Electric Vehicle Cost-Benefit Analysis

Plug-in Electric Vehicle Cost-Benefit Analysis: Nevada

MJB & A

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Contents

List of Figures

List of Tables

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Executive Summary

This study estimated the costs and benefits of increased penetration of plug-in electric vehicles (PEV) in the state of Nevada, for two different penetration levels between 2030 and 2050.[1] The "ZEV Goal" scenario is based upon near-term (2025) Zero Emission Vehicle goals adopted by states that together comprise about a third of the automotive market, goals Governor Steve Sisolak has indicated Nevada will soon adopt.[2] The "State GHG Goal" scenario is based on the PEV penetration that would be required to achieve Nevada's long-term goals of economy wide zero or near-zero greenhouse gas (GHG) emissions in 2050.

This study focused on passenger vehicles and trucks; there are additional opportunities for electrification of non-road equipment and medium- and heavy-duty trucks and buses, but evaluation of these applications was beyond the scope of this study.

The study estimated the benefits that would accrue to all electric utility customers in Nevada due to increased utility revenues from PEV charging. This revenue could be used to support operation and maintenance of the electrical grid, thus reducing the need for future electricity rate increases. These benefits were estimated for a baseline scenario in which Nevada drivers 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 Nevada drivers with price signals or incentives to delay the start of PEV charging until after the daily peak in electricity demand (managed off-peak charging).

Increased peak hour load increases a utility's cost of providing electricity and may result in the need to upgrade distribution infrastructure. As such, managed off-peak PEV charging can provide net benefits to all utility customers by shifting PEV charging to hours when the grid is underutilized.

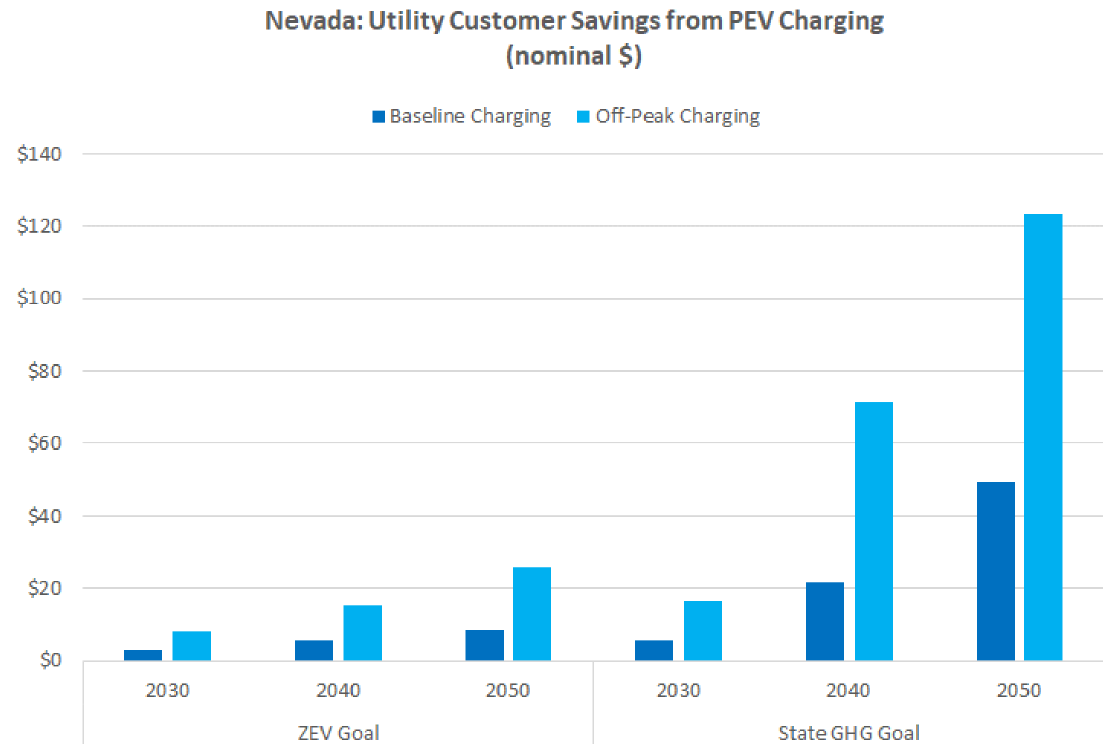
See Figure 1 for a summary of how the projected potential utility net revenue from PEV charging might affect average residential electricity bills for all Nevada electric utility customers.[3] As shown in the figure, under the State GHG Goal scenario, with managed off-peak charging, the average Nevada residential household could realize approximately $123 in annual utility bill savings in 2050 (nominal dollars).

[1] PEVs include battery-electric vehicles (BEV) and plug-in hybrid vehicles (PHEV).

[2] In 2013, six Northeast/Mid-Atlantic states (MD, MA, NY, CT, RI, VT) and two Pacific coast states (CA, OR) joined in a Zero Emission Vehicle Memorandum of Understanding to enact policies that will ensure the deployment of 3.3 million ZEVs by 2025.

[3] Based on 2019 average electricity use of 10,142 kWh per housing unit in Nevada.

Figure 1 Potential Effect of PEV Charging Net Revenue on Utility Customer Bills (nominal $)



In addition, the study estimated the potential annual financial benefits to Nevada drivers – from fuel and maintenance cost savings compared to owning gasoline vehicles, and societal benefits that could result from avoided emissions.

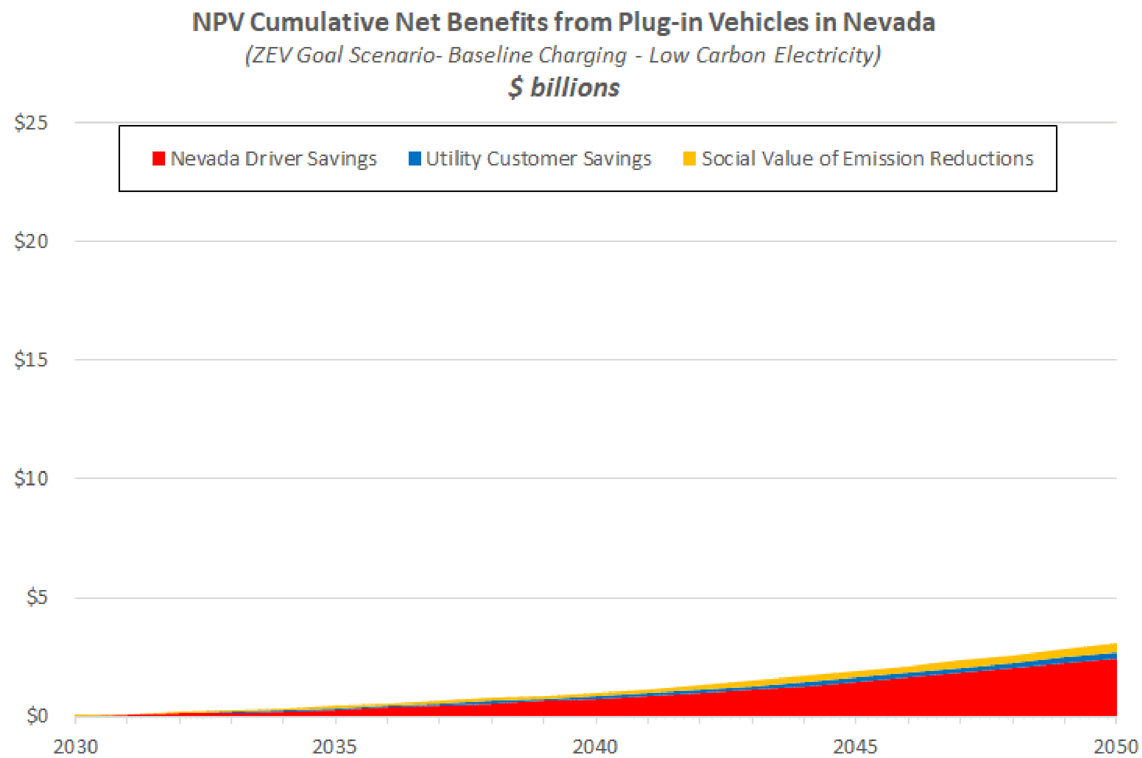
As shown in Figure 2 (ZEV Goal scenario), if Nevada meets short term (2025) goals for PEV penetration, and the increase in percent PEV penetration then continues at the same annual rate in later years, the net present value of **cumulative net benefits from greater PEV use in Nevada will exceed $3.2 billion state-wide by 2050**.[4] Of these total net benefits:

- At least $0.3 billion will accrue to electric utility customers in the form of reduced electric bills[5],
- $2.5 billion will accrue directly to Nevada drivers in the form of reduced annual vehicle operating costs, and
- $0.4 billion will accrue to society at large, as the value of reduced emissions.

[4] Using a 3 percent discount rate

[5] Figure 2 includes utility customer savings under the baseline charging scenario; savings would be higher under the managed off-peak charging scenario.

Figure 2 *NPV Cumulative Societal Net Benefits from NV PEVs – ZEV Goal scenario*

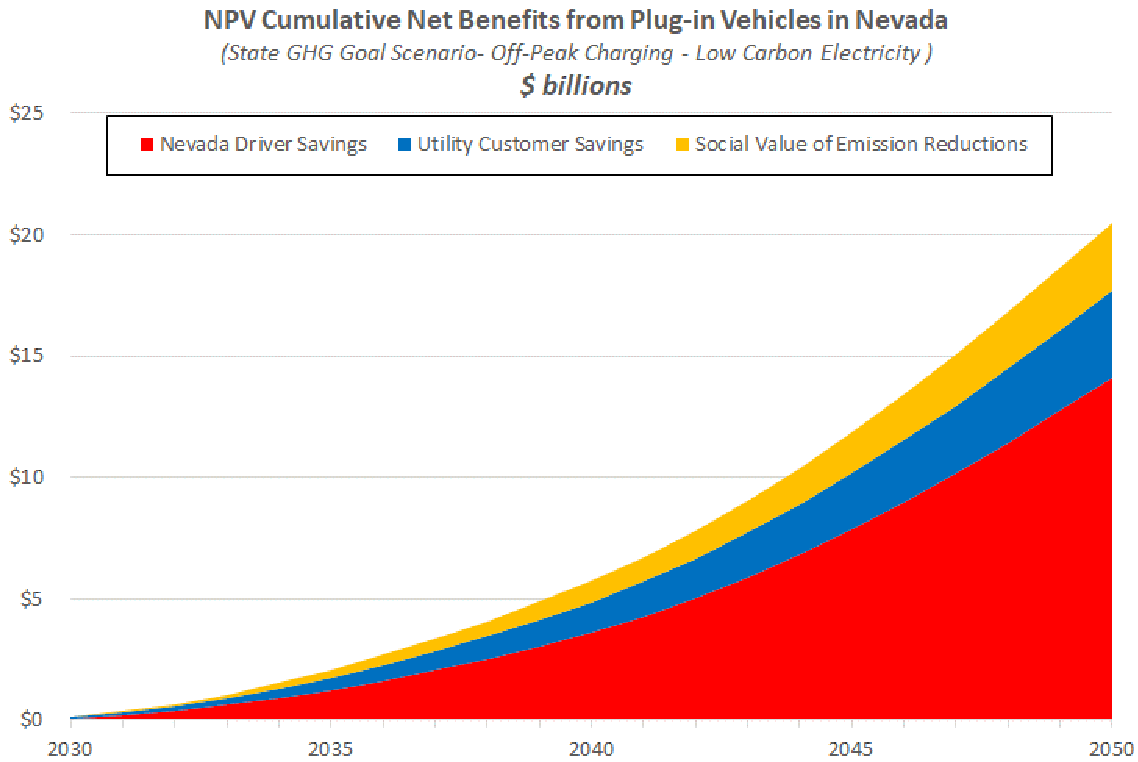


As shown in Figure 3 (State GHG Goal scenario), if the state meets its long-term goals of economy wide GHG emissions reductions in 2050, which requires even greater PEV penetration, the net present value of **cumulative net benefits from greater PEV use in Nevada could be nearly $21 billion state-wide by 2050**. Of these total net benefits:

- $3.6 billion will accrue to electric utility customers in the form of reduced electric bills[6]
- Up to $14.1 billion will accrue directly to Nevada drivers in the form of reduced annual vehicle operating costs
- $2.8 billion will accrue to society at large, as the value of reduced emissions

[6] Figure 3 includes utility customer savings under the managed off-peak charging scenario; savings would be lower under the baseline charging scenario.

Figure 3 *NPV Cumulative Societal Net Benefits from NV PEVs – State GHG Goal scenario*



By 2050, PEV owners are projected to save nearly $2,221 per vehicle (nominal $) in annual operating costs, compared to owning gasoline vehicles. A large portion of this direct financial benefit to Nevada drivers derives from reduced gasoline use—from purchase of lower cost, regionally produced electricity instead of gasoline imported to the state. Under the ZEV Goal scenario, PEVs will reduce cumulative gasoline use in the state by nearly 1.0 billion gallons through 2050 – this cumulative gasoline savings grows to almost 4.5 billion gallons through 2050 under the State GHG Goal scenario. In 2050, annual average gasoline savings will be approximately 203 gallons per PEV under the ZEV Goal scenario, while projected savings under the State GHG Goal scenario are 237 gallons per PEV.

This projected gasoline savings will help to promote energy security and independence and will keep more of vehicle owners' money in the local economy, thus generating even greater economic impact. Studies in other states have shown that the switch to PEVs can generate up to $570,000 in additional economic impact for every million dollars of direct savings, resulting in up to 25 additional jobs in the local economy for every 1,000 PEVs in the fleet [1].

In addition, this reduction in gasoline use will reduce cumulative net GHG emissions by nearly 10.2 million metric tons through 2050 under the ZEV Goal scenario, and over 46 million metric tons under the State GHG Goal scenario.[7] The switch from gasoline vehicles to PEVs is also projected to reduce annual NOx emissions in the state by over 105 tons in 2050 under the ZEV Goal scenario, and by over 575 tons under the State GHG Goal scenario.

[7] Net of emissions from electricity generation

Background - Nevada

On June 3, 2019, Nevada Governor Steve Sisolak signed Senate Bill (SB) 254, which set goals of a 28 percent reduction of statewide GHG emissions by 2025 and 45 percent reduction by 2030, both below 2005 levels, as well as “zero or near-zero” emissions by 2050. SB 254 also updated the state’s GHG emissions inventory mandate to require state agencies to issue an annual statewide GHG emissions inventory, as well as a 20-year forecast of future emissions. The annual reports are also required to include a “statement of policies” for consideration in addressing GHG emissions in Nevada and, in certain years, a quantification of emissions reductions necessary to meet the 2025 and 2030 GHG reduction targets. Nevada has since released an update to its GHG inventory concerning data from 2017 and projections of future emissions through 2040. [2]

In the same year, Governor Sisolak also signed SB 358 into law, committing Nevada to raise the stringency of its Renewable Portfolio Standard (RPS) governing retail electricity. The law requires electric retail providers to obtain not less than 50 percent of electricity from eligible renewable resources by 2030, up from the previous requirement of 25 percent by 2025. SB 358 also codified a legislative goal of “achieving by 2050 an amount of energy production from zero carbon dioxide emission resources equal to the total amount of electricity sold by providers of electric service in this state.” [3]

In November 2019, Governor Sisolak issued an Executive Order (EO) directing his administration to develop a State Climate Strategy, which was delivered to the Governor on December 1, 2020. The EO directed the State Climate Strategy to include “specific policy and budget recommendations to reduce [GHG] emissions and mitigate the effects of climate change as needed to meet the goals set forth under this [EO].” [4]

The State Climate Strategy acts as a “roadmap” for policymakers at the state and local level and focuses on three distinct goals: 1) develop a framework to implement the GHG reduction targets set in 2019 for the entire economy in Nevada, 2) create a foundation to improve resilience to climate-related impacts in the State, and 3) layout a plan for continuing climate action in the State to achieve Nevada’s climate goals.

In 2020, Governor Sisolak announced that Nevada will begin a rulemaking process to evaluate the adoption of California’s Low-Emission Vehicle standards and Zero-Emission Vehicle standards. These regulations would require an increasing number of electric and zero-emission vehicles sold in the state. Nevada is currently in the rulemaking process; the state could adopt the regulations by as early as 2021 and become effective in 2024. [5]

Clean Transportation in Nevada

PEV Vehicles in Nevada

In 2018, Nevada saw new sales of 2,325 PEVs and PHEVs, a 117 percent increase from 2017. With these new sales, the annual market share of PEVs and PHEVs (percent sold out of the total number light-duty vehicles within the state during a calendar year) reached 1.62 percent in 2018, up from 0.79 percent in 2017 – earning Nevada the fourteenth highest market share of EVs in the country. [6] This trend continued in 2019, with sales of 2,955 new PEVs added through the end of October 2019, bringing the total PEV registrations in Nevada to 9,251 and increasing the annual market share to 2.41 percent. [7]

Public PEV Charging Stations in Nevada

Nevada currently has 274 electric charging stations open to the public, with a total of 987 outlets, both regular and fast-charging. With this number, Nevada has the 26th highest count of EV charging stations in the U.S. [8] Many of these stations are clustered in the metropolitan areas of Las Vegas and Reno. [9]

The Nevada Electric Highway initiative is a partnership between the Governor’s Office of Energy (GOE), and energy service providers in the state to expand the state’s EV charging infrastructure along major interstates.

Phase I of the initiative is largely complete, resulting in the placement of several new charging stations at cost-effective and strategic locations between Reno and Las Vegas. Phase II was initiated in 2017 and GOE is looking to complete the Nevada Electric Highway in 2021. [10]

Time-of-Use (TOU) Charging Rates

NV Energy offers several EV time-of-use (TOU) rates that allow customers to pay a discounted rate if they charge the vehicle during specified off-peak periods. Each TOU offering has summer (June through September) and winter (October through May) seasons, with different hourly rates that reflect seasonal differences in the timing of peak electric demand. The TOU rates are available to customers in NV Energy's northern and southern service territories and are available for both residential and commercial customers.

The residential charging rate schedule has a recharge period of 10:01pm through 8:00am. For residential customers, the entire house or apartment receives the rate discount, not just the energy used to charge the vehicle. The commercial charging rate schedule has a ten-year "demand charge rate reduction" transition period and a 10:01pm through 7:00am recharge period. [11]

NV Energy also provides rebates to eligible business customers for the purchase and installation of Level 2 chargers and direct current (DC) fast-charging stations. [12]

Study Methodology

This section briefly describes the methodology used for this study. For more information on how this study was conducted, including a general discussion of the assumptions used and their sources, see the report: *Mid-Atlantic and Northeast Plug-in Electric Vehicle Cost-Benefit Analysis, Methodology & Assumptions* (October 2016).[8] This report can be found at:

http://mjbradley.com/sites/default/files/NE_PEV_CB_Analysis_Methodology.pdf

This study evaluated the costs and benefits of two different levels of PEV penetration in Nevada between 2030 and 2050. These PEV penetration scenarios bracket short and long-term policy goals for ZEV adoption and GHG reductions which have been adopted by Nevada and other states, and localities.[9]

ZEV Goal Scenario: Penetration of PEVs equivalent to Nevada's participation in a program similar to the *8-state ZEV Memorandum of Understanding*. Compliance with this MOU would require approximately 6 percent of in-use light duty vehicles in Nevada to be ZEV by 2025. Assuming the increase in percent PEV penetration then continues at the same annual rate in later years, PEV penetration is assumed to be 8.9 percent in 2030, 14.7 percent in 2040, and 20.6 percent in 2050.[10]

State GHG Goal Scenario: The level of PEV penetration required to reduce total light-duty GHG emissions in Nevada in 2050 by more than 90 percent from 2005 levels with 100 percent carbon free electricity, to meet Nevada's goal for "zero or near zero" emissions. This will require PEV penetration of 17 percent in 2030, 66 percent in 2040 and 95 percent in 2050.

Both of these scenarios are compared to a baseline scenario with very little PEV penetration and continued use of gasoline vehicles. The baseline scenario is based on future annual vehicle miles traveled (VMT) and fleet characteristics (e.g., cars versus light trucks) as projected by the Nevada Department of Transportation.

Based on assumed future PEV characteristics and usage, the analysis projects annual electricity use for PEV charging at each level of penetration, as well as the average load from PEV charging by time of day. The analysis then projects the total revenue that Nevada's electric distribution utilities would realize from sale of this electricity, their costs of providing the electricity to their customers, and the potential net revenue (revenue in excess of costs) that could be used to support maintenance of the distribution system.

For each PEV penetration scenario, this analysis calculates utility revenue, costs, and net revenue for two different PEV charging scenarios: 1) a baseline scenario in which all PEVs are plugged in and start to charge as soon as

[8] This analysis used the same methodology as described in the referenced report, but used different PEV penetration scenarios, as described here. In addition, for this analysis fuel costs and other assumptions taken from the Energy Information Administration (EIA) were updated from EIA's Annual Energy Outlook 2016 to those in the Annual Energy Outlook 2020. Baseline assumptions as to fuel economy of future new gasoline vehicles were also updated to reflect the SAFE rule adopted by EPA and the National Highway Traffic Safety Administration (NHTSA) in 2020. This rule reduced new car fuel economy increases required under the Corporate Average Fuel Economy (CAFE) program for model years 2021 – 2026, compared to prior CAFE standards that had been adopted in 2012. For projections of future PEV costs, this analysis also used updated assumptions from a 2019 study by the International Council on Clean Transportation [13]. In addition, as further described in this section, this analysis used a modified methodology to calculate incremental energy, generation capacity and transmission/distribution costs associated with PEV charging. This analysis also includes an estimate of NOx reductions resulting from transportation electrification; the methodology used is not included in the cited report but is described here.

[9] The states of CA, CT, FL, MA, MD, ME, MN, NH, NJ, NY, OR, RI, and VT have all set economy-wide goals of 75-80 percent GHG reduction by 2050. The starting point for the target 2050 GHG reduction percentage varies by state, from 1990 to 2006. The District of Columbia has also adopted a goal to reduce GHG emissions by 80 percent from 2006 levels by 2050.

[10] While the 8-state MOU counts fuel cell vehicles and PEVs as zero emission vehicles, this scenario assumes that all ZEVs will be PEV given the fact fuel cell technology lags behind battery technology and fuel cell vehicles face a greater infrastructure challenge.

they arrive at home each day, and 2) a managed off-peak charging scenario in which a significant portion of PEVs delay the start of charging until non-peak periods each day.

Real world experience from the EV Project demonstrates that, without a "nudge", drivers will generally plug in and start charging immediately upon arriving home after work (scenario 1), exacerbating system-wide afternoon/evening peak demand.[11] However, if given a "nudge" - in the form of a properly designed and marketed financial incentive - many Nevada drivers will choose to delay the start of charging until off-peak times, thus reducing the effect of PEV charging on evening peak electricity demand (scenario 2). [14]

The costs of serving PEV load include the cost of electricity generation, the cost of transmission, incremental peak generation capacity costs for the additional peak load resulting from PEV charging, and annual infrastructure upgrade costs for increasing the capacity of the transmission and secondary distribution systems, to handle the additional load.

This analysis calculates average system-wide electricity generation costs based on projections by the Energy Information Administration, but then adds incremental costs associated specifically with PEV charging load under each charging scenario, based on timing of the charging load. This was done using forecast data from NV Energy. This data shows that the cost for Nevada utilities to purchase bulk electricity varies by year and time of day, with current average annual costs ($/MWh) highest during the afternoon peak load period (6:00 PM – 10:00 PM), lower in the early morning (12:00 AM – 6:00 AM), and lowest in the middle of the day. NV Energy projects that current cost trends will evolve over time as higher levels of renewables are integrated into the grid to meet state RPS goals, with the result that costs will be even lower during the day and higher at night. Even accounting for these trends, as discussed below, compared to baseline charging, managed off-peak charging reduces utility net costs to supply the load (demand and supply) as load shifts from the late afternoon/early evening to the early morning hours.

To calculate the costs associated with adding generation and transmission/distribution capacity to handle the incremental PEV charging load, this analysis uses a value of $162/kW-year in 2020 (nominal dollars). This value is increased by 2.58 percent per year in later years to account for inflation.[12] For each scenario in each year, this value is multiplied by the estimated incremental load (kW) imposed by EV charging during the late afternoon peak load period (4 p.m. – 8 p.m.), to calculate incremental capacity costs resulting from PEV charging.

For each PEV penetration scenario, this analysis also calculates the total incremental annual cost of purchase and operation for all PEVs in the state, compared to "baseline" purchase and operation of gasoline cars and light trucks. For both PEVs and baseline vehicles, annual costs include the amortized cost of purchasing the vehicle, annual costs for gasoline and electricity consumption, and annual maintenance costs. For PEVs it also includes the amortized annual cost of the necessary home charger. This analysis is used to estimate average annual financial benefits to Nevada drivers.

For each PEV penetration scenario, this analysis also calculates annual greenhouse gas (GHG) emissions from electricity generation for PEV charging and compares that to baseline emissions from operation of gasoline vehicles. For the baseline and PEV penetration scenarios, GHG emissions are expressed as carbon dioxide equivalent emissions (CO_2-e) in metric tons (MT). GHG emissions from gasoline vehicles include direct tailpipe emissions as well as "upstream" emissions from production and transport of gasoline.

For each PEV penetration scenario, GHG emissions from PEV charging are calculated based on a "low carbon electricity" scenario. For the ZEV Goal scenario, the electric grid is assumed to reach 50 percent carbon-free by 2030 and then remain at 50 percent through 2050. For the State GHG Goal scenario, low carbon electricity is

[11] The EV Project is a public/private partnership partially funded by the Department of Energy which has collected and analyzed operating and charging data from more than 8,300 enrolled plug-in electric vehicles and approximately 12,000 public and residential charging stations over a two-year period.

[12] Based on data provided by NV Energy's Resource team and MJB&A's inflation adjustment. [15]

based on Nevada achieving 50 percent renewable energy by 2030 and 100 percent carbon-free electricity generation by 2050, in accordance with goals established under the state's RPS rules (SB 358).

Net annual GHG reductions from the use of PEVs are calculated as baseline GHG emissions (emitted by gasoline vehicles) minus GHG emissions from each PEV penetration scenario. The monetized "social value" of these GHG reductions from PEV use are calculated using the Social Cost of Carbon ($/MT), as calculated by the U.S. government's Interagency Working Group on Social Cost of Greenhouse Gases. The Interagency Working Group calculated GHG social values based on discount rates of 2.5 percent, 3 percent, and 5 percent; for this analysis we used the average values generated with a 3 percent discount rate, which is in the middle of the range of reported values. The values used are $43 per metric ton in 2015, rising to $122/MT in 2050 (constant 2015$).

Finally, this analysis projected annual net reductions in nitrogen oxide (NOx) emissions under each PEV penetration scenario that would result from the use of electric vehicles instead of gasoline vehicles.[13] To do so, the reduction in emissions due to reducing miles driven by conventional vehicles was estimated, then subtracted the emissions resulting from generation of the electricity required to charge the electric vehicles that replaced them. To calculate the reduction in emissions from conventional vehicles, for each year in the analysis the authors used emission factors (grams/mile) for new conventional vehicles purchased in that year. These emission factors were derived from the United States Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES) model [16].

The monetized social value of these NOx reductions was calculated using a national average value of $15,909 per ton of NOx in 2018, escalated in future years using EIA inflation assumptions. The 2018 value was derived from modeling done by the Environmental Protection Agency using their Response Surface Model [17]; this value represents a national average for mobile source NOx.

[13] These reductions are net of projected NOx emissions from production of electricity required to charge the PEVs.

Study Results

This section summarizes the results of this study, including the projected number of PEVs; electricity use and load from PEV charging; projected GHG reductions compared to continued use of gasoline vehicles; benefits to utility customers from increased electricity sales; and projected financial benefits to Nevada drivers compared to owning gasoline vehicles.

All costs and financial benefits are presented as net present value (NPV), using a 3 percent discount rate, unless otherwise noted.

Plug-in Vehicles, Electricity Use, and Charging Load

Vehicles and Miles Traveled

The projected number of PEVs and conventional gasoline vehicles in the Nevada light duty fleet under each PEV penetration scenario is shown in Figure 4, and the projected annual miles driven by these vehicles is shown in Figure 5.[14]

There are currently 0.7 million cars and 0.6 million light trucks registered in Nevada, and these vehicles travel 14.6 billion miles per year. Both the number of vehicles and total annual vehicle miles are projected to increase by 25 percent through 2050, to 1.6 million light duty vehicles traveling 18.2 billion miles annually.[15]

In order to meet the ZEV Goal scenario, the number of PEVs registered in Nevada would need to increase from approximately 8,000 today, to 78,000 by 2025. Assuming the same annual increase in percent PEV penetration in later years, there would be 128,000 PEVs in the state in 2030, 217,000 in 2040, and 329,000 in 2050 (ZEV Goal penetration scenario).

In order to put the state on a path to achieve “near zero” in light-duty GHG emissions from 2005 levels by 2050 (State GHG Goal scenario) there would need to be approximately 244,000 PEVs in Nevada by 2030, rising to nearly 1.0 million in 2040, and 1.5 million in 2050.

Note that under both PEV penetration scenarios the percentage of total VMT driven by PEVs each year is lower than the percentage of plug-in vehicles in the fleet. This is because PEVs are assumed to have a “utility factor” less than one – i.e., due to range restrictions neither a battery-electric nor a plug-in hybrid vehicle can convert 100 percent of the miles driven annually by a baseline gasoline vehicle into miles powered by grid electricity. In this analysis BEVs with 250-mile range per charge are conservatively assumed to have a utility factor of 90 percent in 2030 increasing to 95 percent in 2050, while PHEVs are assumed to have an average utility factor of 75 percent in 2030, rising to 85 percent in 2050. This analysis estimates that Nevada could reduce light-duty fleet GHG in 2050 by 80 percent from 2005 levels if 84 percent of miles were driven by PEVs on electricity (Figure 5). However, in order to achieve this level of electric miles 90 percent of light-duty vehicles would need to be PEVs (Figure 4).

[14] This analysis only includes cars and light trucks. It does not include medium- or heavy-duty trucks and buses.
[15] Vehicle fleet and VMT growth is assumed to mirror projected population growth.

Figure 4 Projected Nevada Registered Vehicles

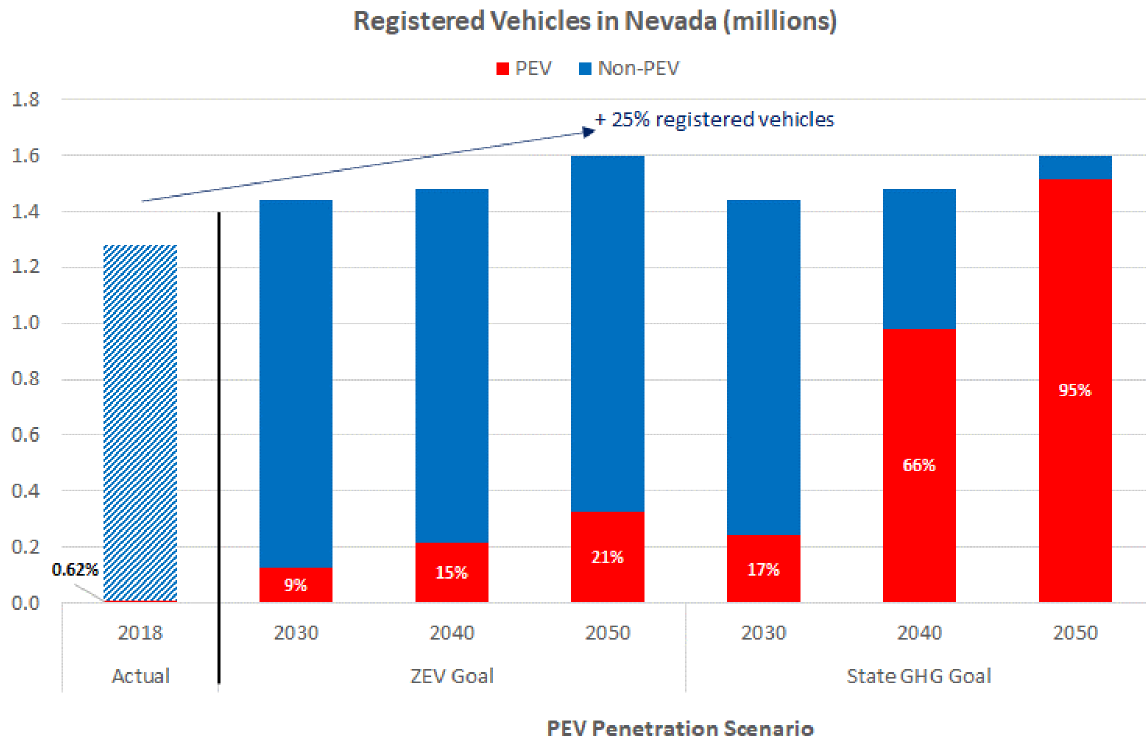
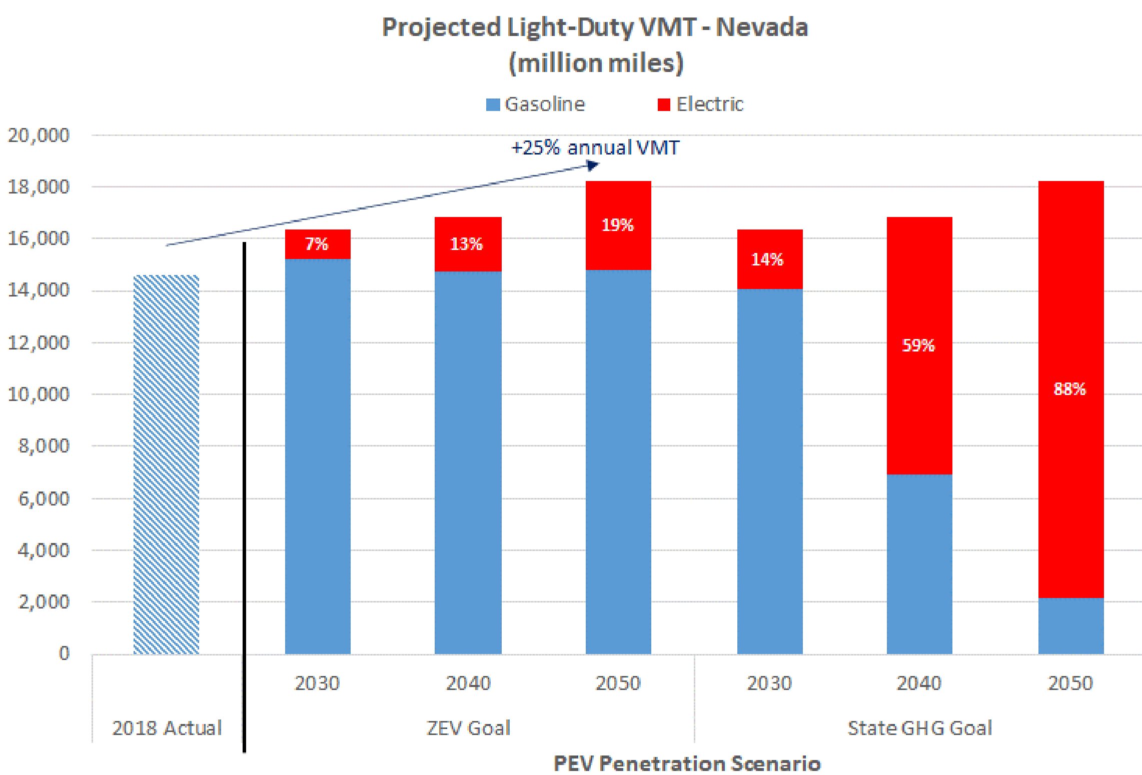


Figure 5 Projected Nevada Light Duty Fleet Vehicle Miles Traveled



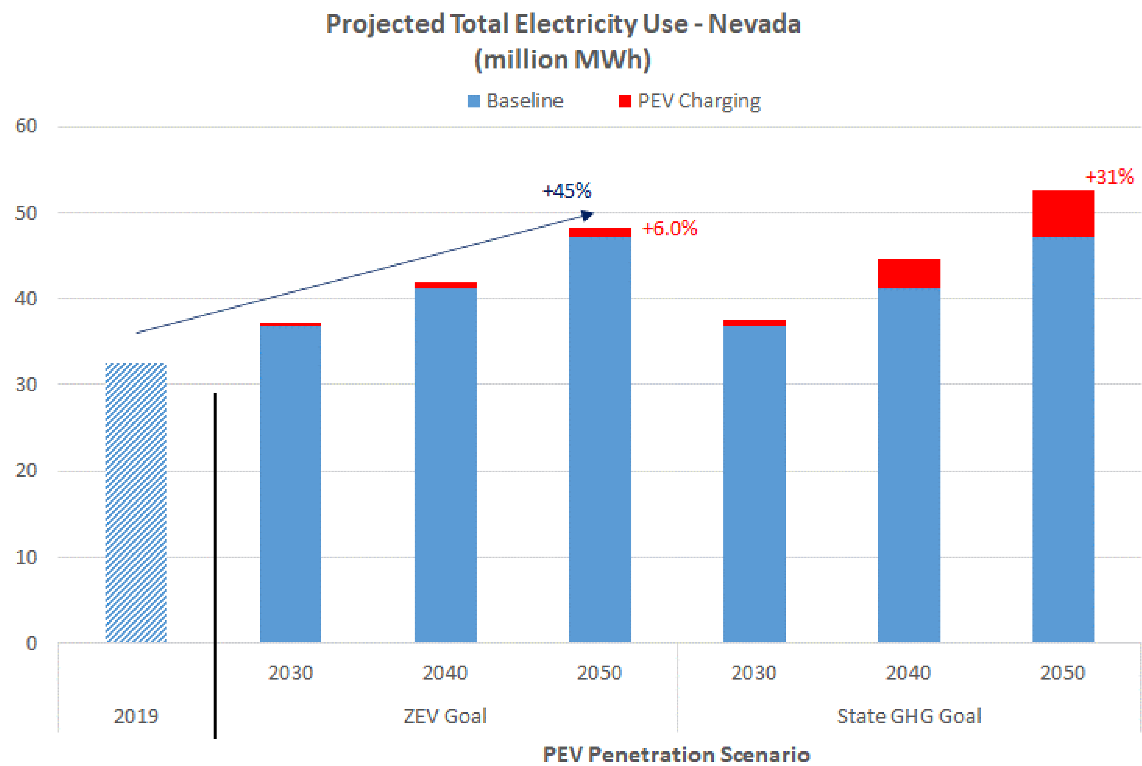
Charging Electricity Use

The estimated total PEV charging electricity used in Nevada each year under the PEV penetration scenarios is shown in Figure 6.

In Figure 6, projected baseline electricity use without PEVs is shown in blue and the estimated incremental electricity use for PEV charging is shown in red. State-wide electricity use in Nevada is currently 32.4 million MWh per year. Annual electricity use is projected to increase to 36.8 million MWh in 2030 and continue to grow after that, reaching 47.2 million MWh in 2050 (45 percent greater than 2019 level).

Under the ZEV Goal penetration scenario, electricity used for PEV charging is projected to be 0.4 million MWh in 2030 – an increase of 2.9 percent over baseline electricity use. By 2050, electricity for PEV charging is projected to grow to 1.1 million MWh – an increase of 6.0 percent over baseline electricity use. Under the State GHG Goal scenario electricity used for PEV charging is projected to be 0.8 million MWh in 2030, growing to 5.4 million MWh and adding 31 percent to baseline electricity use in 2050.

Figure 6 Estimated Total Electricity Use in Nevada



PEV Charging Load

This analysis evaluated the effect of PEV charging on the Nevada electric grid under two different charging scenarios. Under both scenarios, 78 percent of all PEVs are assumed to charge exclusively at home and 22 percent are assumed to charge both at home and at work. Under the baseline charging scenario, all Nevada drivers are assumed to plug-in their vehicles and start charging as soon as they arrive at home or at work (if applicable) each day. Under the managed off-peak charging scenario 80 percent of Nevada drivers who arrive at home after noon each day are assumed to delay the start of home charging until after 9 PM – in response to a price signal or incentive provided by their utility.[16] Further, this scenario assumes that off-peak charging will be managed by

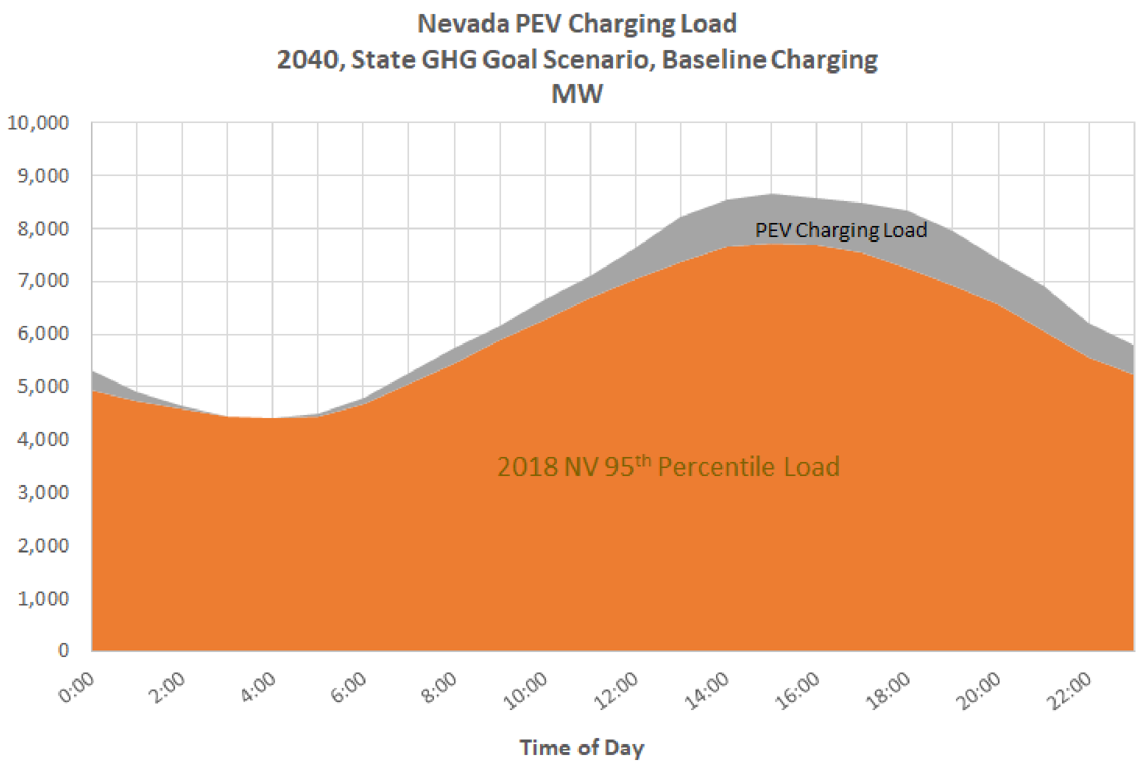
[16] Utilities have many policy options to incentivize off-peak PEV charging. This analysis does not compare the efficacy of different options.

staggering charge start times between 10 PM and 8 AM for individual PEVs, to avoid a sharp secondary peak at 10 PM.[17]

See Figure 7 (baseline) and Figure 8 (managed off-peak) for a comparison of PEV charging load under the baseline and managed off-peak charging scenarios, using the 2040 State GHG Goal penetration scenario as an example. In each of these figures, the 2019 Nevada 95th percentile load (MW) by time of day is plotted in orange, and the projected incremental load due to PEV charging is plotted in grey. [18]

In 2019 daily electric load in Nevada was generally in the range of 4,400 – 5,000 MW from midnight to 5 AM, ramping up through the morning and early afternoon to peak at approximately 7,700 MW between 3 PM and 5 PM, and then falling off through the late afternoon and evening hours.

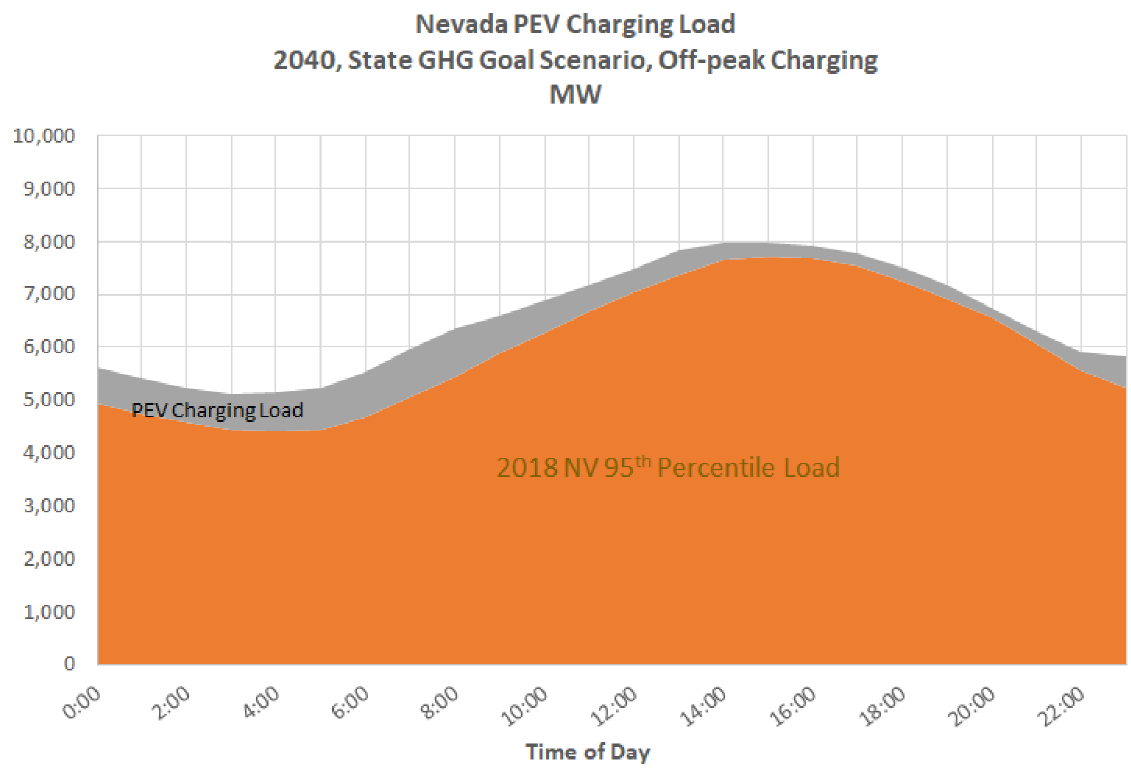
Figure 7 2040 Projected Nevada PEV Charging Load, Baseline Charging (State GHG Goal scenario)



As shown in Figure 7, baseline PEV charging is projected to add load primarily between 7 AM and midnight, as people charge at work early in the day and then at home later in the day. The PEV charging peak coincides with the existing afternoon peak load period between 3 PM and 5 PM.

[17] Utilities have multiple policy and technical options for implementing managed charging. This analysis does not endorse any particular methodology.
[18] For each hour of the day actual load in 2019 was higher than the value shown on only 5 percent of days (18 days).

Figure 8 2040 Projected Nevada PEV Charging Load, Off-peak Charging (State GHG Goal scenario)



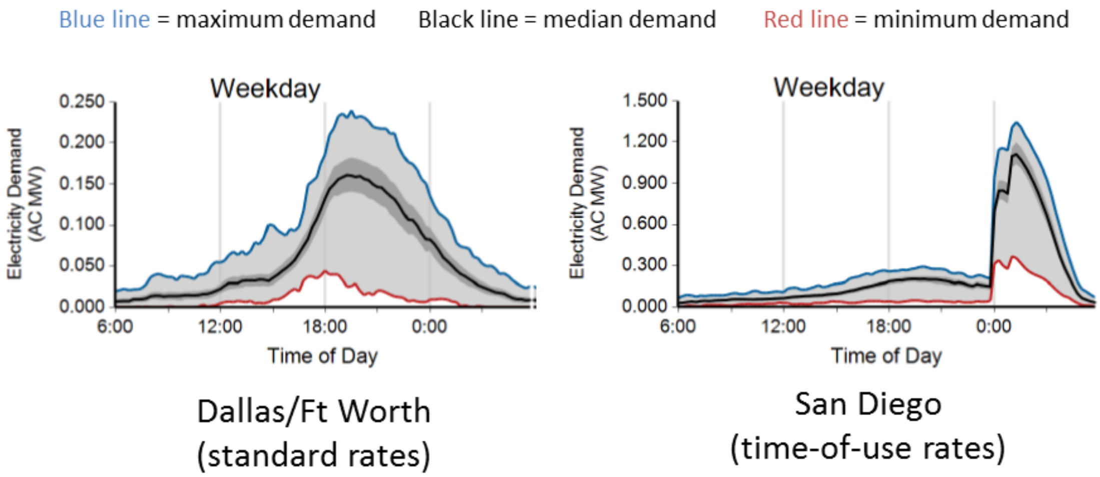
As shown in Figure 8, off-peak charging significantly reduces the incremental PEV charging load during the afternoon peak load period but distributes load through the late evening and continuing into the early morning hours, between 10 PM and 8 AM. The shape of this late evening/early morning peak can potentially be controlled based on the design of off-peak charging incentives[19]. It should also be noted that those early morning hours are often the hours of the day when wind generation peaks.

These baseline and off-peak load shapes are consistent with real world PEV charging data collected by the EV Project, as shown in Figure 9. In Figure 9 the graph on the left shows PEV charging load in the Dallas/Ft Worth area where no off-peak charging incentive was offered to drivers. The graph on the right shows PEV charging load in the San Diego region, where the local utility offered drivers a time-of-use rate with significantly lower costs ($/kWh) for charging during the "super off-peak" period between midnight and 5 a.m. [14] [20]

[19] This analysis assumes off-peak charging will be managed, with individual vehicles starting to charge between 10 PM and 8 AM. Based on annual mileage per vehicle, and projected PEV energy use, the average over-night charge is projected to take less than 3 hours using Level 1 and Level 2 home chargers.

[20] Off-peak charging start times in San Diego are not actively controlled based on the design of the incentive, so there is typically a sharp peak in load at midnight, the start of the 'super off-peak" period with lower energy costs.

Figure 9 PEV Charging Load in Dallas/Ft Worth and San Diego areas, EV Project



See Table 1 for a summary of the projected incremental afternoon peak hour load (MW) in Nevada, from PEV charging under each penetration and charging scenario. This table also includes a calculation of how much this incremental PEV charging load would add to the 2019 95th percentile peak hour load.

Under the ZEV Goal penetration scenario, PEV charging would add 124 MW load during the afternoon peak load period on a typical weekday in 2030, which would increase the 2019 baseline peak load by about 1.6 percent. By 2050, the afternoon incremental PEV charging load would increase to 322 MW, adding more than 4 percent to the 2019 baseline afternoon peak. By comparison the afternoon peak hour PEV charging load in 2030 would be only 31 MW for the off-peak charging scenario, increasing to 80 MW in 2050.

Under the State GHG Goal penetration scenario, baseline PEV charging would increase the total 2019 afternoon peak electric load by about 19 percent in 2050, while off-peak charging would only increase it by about 5 percent.[21]

Table 1 Projected Incremental Afternoon Peak Hour PEV Charging Load (MW)

		ZEV Goal			**State GHG Goal**		
		2030	**2040**	**2050**	**2030**	**2040**	**2050**
Baseline Charging	PEV Charging (MW)	124.5	211.9	321.5	262.1	1,087.4	1,408.0
	Increase relative to 2019 Peak	*1.6%*	*2.8%*	*4.2%*	*3.4%*	*14.2%*	*19.3%*
Off-Peak Charging	PEV Charging (MW)	30.6	52.4	80.1	63.2	263.7	353.2
	Increase relative to 2019 Peak	*0.4%*	*0.7%*	*1.0%*	*0.8%*	*3.4%*	*4.8%*

[21] Given projected significant increases in total state-wide electricity use through 2050, baseline peak load (without PEVs) is also likely to be higher in 2050 than 2019 peak load; as such the percentage increase in baseline peak load due to high levels of PEV penetration is likely to be lower than that shown in Table 1.

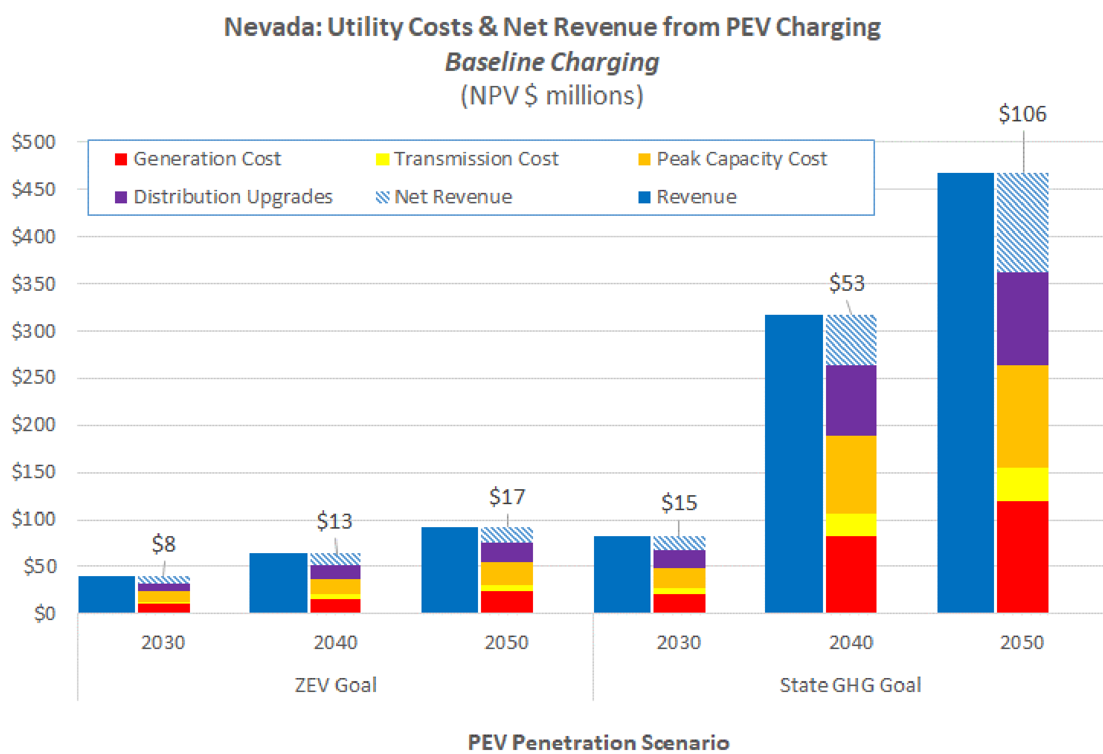
As discussed below, increased peak hour load increases a utility's cost of providing electricity, and may result in the need to upgrade distribution infrastructure. As such, off-peak PEV charging can provide net benefits to all utility customers by bringing in significant new revenue in excess of associated costs.

Utility Customer Benefits

The estimated NPV of revenues and costs for Nevada' electric utilities to supply electricity to charge PEVs under each penetration scenario are shown in Figure 10, assuming the baseline PEV charging scenario.

In Figure 10, projected utility revenue is shown in dark blue. Under the ZEV Goal penetration scenario, the NPV of revenue from electricity sold for PEV charging in Nevada is projected to total $40 million in 2030, rising to $92 million in 2050. Under the State GHG Goal scenario, the NPV of utility revenue from PEV charging is projected to total $82 million in 2030, rising to $468 million in 2050.

Figure 10 NPV of Projected Utility Revenue and Costs from Baseline PEV Charging



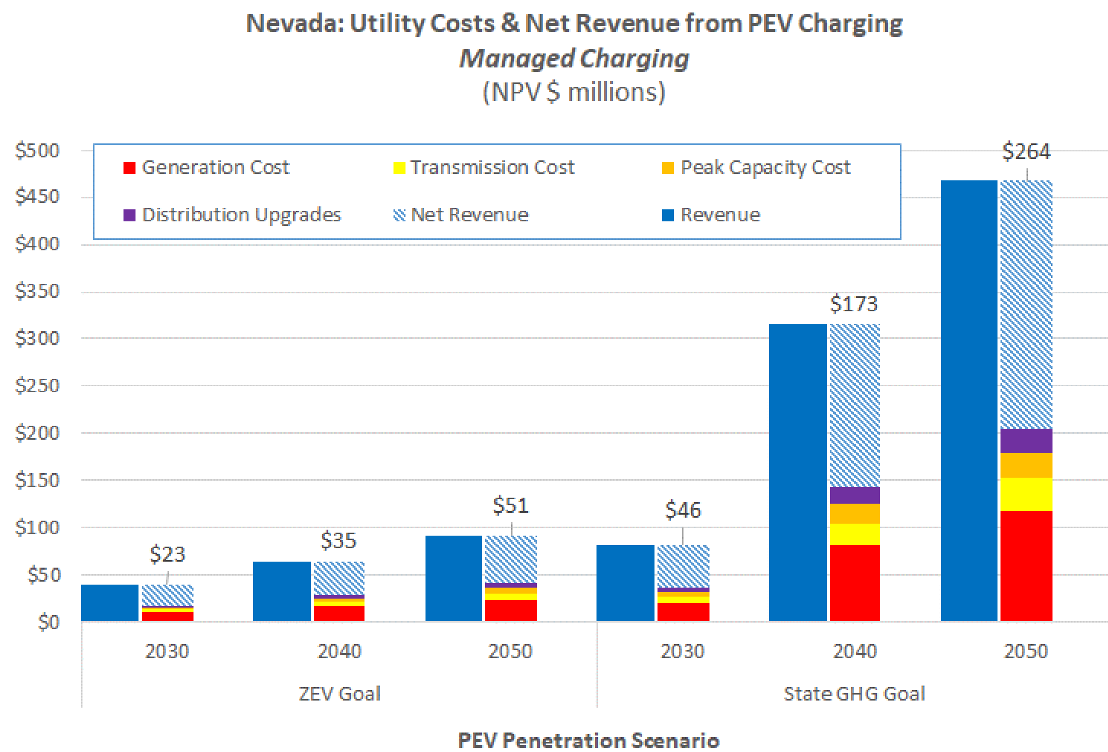
The different elements of incremental cost that utilities would incur to purchase and deliver additional electricity to support PEV charging are shown in red (generation), yellow (transmission), orange (peak capacity), and purple (transmission and distribution upgrade cost). Generation and transmission costs are proportional to the total power (MWh) used for PEV charging, while peak capacity costs are proportional to the incremental peak load (MW) imposed by PEV charging. Transmission and distribution upgrade costs are costs incurred by the utility to upgrade their own distribution infrastructure to handle the increased peak load imposed by PEV charging.

The striped light blue bars in Figure 10 represent the NPV of projected "net revenue" (revenue minus costs) that utilities would realize from selling additional electricity for PEV charging under each PEV penetration scenario. Under the ZEV Goal penetration scenario, the NPV of net revenue in Nevada is projected to total $8 million in 2030, rising to $17 million in 2050. Under the State GHG Goal scenario, the NPV of utility net revenue from PEV charging is projected to total $15 million in 2030, rising to $106 million in 2050. The NPV of projected annual utility net revenue averages $63 per PEV in 2030, and $51 - $70 per PEV in 2050.

Figure 11 summarizes the NPV of projected utility revenue, costs, and net revenue for off-peak charging under each PEV penetration scenario. Compared to baseline charging (Figure 10) projected revenue, and projected transmission costs are the same, but projected generation, peak capacity and transmission and distribution upgrade costs are lower due to a smaller incremental peak load (see Table 1) and shifting of load to night-time hours when utilities' cost to purchase bulk electricity can be lower.

Compared to baseline charging, off-peak charging will increase the NPV of annual utility net revenue by $14 million in 2030 and $34 million in 2050 under the ZEV Goal penetration scenario, due to lower costs. Under the State GHG Goal scenario, off-peak charging will increase the NPV of annual utility net revenue by $31 million in 2030 and $158 million in 2050. This analysis estimates that compared to baseline charging, off-peak charging will increase the NPV of annual utility net revenue by $120 per PEV in 2030 and $104 per PEV in 2050.

Figure 11 NPV of Projected Utility Revenue and Costs from Off-peak PEV Charging

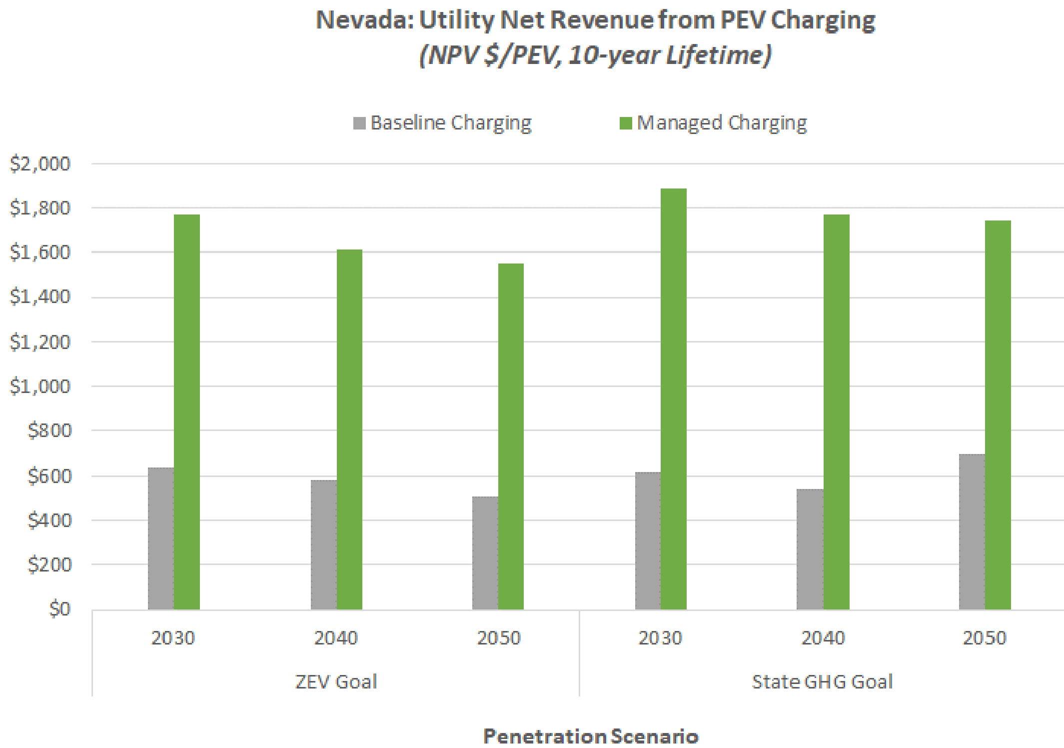


Of note is the effect of managed off-peak charging on generation costs. Based on the 2019 daily load shape and forecasted marginal price data from NV Energy [18], this analysis estimates that Nevada utilities could pay an average of approximately $44/MWh for bulk power in 2030. Under the baseline charging scenario, the cost of the power needed to charge PEVs in 2030 would average $45/MWh, approximately 2 percent more than the average, due to the timing of the load, with a greater percentage during high-cost late afternoon/early evening hours. Under the managed off-peak charging scenario, load shifting to lower-cost early morning hours will reduce average bulk power costs for PEV charging to just over $43/MWh, a 2 percent reduction compared to the baseline scenario. This reduction is reflected in the net revenue figures shown in Figures 11 and 12. This relatively small reduction in bulk power savings is due to Nevada's RPS requirements for carbon-free renewables, which are projected to reduce bulk costs during daylight hours when solar generation peaks. As discussed previously, managed charging programs can be tailored to signal PEV owners to charge their vehicles when costs are low (e.g., early morning).

As utilities shift to increasing amounts of renewables, managed charging initiatives should also be adjusted to reflect these changes to bulk power pricing.

The NPV of projected life-time utility net revenue per PEV is shown in Figure 12. Assuming a ten-year life, the average PEV in Nevada in 2030 is projected to increase utility net revenue by about $1,800 over its lifetime, if charged off-peak. PEVs in service in 2050 are projected to increase utility net revenue by nearly $1,700 over their lifetime (NPV) if charged off-peak.

Figure 12 NPV of Projected Life-time Utility Net Revenue per PEV

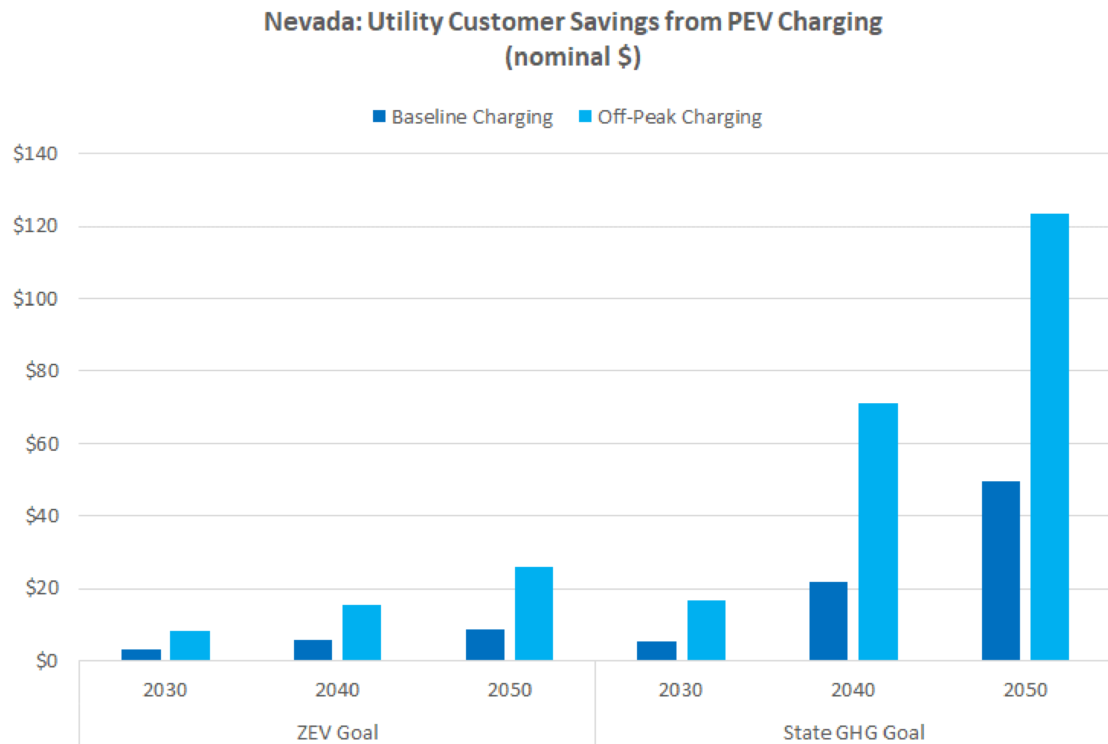


In general, a utility's costs to maintain their distribution infrastructure increase each year with inflation, and these costs are passed on to utility customers in accordance with rules established by the Public Utilities Commission of Nevada (PUCN), via periodic increases in residential and commercial electric rates. However, projected utility net revenue from increased electricity sales for PEV charging would put downward pressure on rates.

See Figure 13 for a summary of how the projected utility net revenue from PEV charging might affect average residential electricity bills for all Nevada electric utility customers.[22] As shown in the figure, under the State GHG Goal scenario, projected average residential electric rates in Nevada could be reduced up to 6 percent by 2050, resulting in an annual savings of approximately $123 (nominal dollars) per household in Nevada in 2050.

[22] Based on 2019 average electricity use of 10,142 kWh per housing unit in Nevada.

Figure 13 Potential Effect of PEV Charging Net Revenue on Utility Customer Bills (nominal $)



Nevada Driver Benefits

Current PEVs are more expensive to purchase than similar sized gasoline vehicles, but some PEVs are eligible for various government purchase incentives, including up to a $7,500 federal tax credit. These incentives are important to spur an early market, but PEVs are projected to provide a total lower cost of ownership than conventional vehicles in Nevada on an unsubsidized basis by 2030, as described below.

The largest contributor to incremental purchase costs for PEVs compared to gasoline vehicles is the cost of batteries. Battery costs for light-duty plug-in vehicles have fallen from over $1,000/kWh to less than $200/kWh in the last decade; many analysts and auto companies project that battery prices will continue to fall – to below $100/kWh by 2025. [19]

Based on these battery cost projections, this analysis forecasts that the average annual cost of owning a PEV in Nevada will fall below the average cost of owning a gasoline vehicle by 2025, even without government purchase subsidies.[23] See Table 2 which summarizes the average projected annual cost of Nevada PEVs and gasoline vehicles under each penetration scenario. All costs in Table 2 are in nominal dollars, which is the primary reason why costs for both gasoline vehicles and PEVs are higher in 2040 and 2050 than in 2030 (due to inflation). In addition, the penetration scenarios assume that the relative number of PEV cars and higher cost PEV light trucks will change over time; in particular the State GHG Goal scenario assumes that there will be a significantly higher percentage of PEV light trucks in the fleet in 2050 than in 2030, which further increases the average PEV purchase cost in 2050 compared to 2030.

[23] The analysis assumes that all battery electric vehicles in-use after 2030 will have 250-mile range per charge and that all plug-in hybrid vehicles will have 50-mile all-electric range.

Table 2 Projected Fleet Average Vehicle Costs to Vehicle Owners (nominal $)

GASOLINE VEHICLE		**ZEV Goal**			**State GHG Goal**		
		2030	**2040**	**2050**	**2030**	**2040**	**2050**
Vehicle Purchase	$/yr	$6,093	$7,714	$9,914	$6,296	$8,219	$10,935
Gasoline	$/yr	$1,052	$1,338	$1,801	$1,089	$1,439	$2,029
Maintenance	$/yr	$244	$305	$389	$247	$313	$404
TOTAL ANNUAL COST	**$/yr**	**$7,390**	**$9,358**	**$12,104**	**$7,632**	**$9,970**	**$13,369**

PEV -NV		**ZEV Goal**			**State GHG Goal**		
Baseline Charging		**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
Vehicle Purchase	$/yr	$6,272	$7,608	$9,329	$6,491	$7,994	$9,933
Electricity	$/yr	$424	$533	$680	$453	$583	$749
Gasoline	$/yr	$151	$144	$122	$129	$122	$125
Personal Charger	$/yr	$81	$101	$128	$81	$101	$128
Maintenance	$/yr	$132	$168	$216	$136	$171	$213
TOTAL ANNUAL COST	**$/yr**	**$7,061**	**$8,555**	**$10,475**	**$7,290**	**$8,971**	**$11,148**
Savings per PEV	**$/yr**	**$329**	**$803**	**$1,629**	**$342**	**$999**	**$2,221**

As shown in Table 2, 2030 average PEV purchase costs are projected to be higher than average purchase costs for gasoline vehicles (with no government subsidies), but the annualized effect of this incremental purchase cost is outweighed by significant fuel cost savings, as well as savings in scheduled maintenance costs. In 2030, the average Nevada driver is projected to save $329 – $342 per year compared to the average gasoline vehicle owner, without government subsidies. These annual PEV savings are projected to increase to an average of $803 - $999 per PEV in 2040, and $1,629 - $2,221 per PEV in 2050, as relative PEV purchase costs continue to fall, and the projected price of gasoline continues to increase faster than projected electricity prices. The NPV of annual savings for the average PEV owner in Nevada is projected to be $242 in 2030, rising to $770 in 2050.

The NPV of total annual cost savings to Nevada drivers from greater PEV ownership are projected to be $42 million in 2030 under the ZEV Goal penetration scenario, rising to $175 million in 2040 and $536 million in 2050. Under the State GHG Goal scenario, the NPV of total annual cost savings to Nevada drivers from greater PEV ownership are projected to be $83 million in 2030, rising to $980 million in 2040 and $3.4 billion in 2050.

Other Benefits

Fuel and Emissions Reductions

Along with the financial benefits to electric utility customers and PEV owners described above, light-duty vehicle electrification can provide additional benefits, including significant reductions in gasoline fuel use and transportation sector emissions.

The estimated cumulative fuel savings (barrels of gasoline) from PEV use in Nevada under each penetration scenario are shown in Figure 14.[24] Annual fuel savings under the ZEV Goal penetration scenario are projected to

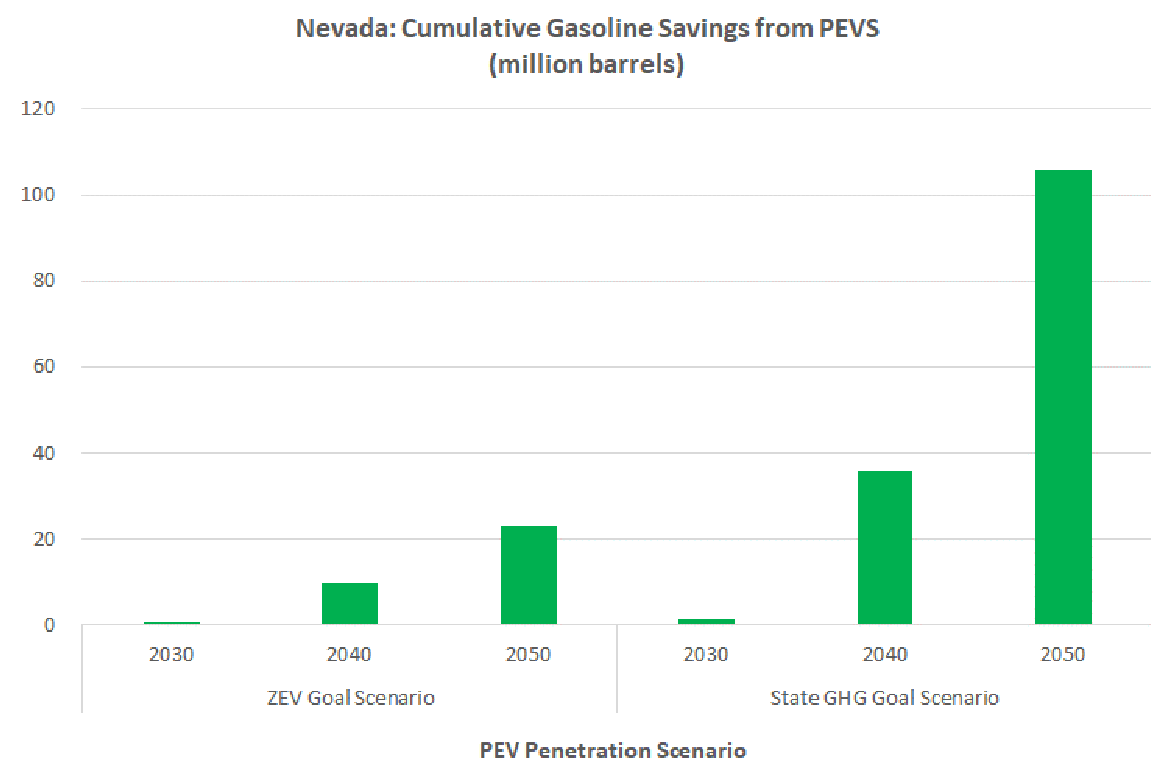
[24] One barrel of gasoline equals 42 US gallons.

total 0.7 million barrels in 2030, with cumulative savings of more than 23 million barrels by 2050. For the State GHG Goal scenario, annual fuel savings in 2030 are projected to be 1.4 million barrels, and by 2050 cumulative savings could equal 106 million barrels.

These fuel savings can help put the U.S. on a path toward energy independence, by reducing the need for imported petroleum. In addition, a number of studies have demonstrated that EVs can generate significantly greater local economic impact than gasoline vehicles - including generating additional local jobs - by keeping more of vehicle owners' money in the local economy rather than sending it out of state by purchasing gasoline.

Economic impact analyses for the states of California, Florida, Ohio and Oregon have estimated that for every million dollars in direct PEV owner savings, an additional $0.29 - $0.57 million in secondary economic benefits will be generated within the local economy, depending on PEV adoption scenario. These studies also estimated that between 13 and 25 additional in-state jobs will be generated for every 1,000 PEVs in the fleet. [1]

Figure 14 Cumulative Gasoline Savings from PEVs in Nevada

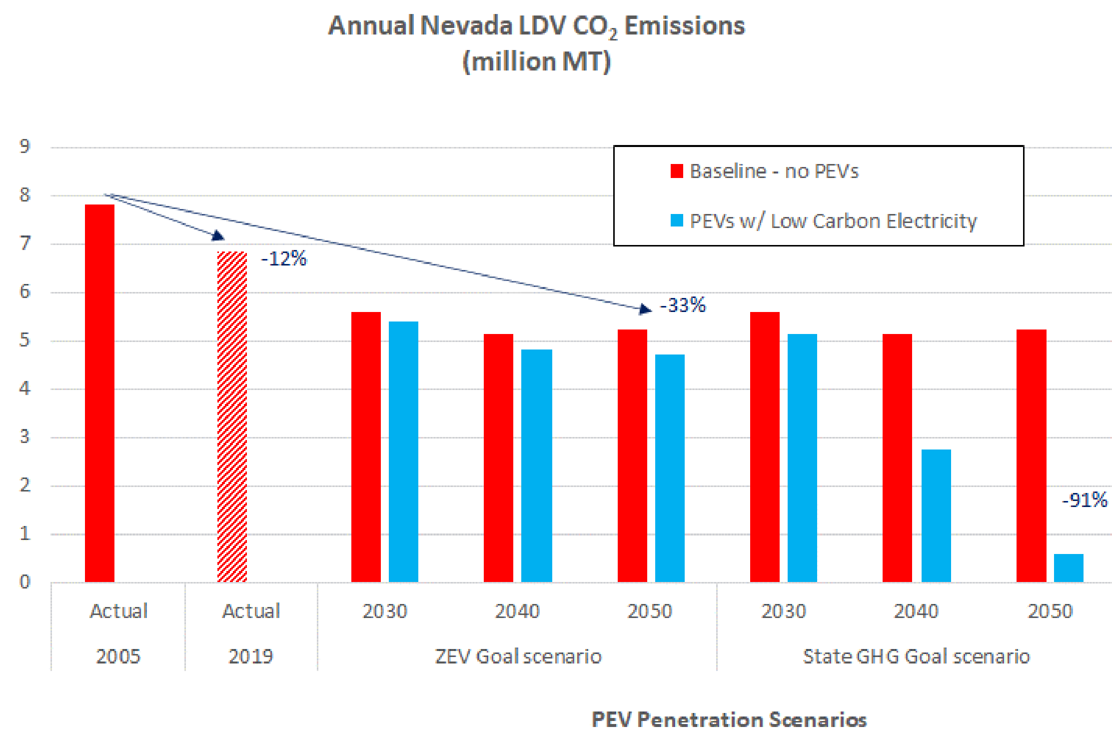


The projected annual greenhouse gas (GHG) emissions (million metric tons carbon-dioxide equivalent, CO_2-e million tons) from the Nevada light duty fleet under each PEV penetration scenario are shown in Figure 15. In this figure, projected baseline emissions from a gasoline fleet with few PEVs are shown in red for each year; the values shown represent "wells-to-wheels" emissions, including direct tailpipe emissions and "upstream" emissions from production and transport of gasoline. Projected total fleet emissions for each PEV penetration scenario are shown in blue; this includes GHG emissions from generating electricity to charge PEVs, as well as GHG emissions from gasoline vehicles in the fleet.

For the PEV penetration scenarios, projected GHG emissions are shown for a "low carbon" electricity scenario (light blue). For the ZEV Goal scenario, the electric grid is assumed to reach 50 percent carbon free by 2030 and then remain at 50 percent through 2050. For the State GHG Goal scenario, low carbon electricity is based on

Nevada achieving 50 percent renewable energy by 2030 and 100 percent carbon free electricity generation by 2050, in accordance with goals established under the state's RPS rules (SB 358).

Figure 15 Projected GHG Emissions from the Light Duty Fleet in Nevada



As shown in Figure 15, GHG emissions from the light duty fleet were approximately 7.8 million metric tons in 2005, but fell by 12 percent through 2019, to 6.9 million tons. Even without significant PEV penetration, baseline annual fleet emissions are projected to fall even further to 5.2 million tons by 2050, a reduction of 33 percent from 2005 levels and 24 percent from current levels. This projected reduction is based on turnover of the existing vehicle fleet to more efficient vehicles that meet more stringent fuel economy and GHG standards issued by the Department of Transportation and Environmental Protection Agency[25]. Under the ZEV Goal penetration scenario, PEVs are projected to reduce annual light duty fleet emissions by up to 3.1 million tons in 2050 compared to 2005 baseline emissions (-39 percent). Under the State GHG Goal scenario, annual GHG emissions in 2050 will be as much as 7.2 million tons lower than 2005 baseline emissions (-91 percent).

Figure 16 summarizes the NPV of the projected monetized "social value" of GHG reductions that will result from greater PEV use in Nevada. The social value of GHG reductions represents potential cost savings from avoiding the negative effects of climate change, if GHG emissions are reduced enough to keep long-term warming below two degrees Celsius from pre-industrial levels. The values summarized in Figure 16 were developed using the

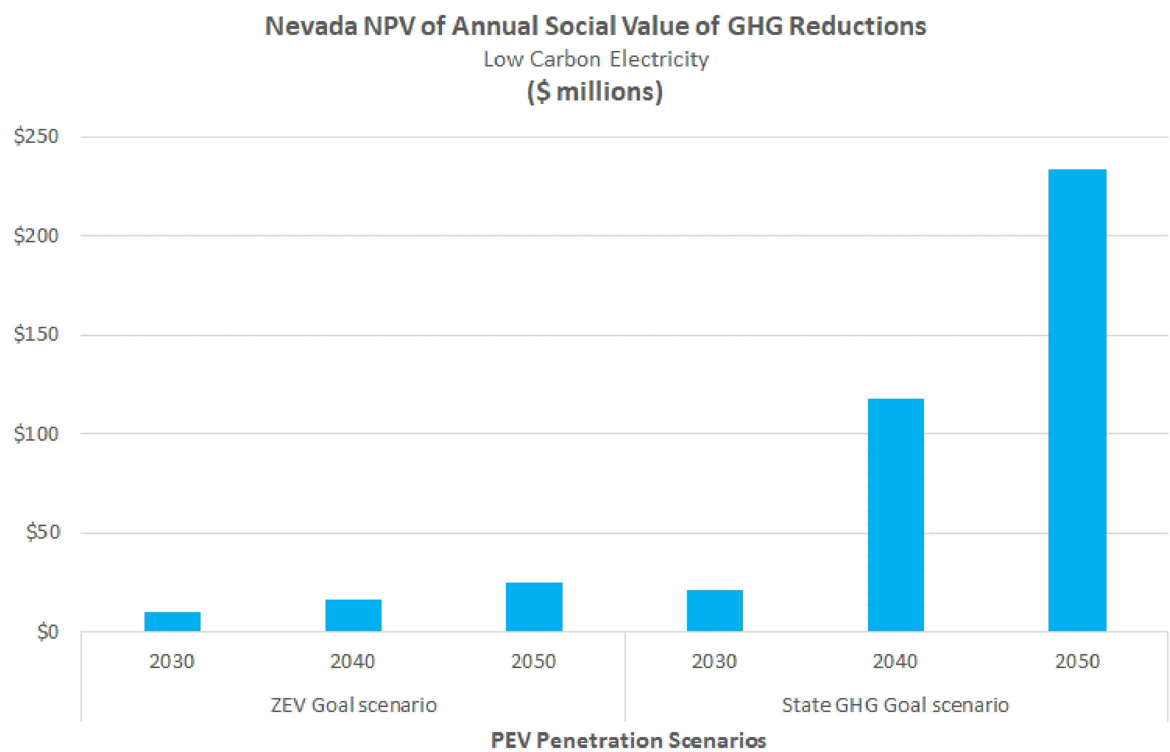
[25] This is based on current new car fuel efficiency standards still in effect, which mandate significant increases in fuel economy for new cars produced every year through model year 2025. This does not account for recent proposed rollbacks of these standards - which would cap fuel economy improvements at model year 2021 levels - that are under consideration by the Department of Transportation and the Environmental Protection Agency

Social Cost of CO_2 ($/MT) as calculated by the U.S. government's Interagency Working Group on Social Cost of Greenhouse Gases.

The NPV of the monetized social value of GHG reductions resulting from greater PEV use is projected to total $10 million per year in 2030 under the ZEV Goal penetration scenario, rising to as much as $25 million per year in 2050. Under the State GHG Goal scenario the NPV of the monetized social value of GHG reductions from greater PEV penetration is projected to be $21 million per year in 2030, rising to as much as $233 million per year in 2050.

The NPV of the projected monetized social value of annual GHG reductions averages $84 per PEV in 2030, and $77 - $152 per PEV in 2050.

Figure 16 NPV of Projected Social Value of PEV GHG Reductions



NOx Emissions

Light-duty fleet electrification can reduce net nitrogen oxide (NOx) emissions from vehicles due to the switch from internal combustion engines used in conventional vehicles. Electric vehicles do not emit any tailpipe emissions, however; they are not necessarily zero emission vehicles. Depending on the electricity grid mix, NOx can be emitted when generating electricity for vehicle charging. PEVs in Nevada charging with the existing grid mix already have lower NOx emissions (grams per mile) than new gasoline and diesel vehicles. This gap is projected to increase in future years, as zero-emission renewable generation (wind, solar) makes up a greater percentage of the new capacity required to meet rising electricity demand.

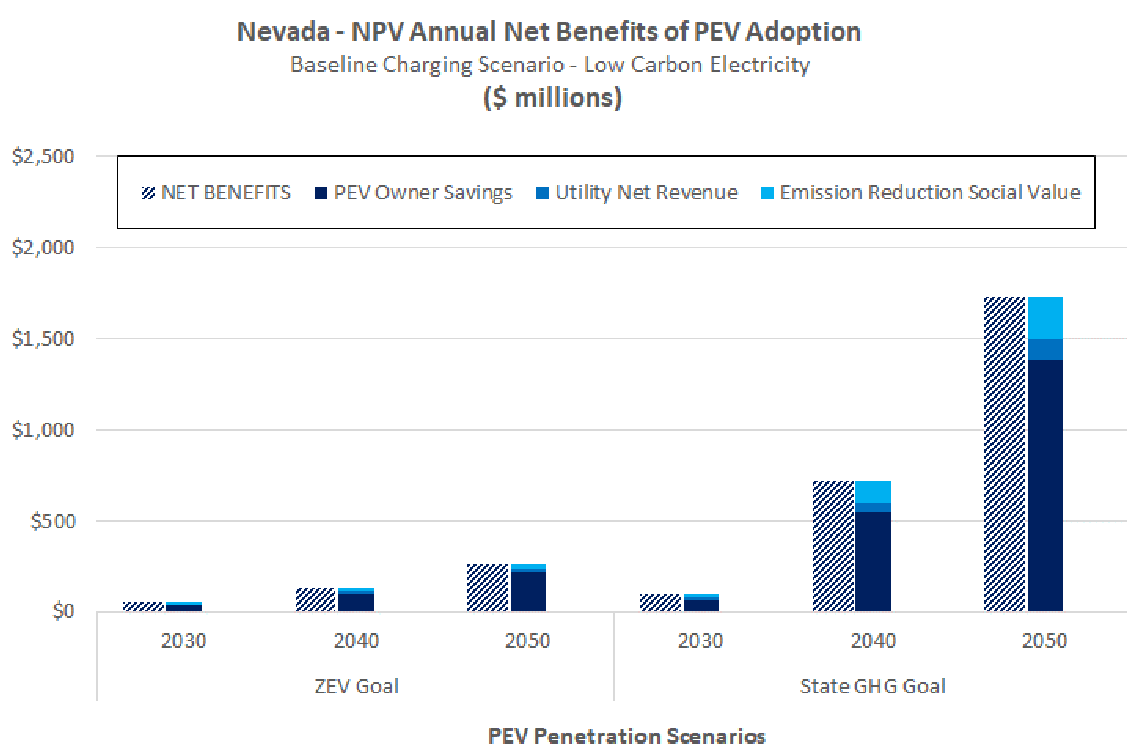
Under the low carbon electricity scenario modeled here and the ZEV Goal Scenario, by 2050 light-duty vehicle electrification in Nevada could reduce annual NOx emissions by 105 tons. Under the State GHG Goal Scenario, total NOx reductions in 2050 could reach 575 tons per year.

Based on EPA's national average damage value of $15,909/ton of mobile source NOx[26], these NOx reductions would have a social value of $0.8 million in 2030 under the ZEV Goal Scenario, rising to $3.4 million in 2050. Under the State GHG Goal Scenario the social value of these NOx reductions would be $1.6 million in 2030, rising to nearly $19 million in 2050. Additional societal benefits would accrue from the electrification of medium and heavy-duty vehicles that are disproportionately responsible for NOx and other criteria emissions; however, these vehicles were not contemplated as part of this analysis.

Total Societal Benefits

The NPV of total estimated societal benefits from increased PEV use in Nevada under each PEV penetration scenario are summarized in Figures 17 and 18. These benefits include cost savings to Nevada drivers, utility customer savings from reduced electric bills and the monetized benefit of reduced GHG and NOx emissions. Figure 17 shows the NPV of projected societal benefits if Nevada drivers charge in accordance with the baseline charging scenario. Figure 18 shows the NPV of projected societal benefits if Nevada drivers charge off-peak.

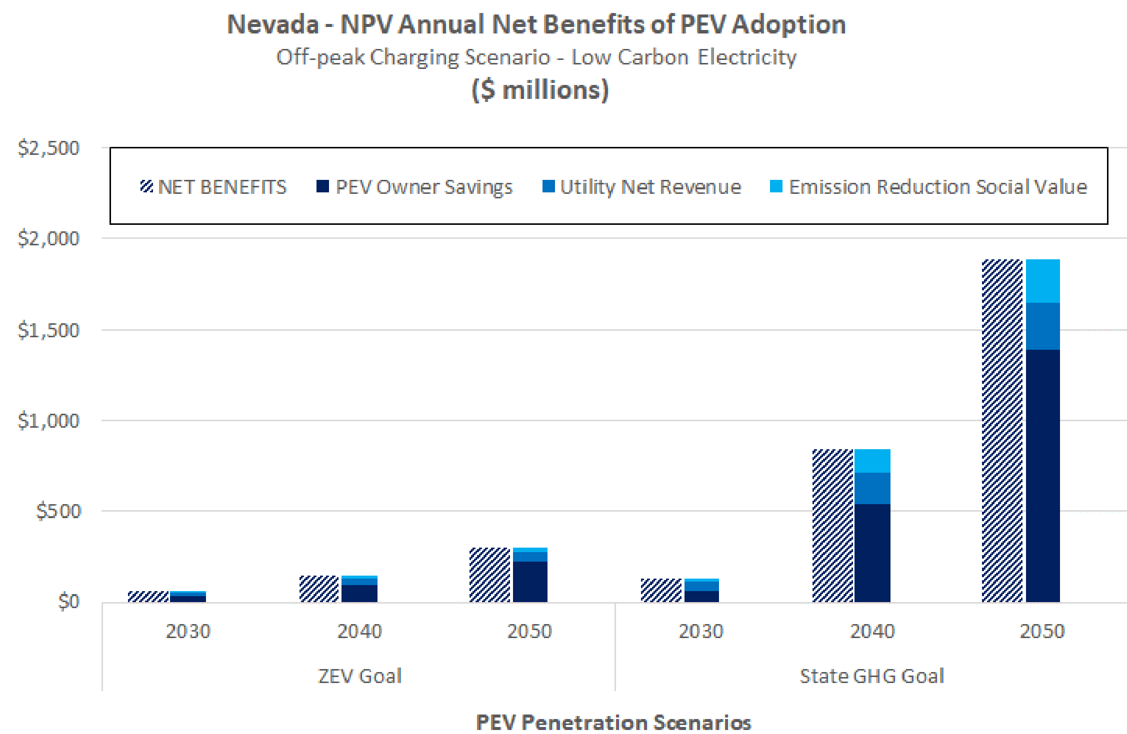
Figure 17 Projected NPV of Total Societal Benefits from Greater PEV use in NV – Baseline Charging



As shown in Figure 17, the NPV of annual societal benefits are projected to be a minimum of $264 million per year in 2050 under the ZEV Goal penetration scenario and $1.7 billion per year in 2050 under the State GHG Goal scenario. Approximately 80 percent of these annual benefits will accrue to Nevada drivers as a cash savings in vehicle operating costs, 6 percent will accrue to electric utility customers as a reduction in annual electricity bills, and 14 percent will accrue to society at large in the form of reduced damage costs from NOx emissions and reduced pressure on climate change from GHG emissions.

[26] EPA's damage value of $15,909 was escalated to $21,138 in 2030, $26,314 in 2040 and $33,270 in 2050 using inflation data from EIA's Annual Energy Outlook for 2020.

Figure 18 Projected NPV of Total Societal Benefits from Greater PEV use in NV – Off-peak Charging



As shown in Figure 18, the NPV of annual societal benefits in 2050 will increase by more than $34 million under the ZEV Goal penetration scenario, and $158 million under the State GHG Goal scenario if Nevada drivers charge off-peak. Of these increased benefits, all will accrue to electric utility customers as an additional reduction in their electricity bills.

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Western Resource Advocates is a non-profit environmental law and policy organization dedicated to “restoring and protecting the natural environment of the Interior American West." Its mission is to “protect the West’s land, air and water to ensure that vibrant communities exist in balance with nature”.

This study is one of eighteen state-level analyses of plug-in electric vehicle costs and benefits developed for different U.S. states, including Arizona, Colorado, Connecticut, Florida, Illinois, Indiana, Kentucky, Maryland, Massachusetts, Michigan, Minnesota, New Mexico, New York, North Carolina, Ohio, South Carolina, and Pennsylvania.

These studies are intended to provide input to state policy discussions about actions required to promote further adoption of electric vehicles.

This report, and the other state reports, are available at www.mjbradley.com.