factors, etc. *This EV impact study is therefore based on modeling details that are tuned to the DPL-DE territory to the greatest extent possible.* In cases where territory-specific data was not available, regional or national statistics were used.

4. **Charge Schedule:** The impact that EV charging has on electricity markets and utility infrastructure, with the associated physical, environmental, and economic benefits (as detailed in the sections below), depends heavily on WHEN the charging occurs. The analysis assumes "managed charging" schedules, since the utility programs are intended to encourage vehicle charging at optimal times. The loading profile for vehicle charging is based on a detailed market model with six segments (private residential, multi-family residential, workplace, fleet, public corridor charging, and public community charging) and time-of-day usage profiles provided by industry and various studies regarding vehicle charge scheduling. The Managed Charging profile assumes that most residential charging responds to programs intended to encourage optimal charge scheduling, including a) deferral of the start of charge until after peak hours, and b) spreading vehicle charging loads out over an 8-hr period overnight. The utility program being proposed provides for an early implementation of programs to encourage optimal charge scheduling, a mix of solutions to allow learning about which offers work best with consumers, and establishes a foundation for more advanced managed charging programs medium term.

5. **Impact Modeling:** These input statistics are combined in a specialized model that quantifies physical and economic impacts, as described more completely in Section 5:

    a. Physical impacts include gasoline displacement, changes in energy use (MWhrs, PJM-coincident peak), implications for PJM generation requirements, and NET changes in emissions of $CO_2$, NOx, and SO2. These emission changes account for the NET impact of reduced tailpipe emissions and increased emissions associated with electricity generation induced by vehicle charging. Power plant emissions are determined through the PJM dispatch simulation described below, which aggregates the projected emissions, asset by asset, hour-by-hour, over the year as required to meet the load[d]. *This analysis is therefore based on very granular simulation of actual plant dispatch with known emission rates, rather than using more general gross emission factors.*

    b. Economic impacts are examined from three perspectives: changes in electricity costs as seen by all ratepayers, reduced operating expenses for EV owners, and the societal value associated with reduced emissions, as described in more detail below.

6. **Electricity Costs:** Determining how EV charging affects electricity costs is a primary focus for the study, and is achieved through a comprehensive model that examines wholesale market impacts, implications for capacity and transmission costs, and impacts on the distribution revenues collected by the utility. Both aggregate (total $, and total MWHR) and unit-cost impacts are quantified, which allows for determination of electricity cost changes that affect all ratepayers.

    a. **Wholesale Cost Impacts[e]**: EV charging, especially if done during off-peak times, changes the shape of the aggregate load curve. This modified load curve results in a change in the average wholesale cost of electricity since more electricity is purchased during lower cost, off-peak times[f]. Gabel forecasts these impacts based on a detailed asset dispatch simulation using AURORAxmp (AURORA). AURORA is an

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[d] The simulation mostly assumes business as usual for asset dispatch. Increased use of cleaner sources, especially class I renewables, could make the benefit impacts quantified in this study even stronger. Note that the utility program proposal includes use of renewable energy for supply on some program elements, which is more advantageous than the "business as usual" assumptions conservatively used in the study.

[e] For the purposes of this analysis, "wholesale costs" reflect the raw "factory gate" price for generating electricity considering capacity factors, fuel sources and costs, marginal pricing, etc. Other costs that are also part of the wholesale market, including PJM ancillary charges, capacity costs, RPS costs, etc, are captured as part of the other electricity cost elements (either capacity and transmission, or bundled as part of the utility distribution costs). This structure is used because changes in average pricing affect only the raw generation costs, not necessarily other PJM costs in a similar way, and this approach ensures the most conservative, fair, and transparent impact assessment.

[f] EV charging creates a Charging Induced Pricing Effect (ChIPE) that is similar to the Demand Response Induced Price Effect (DRIPE) factor recognized for energy efficiency/demand response programs, although the market impact dynamic is very different. Optimal vehicle charging "fills the trough" in the aggregate off-peak load profile resulting in ChIPE, while demand reduction programs "shave the peak" to create DRIPE. The affects are similar, however in that the modified load curve changes the overall average cost of wholesale electricity.

industry-leading software and data package that simulates the hourly commitment and dispatch of electric generators to serve load, recognizing utility-level peak demand, transmission constraints, operational characteristics of generators, delivered fuel prices, emissions prices, etc. Gabel completed hour-by-hour market simulations using AURORA, for every year from 2018 - 2035. Total electricity costs ($ per year), average wholesale unit costs ($/kwhr)[8], and generation emissions (tons) are the primary outputs of the simulation. *Unlike other EV impact studies that depend on gross emission and cost-change factors, this study makes use of detailed market dispatch simulations specific to the EV adoption forecast and market conditions in the DPL-DE territory and PJM.*

b. **Capacity and Transmission Costs**: The dispatch simulation noted above computes the PJM-coincident peak for each year. Costs related to the charging-induced capacity (with reserve) and transmission requirements are computed based on forecasted cost factors for PJM capacity and transmission. See Appendix A for more details on capacity and transmission cost calculations.

c. **Utility Distribution Costs**: A detailed analysis of current DPL tariffs for the DE territory was completed, as well as analysis of significant information provided by the utility regarding distribution-costs and revenue requirements (see Appendix A for more details). The resulting distribution costs were projected forward using both utility and Energy Information Administration (EIA) statistics on distribution revenue growth to establish the utility distribution costs.

d. **Total Electricity Cost Impacts:** The PJM dispatch simulation and revenue requirement analysis summarized above allows the wholesale, capacity, transmission, and distribution costs for a given load profile to be determined for each year of the study period. This analysis is completed for both the baseline case without EVs, and the load profile under consideration including EV charging. Both the gross electricity costs (annual $) and the average unit cost ($/kwhr) are determined. The difference between the EV scenario and the baseline represents the impact on overall electricity costs. Overall electricity use (total MWhrs) goes up due to the increased electricity use associated with vehicle charging, but unit costs ($/kwhr) go down due to the combination of reductions in average wholesale unit costs due to more optimal loading, and dilution of distribution costs through increased MWhr volume. The combined economic impact of these considerations are summarized in Section 5.2.4.

[8] This average unit-cost represents a load-weighted average across all times and locations, and is really a gross indicator for wholesale electricity costs. In a competitive market like PJM, those costs efficiencies are expected to eventually flow through to customers. How those savings are allocated to a particular customer class or tariff depends on wholesale market response and future utility rate case decisions, and so individual customer impact may vary by class or tariff.

7. **EV Operating Costs:** It costs less to "fuel" an EV with electricity than it does to fuel a traditional vehicle with gasoline. Furthermore, early market evidence suggests that EVs cost less to maintain due to the simplified drive train. These two factors combine to generate significant savings for EV owner/operators[h]. The fuel savings are computed based on a projection of electricity and gasoline prices, while maintenance savings are estimated based on results from an independent vehicle operating cost study on a per-mile basis. To ensure a fair comparison, an additional expense is assumed for EV owners based on replenishment of the infrastructure funding lost through avoided state and federal gasoline taxes. See Appendix A for more details on EV operating cost analysis.

8. **The Value Of Avoided Emissions**: Current levels of vehicle emissions impose significant costs on society through health care expenses, extreme weather damage, lost worker and business productivity, asset devaluation, etc. Although frequently considered an "externality", there is real economic value that accrues to society due to the avoided emissions enabled by widespread EV adoption. The study calculates the value of this avoided emissions (for $CO_2$, $NO_x$, and $SO_2$) based on social cost studies from independent sources on a per-ton basis. See Appendix A for more details on the economic calculations related to avoided emissions.

9. **Program Costs:** The utility is proposing a program that delivers equipment and services to participating customers to better support the needs associated with EV adoption, and to help address adoption barriers that will help expand and accelerate EV use. These programs represent direct investment and expense. In addition, as EV use grows and utility infrastructure is required to deliver the additional electricity required for vehicle charging, additional investments in grid reinforcement may be required. Lastly, EV adoption imposes additional costs on non-utility participants, such as the premium associated with vehicle purchase, or investments in charging infrastructure being made by private (non-utility) entities. The study estimated the costs associated with all three areas to create a more complete profile of potential costs, which are detailed in Section 6. See Appendix A for more information about how costs were estimated.

10. **Formal Net Benefit Tests:** The net economic benefits from forecasted EV adoption are summarized in Section 5.2, and potential costs are summarized in Section 6. These benefits and costs can be combined to provide a NET benefit, after accounting for costs. There is no formal consensus on how to calculate net benefits related to proposed EV programs, but there are well established methods for evaluating the merit of energy efficiency (EE) programs. These EE tests need to be modified to account for conditions specific to EV adoption, but once properly adapted, they can be used to quantify the policy merit for proposed EV programs. Based on a review of methods used by others and synthesis of associated best practice, three adapted tests have been developed for this study: a Ratepayer Impact Measure (RIM), the Societal Cost Test (SCT), and the Total Resource Cost

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[h] The benefit analysis quantifies the operating expense savings realized by EV owners. Full characterization of economic benefit must also consider potential vehicle purchase premiums, as well as other incentives that might apply to offset vehicle purchase price. These factors are incorporated in the NET benefit tests outlined in Section 7.

(TRC) test. These different tests characterize how different impacted populations experience net benefits, and taken together provide a well-rounded view on overall merit. The formal NET benefit tests are described in Section 7.

11. Additional details about scope, assumptions, and methodology can be found in Appendix A.

# 5 KEY RESULTS: The Impacts Of EV Adoption

EV adoption delivers an unusually broad range of impacts, across a range of populations and market segments. The study quantified these impacts as a function of EV adoption over time, including both aggregate physical impacts, and a variety of economic benefits.

## 5.1 Key Results: Physical Impacts

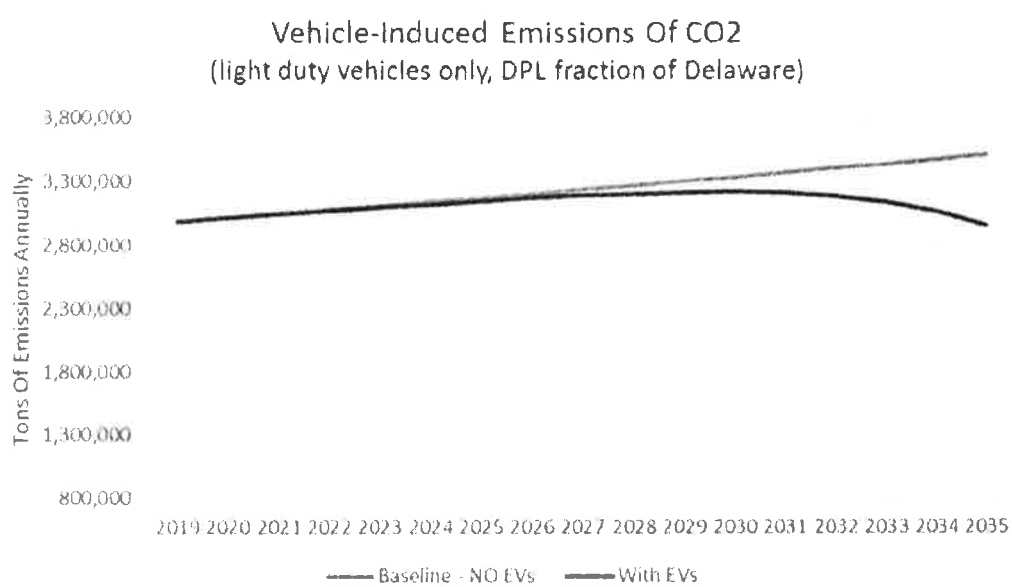
Fueling light duty vehicles with electricity rather than gasoline creates a profound change in fuel usage, electricity usage, and changes in the associated emissions. Based on the EV adoption forecast in Section 4, combined with travel statistics for Delaware and average vehicle performance characteristics, the study identified a variety of physical impacts, including:

- EVs are forecast to account for 0.8% of new vehicle sales in 2019, growing, to 81.2% by 2035.
- EVs account for 0.3% of the light duty fleet overall in 2019, but are projected to grow such that EVs account for 26.4% of light duty vehicles on the road by 2035.
- As EV penetration grows, an increasing fraction of miles driven will be powered by electricity rather than gasoline. By 2035, 21.6% of all light duty vehicle miles driven are expected to be "electrically fueled". This increasing electrification displaces significant gasoline use – in 2035, EVs are projected to avoid consumption of 82,369,166 gallons of gasoline, and a total of 310,183,181 gallons of gasoline will be displaced over the period from 2018 – 2035.
- In 2019, EVs are projected to consume an average of 2,534 kwhrs of electricity per vehicle annually for battery charging[i], or an average 6.94 kwhrs per day. Those consumption factors are expected to increase slightly through 2035, but at a slower pace past 2025 as larger and heavier EVs come onto the market. **For a household with one EV, vehicle charging will account for an average of 20.4% of the electricity consumption for that household over the period.**
- At an aggregate level, EVs are projected to require 3,818 MWhrs of electricity for vehicle charging in 2019 (across all charging segments), growing with EV population to 572,058 MWhrs by 2035.
- When "managed charging" is dominant, most charging (on a kwhr basis) is residential and during off-peak periods at night. In that case, EV induced load increases during the PJM-coincident peak are expected to be modest. Vehicle charging adds a projected 0.263 MW of load at peak time in 2019, growing to 36.549 MW in 2035. The fact that charging-induced electricity consumption increases significantly, while peak loading increases only slightly, implies a significant increase in the overall generation base and infrastructure capacity factors (i.e. utilization), and a much flatter load profile overall with more consumption in off-peak periods. This outcome is a primary driver of the economic benefits summarized in Section 5.2.1.
- By fueling with electricity rather than gasoline, emissions at the tailpipe are eliminated, but emissions at the power plant go up. For most pollutants, vehicle emissions reduce much more

[i] This represents a blended average consumption-per-charge for BEVs and PHEVs.

than power plant emissions increase, resulting in a NET reduction overall. **In 2019, each electrically fueled mile is projected to be 63.8% cleaner (for $CO_2$) than an average gasoline fueled mile.** This "clean-up factor" increases slightly over time as the grid becomes cleaner[j], so that by 2035 EVs could be 70.7% cleaner (for $CO_2$) than average gasoline vehicles.

- Carbon Dioxide ($CO_2$) is a primary GHG, and burning gasoline in vehicles accounts for the largest share of $CO_2$ emissions in the state[7]. As EV penetration grows, NET $CO_2$ emissions decline significantly. **Transportation induced $CO_2$ emissions (light duty vehicles only) are projected to reach 3,507,067 tons by 2035 in the baseline case WITHOUT EVs, but would reduce to 2,948,523 tons by under the forecasted EV adoption scenario – a 15.9% reduction. Over the period, a projected 2,076,234 tons of $CO_2$ are avoided, or 9.01 tons of $CO_2$ avoided per EV sold.** Note this reduction results from EV penetration of 26.4% in 2035, and $CO_2$ reductions continue to grow in lockstep with increased EV adoption. The following chart summarizes the reduction in $CO_2$ emissions resulting from the forecasted rates of EV adoption compared to baseline usage without EVs:




- Nitrogen Oxides (NOx), which are a criteria pollutant that directly affects public health and are also a pre-curser to other forms of air pollution, also declines with increased EV adoption. **NOx declines from a projected 2,121 tons for the no-EV baseline case in 2035, to 1,790 tons instead, a reduction of 15.4%.** The following chart illustrates the decline in NOx emissions resulting from growth in the use of EVs.

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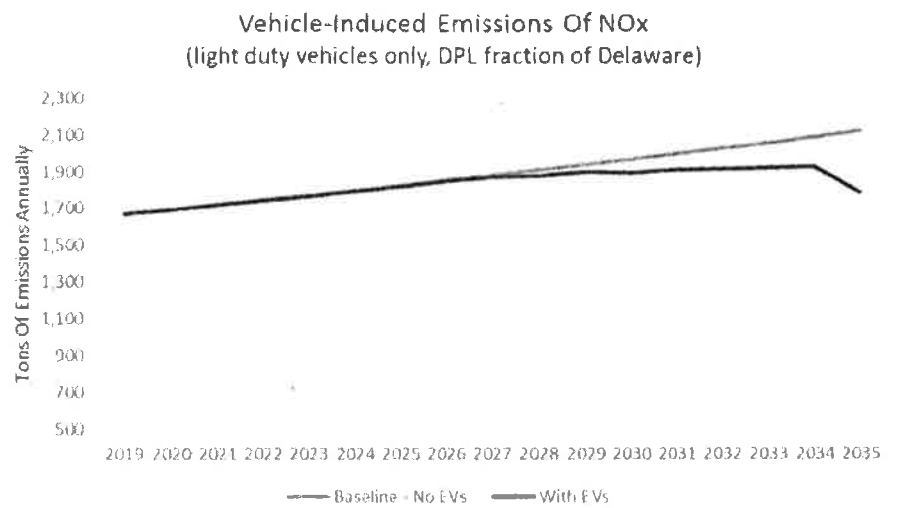
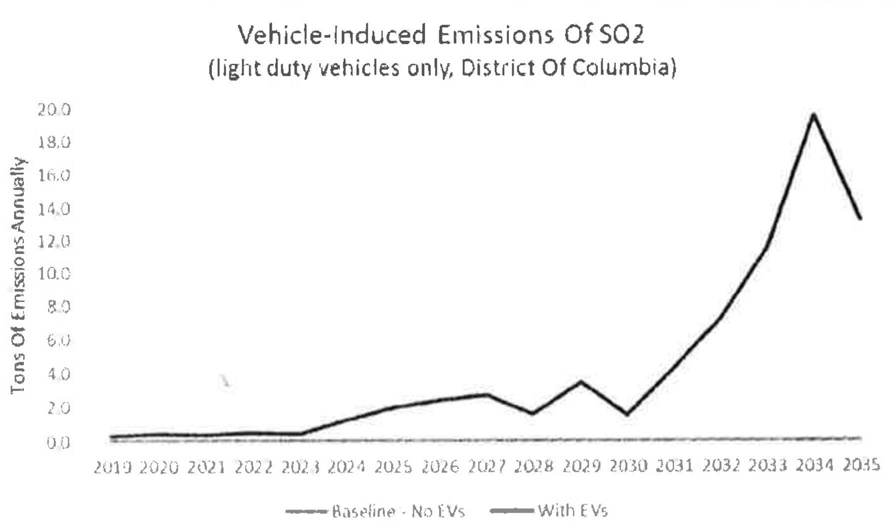
[j] The simulation model assumes "business as usual" for existing generation assets and deployment of any new capacity required. Given the significant displacement of coal generation by natural gas already underway, emission factors of the generation base continue to reduce. Those reductions could be faster and larger, however, with increased use of carbon-free renewable energy. There is a significant synergy between EV adoption and increased grid de-carbonization. Note that the DPL-DE EV proposal will offer a 100% clean energy supply option for EV charging, which could make the "clean up" factor quantified in aggregate through this study stronger.




- Sulfur Dioxide ($SO_2$) is a criteria pollutant that harms human health directly, contributes to the creation of "acid rain", and is a precursor to other air pollutants, especially particulates. $SO_2$ emissions *increase* with EV use – although only slightly. Light duty vehicles emit essentially no $SO_2$, but power plants do – especially in cases where coal is used heavily. As a result, the "zero emissions" of $SO_2$ by gasoline fueled vehicles is replaced by modest $SO_2$ emissions at the power plant. While this is a negative outcome, the difference in scale associated with $SO_2$ emissions should be noted: while $CO_2$ emissions are measured in millions of tons, $SO_2$ emissions increase by an estimated 19.6 tons at the highest point over the period. More importantly, the emissions rate for $SO_2$ continues to decline for electricity generation as the grid migrates to cleaner sources, especially solar and wind. The negative $SO_2$ implications short term will likely soften longer term due to beneficial changes in supply mix.



## 5.2 Key Results: Economic Impacts

Increased EV use is expected to deliver significant economic benefits for a variety of impacted populations, and these benefits scale strongly with aggregate EV adoption level. As summarized in Section 4, the study quantified beneficial impacts through reduced electricity costs (for all ratepayers), reduced vehicle operating costs (for EV owner/operators), and value from avoided emissions (for society at large). The following sections summarize the economic benefits associated with the EV adoption forecast in Section 3, compared with baseline conditions for the DPL-DE territory.

### 5.2.1 Avoided Electricity Costs

EV charging increases overall electricity consumption, and shifts the aggregate load profile to include a larger fraction of energy in lower-cost (off-peak) times, especially under the influence of utility "managed charging" programs that help influence vehicle charging schedules. As a result, overall capacity factor for both generation assets and the distribution system increases, and the load curve that affects energy pricing is more optimal. Together, these efficiencies result in a reduced cost of electricity that benefits all utility ratepayers, not just EV drivers. The study quantified these impacts through the methodology outlined in Section 3, resulting in the benefits summarized below:

- **Ratepayers will realize savings through lower electricity costs, scaling upward with increased EV use, with projected savings exceeding $61.6M a year in 2035.** Those savings represent only non-EV-charging usage[k], and are projected to total over $325.7M over the period (nominal sum of recurring annual benefits), with an NPV of $170.3M[l].

- Electricity costs (on a unit cost, $/kwhr basis) are expected to be 4.5% lower in 2035 than they would otherwise be as a result of the forecasted EV use. Cost improvements continue to accrue as EV adoption grows.

- Those savings reflect a combination of lower average wholesale costs, and dilution of all other costs (especially distribution costs) over larger electricity volume as summarized in the Methodology section (see Appendix A for more details on the energy cost impact calculations). Those impacts vary in proportion over time, with dilution effects

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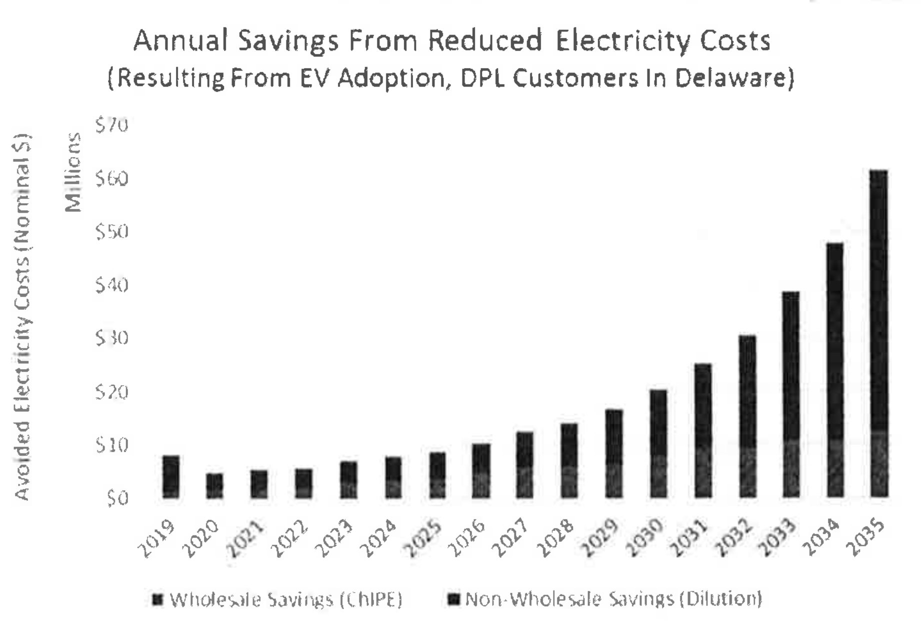
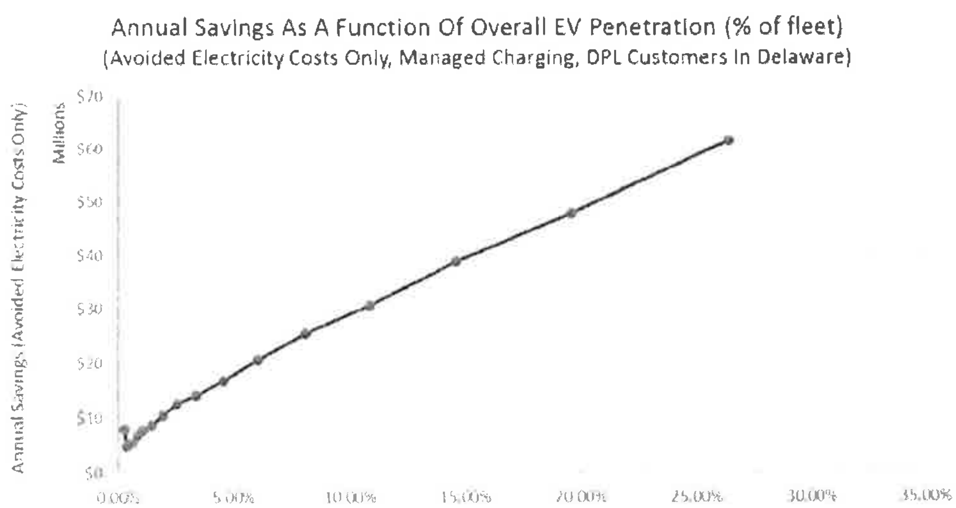
[k] The "rate payer" savings noted reflect the projected lower unit costs ($/kwhr) applied against ONLY non-EV charging loads, which makes that benefit applicable to non-EV owners. EV owners will also realize the benefit of lower electricity costs when powering their vehicle, but that impact is implicitly captured in the EV owner fueling savings. Those calculations are separated to avoid double-counting, and to enable transparent evaluation of the non-EV owner impacts.

[l] As noted in the methodology discussion in Section 4, this analysis identifies overall cost efficiencies at an aggregate level, quantified by an average cost of electricity indicator on a per-kwhr basis. In a competitive market, these cost improvements are expected to eventually flow through to end consumers. Exactly how those cost improvements are applied across rate classes or tariffs, or when those improvements impact bills, cannot be predicted since they depend on a wide variety of future market and regulatory factors. Energy contracting commitments may also impact the timing of when identified cost efficiencies are realized by end consumers.

becoming dominant longer term. This trend is summarized in the following chart, illustrating wholesale pricing effects (ChIPE) versus dilution impacts.




- Electricity cost savings scale strongly with aggregate EV adoption levels (% of light duty vehicle fleet). From a policy perspective, this implies that regardless of what actual EV adoption levels are achieved, incremental EV use generates incremental economic benefit for ratepayers overall. The following chart summarizes the correspondence between EV adoption and avoided electricity costs.



- It is important to emphasize that these benefits are realized by ratepayers overall, not just EV drivers, and reflect only savings delivered through lower electricity costs (not additional economic benefits as quantified below). The fact that overall electricity costs decline as a function of EV adoption is a primary conclusion of the benefit analysis. These economic ratepayer benefits are larger than projected program costs, as quantified more fully in the NET benefit tests in Section 7.

- As noted above, the electric cost reductions noted are based on the scenario where managed charging becomes dominant, as jumpstarted by the utility programs being proposed. The managed charging programs not only enable (and maximize) the potential economic benefits, but also avoid potential harm. For example, as an extreme worst case, if all charging was done at home, and all that charging started when EV drivers got home from work (say at 6PM), that would amplify the existing peak loads (especially during the summer), increase costs, and hasten the need for grid reinforcement (and associated costs). Assuming 75% of all PHEVs are on 1.4KW L1 chargers, 25% of PHEVs are on 7.2KW L2 chargers, and 100% of BEVs are on 7.2KW L2 chargers, in 2035 the projected EV fleet would create 951MW of incremental peak load, in a territory that normally has a PJM-coincident peak around 3,900 MW. That represents an increase of nearly 25% at the worst possible time. Again, this is a worst case scenario that is extremely unlikely to occur since a) some charging happens away from home, and b) even with residential charging, there is a natural spread in the evening. But this demonstrates the potential harm avoided by managed charging (in an extreme case), which both pushes the vehicle charging start past peak time, and when fully implemented, reduces vehicle charging peak load by about a factor of at least six (since it spreads 1-2 hour charging sessions out over a full 8 hour period overnight). The potential economic *harm* that could result from natural charging is not fully represented in this study.

### 5.2.2 Economic Benefits For Electric Vehicle Owners

After the EV purchase, significant economic benefits are realized by the EV owner through lower operating expenses. In particular, EV drivers "fuel" their vehicles with electricity rather than gasoline, and realize significant savings as a result. In addition, EV drivetrains are much simpler and require lower maintenance expense. Based on drive patterns specific to the DPL-DE territory, the study identified the following benefits for EV owner/operators:

- **In 2019 it will cost approximately 11.95 cents/mile to fuel an average traditional vehicle with gasoline, compared with approximately 6.16 cents/mile for EVs (both BEVs and PHEVs, blended results) – a reduction of about 48.4%.** This benefit increases over time, since the cost of gasoline is increasing faster than the cost of electricity. By 2035, EV drivers are projected to be realizing a 62.8% savings in fueling expense. These projections are conservative since a) they assume a reduction in gasoline prices over time due to softening demand for petroleum, and b) EV drivers are assumed to carry an additional expense sufficient to replenish lost revenues from avoided gas taxes (see Appendix A for more details).

- EVs are also expected to have lower maintenance costs due to the simpler drive train. A recent study by the American Automobile Association quantified maintenance expense for both traditional vehicles and EVs (see Appendix A). Based on these factors, as applied to the forecast for the DPL-DE territory, **owners of traditional vehicles are projected to pay approximately 9.26 cents/mile for maintenance of a traditional fueled vehicle, but only 7.97 cents/mile for an EV (blended rate for BEVs and PHEVs) in 2019**. This represents a 13.9% savings on maintenance.

- EV drivers therefore realize real savings through reduced "fueling" costs and maintenance expense. Taken together, and including gas tax replenishment, **EV drivers will realize over $1.1M in operating expense savings in 2019 (nominal sum of recurring annual benefits). This savings grows to $283.6M in 2035, and totals $1.0B over the period (with an NPV of $473.8M).** This represents an average of $2,056 in vehicle operating cost savings per EV sold over the period (nominal dollars). These benefits represent real and substantial cash flow savings for Delaware residents, much of which is returned to the local economy.

### 5.2.3 The Value Of Avoided Emissions

Increased EV use provides substantial reduction in air emissions and other pollutants, especially the GHG emissions associated with climate change. The emission reductions for $CO_2$, NOx, and $SO_2$ are described in Section 5.1, and represent an externality that delivers economic value to society through avoided emission costs. The value of avoided emissions is calculated on a per-ton basis based on impact factors developed by independent studies (see Appendix A for more details), as follows:

- **Avoided emissions ($CO_2$, NOx, and $SO_2$ combined) are projected to generate $213.5K in savings in 2019, growing to $83.5M per year in 2035.** These savings reflect the benefits of decreased $CO_2$ and $NO_x$ net of the incremental cost associated with slightly increased $SO_2$ emissions.

- **The societal value of avoided emissions are projected to total $268.8M over the period (nominal sum of recurring annual benefits), with an NPV of $123.5M.**

- Note that these avoided emission benefits capture a wide variety of impacts, including the public health costs associated with air quality issues (at least in part[m]).

### 5.2.4 Combined Economic Benefits

EV adoption creates economic benefits through reduced electricity costs for ratepayers overall, reduced operating expenses for EV owner/operators, and societal value through avoided

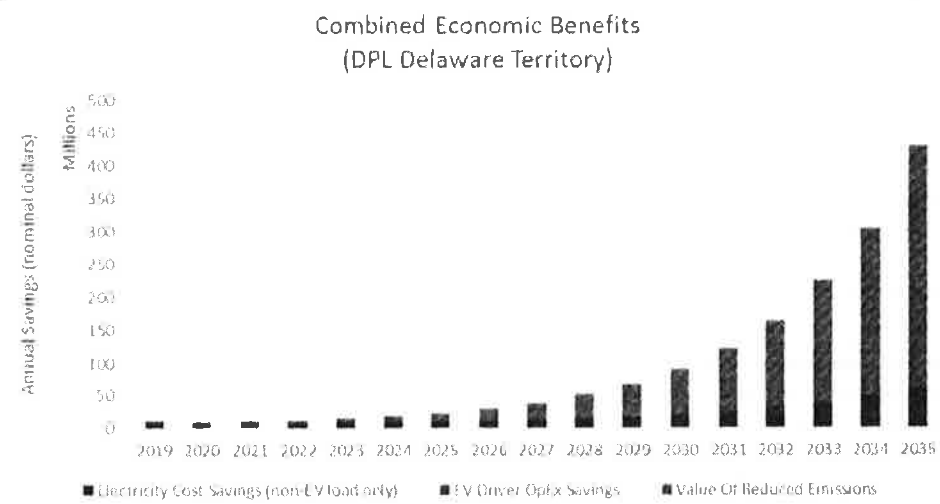
[m] Most studies on air quality impacts attempt to capture costs associated with the public health consequences of air pollution. In most cases, however, they acknowledge that health impacts are so large that their accounting is incomplete. As a result, these projections probably under-estimate the financial value of reduced emissions.

emissions of $CO_2$ and NOx. Taken together, these benefits combine to generate significant value across the impacted populations:

- Combined benefits are projected to total $9.4M in 2019, increasing to $428.8M per year in 2035. These impacts apply across multiple impacted populations, including ratepayers, EV drivers, and society at large.

- **Total benefits (not reflecting costs) are projected to total $1.6B over the period (nominal sum of recurring annual benefits), with an NPV of $767.6M.**

- There are significant benefits across all three populations, but operating expense savings for EV drivers becomes dominant over time. For context, residents of Delaware currently spend approximately $840M per year on gasoline use in light duty vehicles, and EVs are projected to cut those expenses in half[n]. This is a real cashflow savings delivered to every EV-household that will most likely flow into the local economy. This is a relatively equitable benefit opportunity, since any household that owns a vehicle can transition to an EV and realize the associated savings, especially as EVs become cost competitive with traditional vehicles. Emerging consensus is that transition will happen around 2025. The distribution of savings over time is illustrated in the following chart.




[n] The utility EV proposal also supports electrification of medium and heavy duty vehicles, especially electric school buses. That transition will also deliver significant benefits, beyond those quantified in this study focused on light duty vehicles.

### 5.2.5 One Time Benefits For EV Owners

In addition to the recurring benefits noted above, consumers that purchase a new EV may also benefit from a federal tax incentive to offset vehicle purchase costs. The amount of the credit varies by vehicle type and range, up to a maximum of $7,500. It is generally modeled as a benefit, since that economic incentive flows to DE residents from the federal government. That tax credit begins to decline when at least 200,000 EVs from a particular manufacturer have been sold, which market leaders (such as Tesla, Nissan, and Chevrolet) are expected to achieve in the next two years. An analysis of cumulative sales rates for different EV manufacturers was completed to determine the current average incentive level available, and the expected decline rate, based on volume-weighted sales in the U.S. The incentive is applied to all EVs purchased in the DPL-DE territory through 2027 (for BEVs) and 2029 (for PHEVs). **The federal tax incentive totals $83.6M over the period, with an NPV of $59.4M.**

# 6 KEY RESULTS: Program Costs

To properly consider the value of forecasted benefits, it is necessary to also consider potential costs. The study considered three categories of costs related to both the proposed utility EV program, and broader EV adoption as well:

1. **Utility Investments In Charging Infrastructure:** The utility is proposing a variety of customer programs, providing equipment and services that support customers driving an EV. These utility costs include the capital and expense associated with delivering those programs, and is quantified through the proposed program budget. Many of these programs can be considered investments in responsible grid integration of these new EV-charging applications, especially the managed charging programs, which have significant electricity-use and loading implications.

2. **Utility Investments In Grid Reinforcement:** Beyond the direct EV program, there may be the need for additional utility investment in grid reinforcement. As EV adoption grows, the utility will likely be required to deliver more electricity in support of vehicle charging. An estimate of these grid reinforcement investments, which are longer term in nature, has been provided to ensure complete characterization of EV adoption costs. As noted elsewhere throughout this document, the timing of potential reinforcement depends heavily on the success of managed charging programs, as is being initially established by the proposed utility program. Without managed charging, reinforcement requirements will be both earlier and larger.

3. **Investments By Non-Utility Entities:** In addition to actions by utilities, other market participants may be making incremental investments as part of more widespread vehicle adoption. Key examples include premiums associated with EV purchase, customer costs for charging infrastructure (net of utility contributions where applicable), and investments by private capital in public charging infrastructure. Long term estimates of those costs have been provided in support of the broader societal evaluation of net benefit.

## 6.1 Key Results: Utility Investments In Charging Infrastructure

DPL is proposing a customer support program for its Delaware territory, with multiple offers to address growing customer needs related to EV ownership and to address known adoption barriers that should encourage expanded EV adoption by new customers. Most of these programs are related to vehicle charging infrastructure, which is an appropriate role for the utility in the EV market ecosystem given its close technical connection with utility distribution infrastructure. Several of the programs focus on providing managed charging solutions for residential customers, which is a high impact strategy for minimizing EV charging impacts on the public grid, while also maximizing the economic benefits for other ratepayers (through more off-peak charging). These costs associated with the proposed programs are captured in the program budget, as summarized below.

| Program Budget | Number Of Units | Budget |
|---|---|---|
| Offer 1: Residential Whole House TOU Rate | Unlimited | $0 |
| Offer 2: Residential L2 (existing EVSE, with Fleetcarma) | 50 | $81,550 |
| Offer 3: New Residential Smart L2 Charger (utility installed) | 50 | $462,500 |
| Offer 4: New Multi-Family Smart L2 Charger | 10 | $78,000 |
| Offer 5: Neighborhool Smart L2 Chargers | 2 | $30,000 |
| Offer 6: Public DC Fast Chargers | 2 | $240,000 |
| Offer 7: Electric School Buses With V2G | TBD | $400,000 |
| Customer Enrollment and Outreach | N/A | $200,000 |
| Admin, IT Costs, Reporting | N/A | $746,500 |
| **Total Program Costs:** | | **$2,238,550** |

These costs were included as a utility program cost, recovered through rates, with all disbursements assumed to be in calendar year 2019.

## 6.2 Key Results: Utility Investments In Grid Reinforcement

EV charging increases the use of electricity, and longer term, could force reinforcement of utility infrastructure to accommodate those changes in load. These implications were not assessed in detail as part of this study, but Gabel has conducted in-depth engineering analysis of EV implications on utility infrastructure for other territories[8]. Those studies identified several general conclusions that we believe are applicable across a variety of territories, and those guidelines were used to estimate potential costs for grid reinforcement resulting from EV charging loads in the DPL-DE territory. Key guidelines include:

a) When the EV population is small (as an aggregate percentage), there is generally sufficient capacity within the distribution system to handle those incremental EV charging loads, although clustering affects (i.e. multiple EVs within a single neighborhood) could cause localized overload conditions.

b) During this early market phase, overload conditions, if they emerge, will be relatively localized and can be dealt with within the boundaries of routine maintenance and upgrade budgets.

c) Based on consideration of a wide variety of EV loading scenarios, in most cases overload conditions will emerge first on residential single phase transformers, and potentially on taps or overload protection components. Larger impacts on conductor capacity, sub-station elements, and transmission infrastructure are likely longer term, if they emerge at all. The timing, and impact scope, of EV charging depends heavily on residential EV charging patterns, and managed charging – if fully deployed – can defer (but not eliminate) these impacts in time.

d) Once the EV population is approximately equal to the number of single phase transformers, overload conditions will become more common since that condition begins to guarantee multiple vehicle charging loads on a single transformer. Past that point, more proactive grid reinforcement would be prudent to ensure responsible support for increased loading related to EV charging.

e) There are 56,613 single phase transformers in the DPL-DE territory. More proactive grid reinforcement therefore becomes necessary at approximately 7% EV penetration of the light duty fleet.

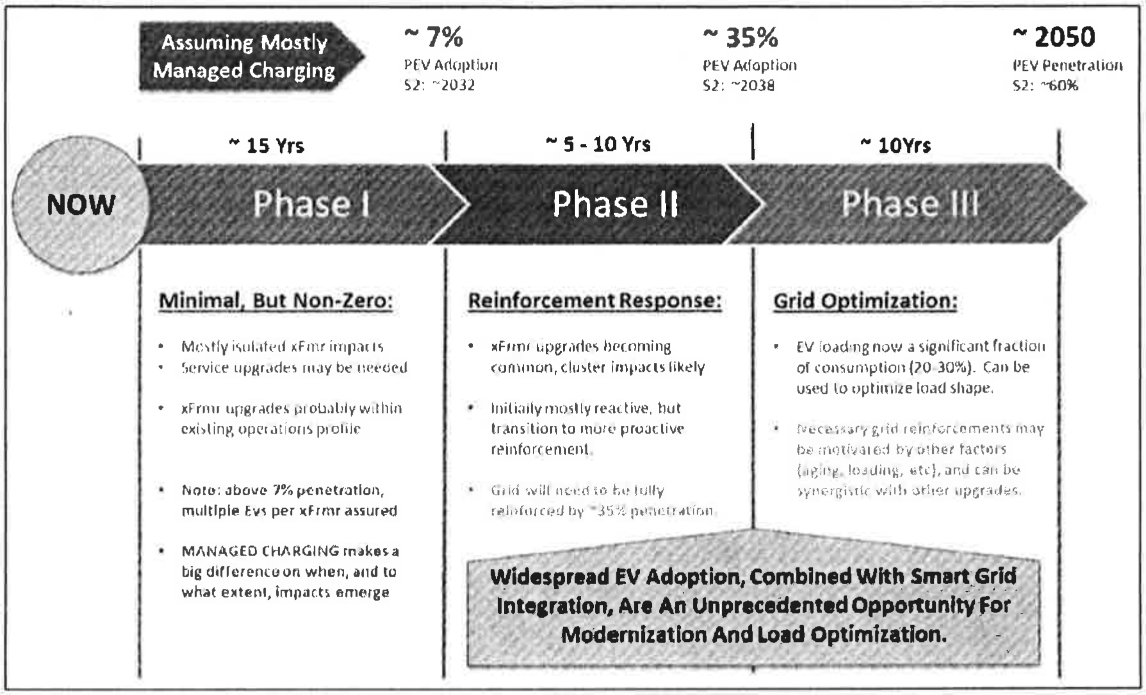
f) The impact analysis from other territories suggests that by the time the EV population is approximately five-times the number of single phase transformers, most grid reinforcement will need to be complete. In the case of the DPL territory in Delaware, this represents approximately 35% fleet penetration. The active grid reinforcement period is therefore expected to be between 7% and 35% EV penetration. For the EV forecast developed for the DPL-DE territory, this is projected to be from approximately roughly 2032 to 2038.

g) Distribution impacts will be felt most strongly on residential circuits, where the majority of vehicle charging electricity is delivered. Impact on commercial circuits, where workplace, public charging, and other specialized infrastructure (i.e. electric buses, etc.) have not been assessed in detail, but are generally expected to be less severe given a) the smaller number of installations and reduced energy delivery requirements (i.e. MWhrs delivered) in those charging segments, and b) the fact that those installations tend to require specialized interconnection engineering by the utility where load requirements can be more specifically accounted for.

h) Past approximately 35% EV penetration, vehicle charging represents a substantial load. A recommended utility priority during this mature phase of market development is using this quasi-dispatchable load to optimize grid loading and maximize economic benefits for ratepayers.

i) The above guidelines assume strong deployment of effective management charging programs, especially for residential customers. These programs must not just delay the start time of evening residential charging, but also spread that aggregate load over the full overnight period (~8 hours). If managed charging is not implemented, bigger impacts on infrastructure are likely to result.

j) The following diagram illustrates these three phases of market engagement based on changing infrastructure needs.




Based these guidelines, proactive grid reinforcement for the DPL-DE territory is assumed to take place from approximately 2032 to 2038, with approximately half the single phase transformer base being reinforced by 2035. A cost of $5,000 per transformer is assumed based on typical equipment and labor costs. Note that these upgrades, although motivated by EV loads, will also accomplish other reinforcement objectives, potentially including improved instrumentation, better resiliency, improved overall capacity, etc. It should also be noted that many of these transformers would require upgrade over a similar period, even if EV adoption did not happen. This assumption of full transformer upgrade is therefore extremely conservative, and probably overstates the costs that should be booked to EV adoption.

Based on these schedule and cost assumptions, **the total utility cost for grid reinforcement is estimated to be $131.1M (nominal sum) from 2032 – 2035, with an NPV of $56.1M.** Additional costs related to sub-station or transmission upgrades, if required, are not reflected[o].

## 6.3 Key Results: Estimated Non-Utility Costs

A market transition to greater use of EVs implies costs for market entities other than utilities, including EV owners, and other investors in vehicle charging infrastructure. These other multi-party costs – although outside the boundaries of utility investment – should be considered to have a comprehensive

[o] We are not aware of significant sub-station or transmission upgrades being identified as required in any other jurisdictions, even California where EV penetration is much higher. While we haven't studied the DPL-DE territory at an engineering level, our high level assessments of other territories are that the risks emerge first at the single phase transformer level (and perhaps other related feeder equipment), and that substation/transmission impacts, if they arise at all, would arise later.

view of total costs appropriate for the broader cost tests. The analysis considered the following components of non-utility costs:

1. **Incremental Vehicle Purchase Price:** In the current market, EVs are perceived to cost more than traditional gasoline vehicles. This conclusion is based on the fact that the average MSRP for all EVs on the market is higher than the average MSRP for all traditional gasoline vehicles on the market. Although this statistic may not be representative of how actual consumers make decisions at a transaction level, it is clear that this is the market *perception*, and consideration of the perceived premium is included in this benefit-cost analysis to make the analysis as comprehensive and transparent as possible. The premium was based on a study done in California on the average premium associated with EVs, as used by San Diego Gas and Electric in their 2014 EV program filing[9]. Those numbers reflect a purchase price premium of $8,694 for BEVs, and $8,081 for a PHEV (with at least 40 miles of electric range), as projected to 2019. Those premiums are estimated in the California study to decline by 10% a year, and this trend is assumed for this analysis through 2030, after which the premium is assumed to be zero (i.e. EVs are price competitive with traditional gasoline vehicles across a wide range of vehicle categories)[10]. The estimated purchase price premium for each year is applied to the total number of EVs sold in the DPL-DE territory over the analysis period, by BEV or PHEV vehicle type, to quantify this total market impact. This premium is estimated to total approximately $141.8M over the period ($94.0M NPV). Which is a relatively small fraction of the estimated $8-10B projected to be spent on new EVs in the DPL territory of Delaware through 2035.

2. **Non-Utility Investment In Charging Infrastructure:** A wide variety of market participants help pay for charging infrastructure, under a variety of business models and ownership paradigms. This makes estimates of total charging infrastructure costs complicated. However, the charging infrastructure required in key charging segments can be estimated based on the EV adoption forecast. The full cost of that infrastructure was quantified as part of the analysis (using typical installation costs for equipment and labor). The difference between this total infrastructure cost, and the costs proposed to be carried by the utilities through the proposed program, represents the non-utility investments in charging infrastructure. Under this methodology, the combination of utility investments and non-utility investments fully capture infrastructure investment requirements over time. Infrastructure needs were estimated for residential, workplace, public L2, and public DCFC charging segments with costs estimated using typical cost factors obtained from other utilities and industry. In general, these cost profiles include the cost of new service (where required), infrastructure to the EVSE installation, and the EVSE equipment (and network services where applicable). The amount of infrastructure needed across the above four segments was calculated to meet projected USAGE requirements, based on infrastructure supply factors from the recent U.S. Department of Energy (DOE) EV charging infrastructure plan[11]. The following table summarizes key assumptions related to the charging infrastructure requirement estimates:

| Charging Infrastructure Estimating Factors | Factor | Units | Trend |
|---|---|---|---|
| Capacity Requirements (Plugs per EV) | | | |
| Residential/Fleet (chargers for BEVs) | 100.0% | % new BEV sales | Constant -> 2035 |
| Residential/Fleet (chargers for PHEVs) | 25.0% | % new PHEV sales | Constant -> 2035 |
| Workplace plugs per EV (BEV & PHEV) | 0.03000 | Plugs/EV | Constant -> 2035 |
| Public L2 plugs per EV (BEV and PHEV) | 0.02200 | Plugs/EV | Constant -> 2035 |
| Public DCFC plugs per BEV | 0.00387 | Plugs/BEV | Constant -> 2035 |
| | | | |
| Cost Factors (Per Plug, equipment and labor) | | | |
| Total Cost per plug: residential/fleet L2 | $1,631 | $/plug | Constant -> 2035 |
| Total Cost per plug: workplace L2 | $6,000 | $/plug | Constant -> 2035 |
| Total Cost per plug: public L2 | $9,000 | $/plug | Constant -> 2035 |
| Total Cost per plug: public DCFC (at least 50KW) | $120,000 | $/plug | Constant -> 2035 |
| | | | |
| Infrastructure Requirements (plugs) | | | |
| New Residential/Fleet L2 Plugs | 140,737 | Plugs | Total Thru 2035 |
| New Workplace L2 Plugs | 3,266 | Plugs | Total Thru 2035 |
| New Public L2 Plugs | 2,042 | Plugs | Total Thru 2035 |
| New Public DCFC plugs | 257 | Plugs | Total Thru 2035 |

**Total costs for the four identified charging segments, net of utility contribution, are estimated to total $297.4M over the period, with an NPV of $137.8M.** Note that some of these assets are for the use of individual vehicle owners (such as private residential settings), others are quasi-public since they are used by multiple approved uses, and the public assets are used by the entire EV ownership fleet. The above numbers represent initial investment for the infrastructure, which may be recovered from EV drivers through usage charges. These non-utility costs are included in the benefit-cost analysis to ensure a broad and comprehensive accounting of net benefit, especially for the broader tests like the TRC and SCT, which are described below in Section 7.

Note: this analysis demonstrates that the utility investment is highly leveraged, meaning that for every utility dollar spent, significant additional investments are being made by other parties. The utility program represents a $2.2M program investment[p] that is matched by $297M of non-utility investment in charging infrastructure as well. The proposed utility programs do not cover the full costs required for infrastructure, and utility investment is matched by significant non-utility investment as well. Since these early stage utility programs help to "seed the market", significant future infrastructure is assumed to be built (especially for residential) without direct utility investment. In addition, the utility programs for public fast charging, are considered highly leveraged since they address key

[p] The cost model also accounts for additional potential utility investment longer term for grid reinforcement to support EV-induced loads. These costs are included to ensure robust coverage of potential costs and conservative net benefit estimates, but may not be required depending on the success of managed charging programs. Note that other investments are also being made – beyond that required for charging infrastructure – including investment in the EVs themselves. Those non-utility investments are also enabled by the utility programs that encourage adoption.