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Impact of Lost Gas Tax Revenue Due to Sale of Electric Vehicles: Analysis and Recommendations for the 50 States

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Executive Summary

Background problem

Although states might have policy reasons to encourage the use of Electric Vehicles (EVs), the impact of future U.S. EV sales present a significant loss of gas tax revenue for each of the states, as these vehicles do not require gas to operate. For the last three years the number of Electric Vehicle registrations have doubled and are steadily increasing as a result of people becoming more economically and ecologically minded. This is proving to be an optimal choice for car purchasers over standard Internal Combustion Engine (ICE) vehicles, as research has shown that Electric Vehicles are superior for exhibiting “faster acceleration, lower maintenance costs, zero tailpipe emissions, and much lower per-mile fueling cost” than cars that are gas operated (Romm, 2019).

Additional factors to consider that initially stagnated the growth of Electric Vehicle sales, are the rising number of e-port charging stations and declining battery prices. The logistical influx of e-port charging stations in each state enables EV owners to charge their vehicles at their convenience and capitalize on financial incentives for re-charging at non-prime time designated hours throughout the week. Also, the reduction in average lithium-ion battery packs costs between the years of 2010 to 2018 "dropped a remarkable 85% from $1,160 to $176" (Romm, 2019). This favorable trend is forecasted to continue to 2030 at an accelerated decline of “65%” where “average battery pack prices will reach $87/kWh in 2025” and then staircase downward again to “$62/kWh” (Romm, 2019).

Purpose

This paper describes and evaluates the growth of Electric Vehicle sales affecting the shortfall in gas tax revenue incurred by each state and provides two suggested resolutions for gas tax revenue recovery.

Brief details of the approach/method

Primary information sites from which data are obtained are as follows:

- US Electric Vehicle Sales Forecast 2019 - 2028
- Electric Vehicle Market Share by State
- State Gasoline Tax Rates as of July 2018
- Total Number of Registered Vehicles Per State for 2017
- National Average Miles Driven Per Year
- Average U.S. Fuel Economy in Miles Per Gallon
- Charging Stations by State
- States That Charge Extra Fees (Surcharge) To Own an Electric Vehicle

Data from years 2019 to 2028 are culled and formatted from these sites with Microsoft Excel and exported to RStudio, which is the primary Business Intelligence tool used for the predictive analysis and to generate all of the figures. None of these figures were copied from other sources. The predictive analysis computes the loss in gas tax revenue by state on an annual basis and also provides suggested solutions for recouping those losses to a break even and to a revenue surplus.

Major results

Results from the analysis indicate that the states can recoup lost gas tax revenue by implementing a break-even yearly Electric Vehicle surcharge that is approximately 550 times the current sales tax per gallon. These yearly surcharge amounts range from the lowest, which is $80.00 for Alaska to the highest, which is $320.00 for Pennsylvania. For 47 states plus District of Columbia, layering an additional $5.00 to this annual surcharge would extend revenues collected beyond break-even to yield a surplus. Additional surcharges are unnecessary for the three other states, Georgia, Mississippi, and West Virginia, because they already have EV surcharges with built in surpluses. (Going forward the District of Columbia should be considered included when all 50 states are cited.)

Impact of Lost Gas Tax Revenue Due to Sale of Electric Vehicles

Overview of Electric Vehicles

Consumer demand of Electric Vehicles (EVs) in the United States is on a steady incline due to their decreasing purchase prices, extended battery ranges, and increased e-port charging stations. Other considerations that make EV ownership a more attractive option over Internal Combustion Engine (ICE) vehicles are “faster acceleration, lower maintenance costs, zero tailpipe emissions, and much lower per-mile fueling cost” (Romm, 2019). Lastly, the lithium-ion battery packs automakers manufacture for EVs have shown a “remarkable decline in cost by 85%” over the last eight years (Romm, 2019). This favorable trend is forecasted to continue to 2030 at an accelerated decline of “65%” where “average battery pack prices will reach $87/kWh in 2025 and $62/kWh in 2030” (Romm, 2019).

The changing paradigm of EV ownership over the purchase of standard ICE Vehicles has a direct impact on utility companies that are assessing the newly adopted “EV infrastructure” and current constraints on the electrical grid (Harper, McAndrews, and Byrnett, 2019). Although EV sales may provide the utility companies higher revenues, managing demand impact will require the issuance of elastic rates as financial incentives to EV owners, such as charging their vehicles at non-prime time designated hours throughout the week.

The dynamic shift in increased EV sales over gas operated vehicles appears to be a winning solution for consumers, automobile manufacturers, and the utility sector alike. However, one key player is being left behind from the cumulative progressions noted in “EV Adoption” (Harper, et. al, 2019). All 50 states are suffering from major reductions in gas tax revenue with no strategic plan in place to cover the shortfall. Additional gas tax revenue reductions are also anticipated due to the sale of new EVs. A predictive analysis provided in this paper determines the impact of those EV sales on the loss of gas tax revenue in the Unites States and also provides a break-even analysis for net zero gas tax revenue, as well as a recommendation to increase the EV surcharge to restore gas tax revenue profitability.

What is a BEV?

Battery-Electric Vehicles (BEV's), unlike hybrid and ICE vehicles, operate exclusively with an electric motor and are ecologically friendly in the sense that these types of cars have "zero tailpipe emissions" that are harmful to the environment (Harper, et. al, 2019). Hybrid vehicles, however, require a supplemental gas engine in addition to the battery-operated electric motor. The variance in electric mile ranges for BEVs, reported in 2018, vary from as low as "58 miles" upward to "315 miles" dependent on the make and model of the automobile manufactured (Harper, et. al, 2019). This paper uses the terms "EVs" and "BEVs" interchangeably and according to the terminology used in the references. The two-leading auto-manufacturers of EV's in the United States are Tesla and General Motors, which have combined sales of "235,000 BEVs"; an estimated "128 percent" profit increase over the course of 2018 (Harper, et. al, 2019). Delving deeper into the EV market segment shows favorable trends for automakers at the forefront of this initiative in regard to declining EV prices, increased ranges in battery life across a variety of popularly sold "BEV models", and easier accessible e-port logistics for re-charging EVs based on consumer demand (Harper, et. al, 2019).

Declining EV Prices

"In three years, EVs will actually be cheaper up front than combustion vehicles, which will make EVs the increasingly attractive option" (Romm, 2019). The declining cost of owning an EV positively correlates with the decreasing prices of lithium-ion batteries sold which was initially considered the major impediment to the growth of the EV market. EV sticker prices have dropped as low as “11%” over the course of one year compounded with lithium-ion battery packs selling at a going price of “$176/kWh in 2018” (Harper, et. al, 2019; Romm, 2019). Consumers are capitalizing on the economic advantages in purchasing an EV in addition to federal and state funded privileges that coincide with becoming an EV owner. EVs clearly are more economically efficient and cost significantly less than gas operated vehicles. The cost associated with fueling up an ICE vehicle with gasoline far surpasses the cost of electricity used to power an EV. “According to the U.S. Department of Energy, gasoline prices would need to decrease to $1.17 per gallon to reach fuel cost parity with electric charging” (Harper, et. al, 2019).

Another factor to consider is the frequency of routine maintenance on EVs compared to traditional ICE vehicles. EVs “do not require oil changes” and are not held to the same maintenance lifecycle as gas operated vehicles reducing the time and cost spent at the dealership or mechanical repair shop (Harper, et. al, 2019). The braking mechanisms in an EV compared to a regularly gas operated vehicle is also a more desirable benefit as EVs are built with “regenerative braking” which results in “less wear” and significantly reduced instances of replacement costs incurred by the owner (Harper, et. al, 2019).

Extended Battery Life Ranges for BEVs

Lithium-ion battery packs are not only noted for their significantly lower costs in powering EVs but also their technological enhancements in enabling EV owners to cover larger territories which minimizes the frequency of stops at e-charging stations. The extended battery life ranges of EVs in the US market have shown an upward incline from “80 miles in 2011” to “119 miles in 2019” (Harper, et. al, 2019). This positive correlation is projected to continue in "two to three year" intervals which is usually when automobile manufacturers of EVs invest in upgrading their lithium-ion battery packs (Harper, et. al, 2019).

When factoring in increased performance by comparing luxury BEV models (e.g., Tesla Model S) to non-luxury BEV models (e.g., Nissan LEAF), forecasted battery life growth is expected to hit benchmark ranges of "350 – 400" miles and "275 – 300" miles, respectively (Harper, et. al, 2019). Using the lower bound figures as projections for the year 2024, suggests battery life optimization by 34% or (119 miles[1] / 350 miles) and 43% or (119 miles[1] / 275 miles). The two strongest contenders in the EV market as of 2019 are the Tesla Model S at "335 miles" and the Nissan LEAF at "225 miles", both of which could surpass "500 miles by 2025" (Harper, et. al, 2019). With continued exponential growth over the next five years for both BEV models, Tesla and Nissan could very well set themselves apart from their competition as a result of the 45% to 67% improvements in their battery life. Also, the performance of their EVs could increase sales, boost customer loyalty, and secure a larger segment of the EV market for both automobile manufacturers.

E-port Logistics for Charging EVs

The upward trend in increased logistics for easily accessible EV charging stations is exhibiting rapid progression across the United States. The top four states at the forefront of this initiative to reduce "range anxiety" among EV owners, who perceived lower range e-port logistics as a drawback, are California, Florida, New York, and Texas (Harper, et. al, 2019). California has the largest number of charging locations, as shown in Figure 1 using EV Adoption as a data source, with slightly more than 5,000 reported in 2018 compared to approximately 4,900 in 2017. Florida, New York, and Texas have similar number charging location increases with an estimated 1,200 in 2018 compared to 1,100 in 2017. The rising influx of "public charging station infrastructures" in all four states shows an increased rate of 100 additional charging locations annually to meet customer demand (Harper, et. al, 2019).

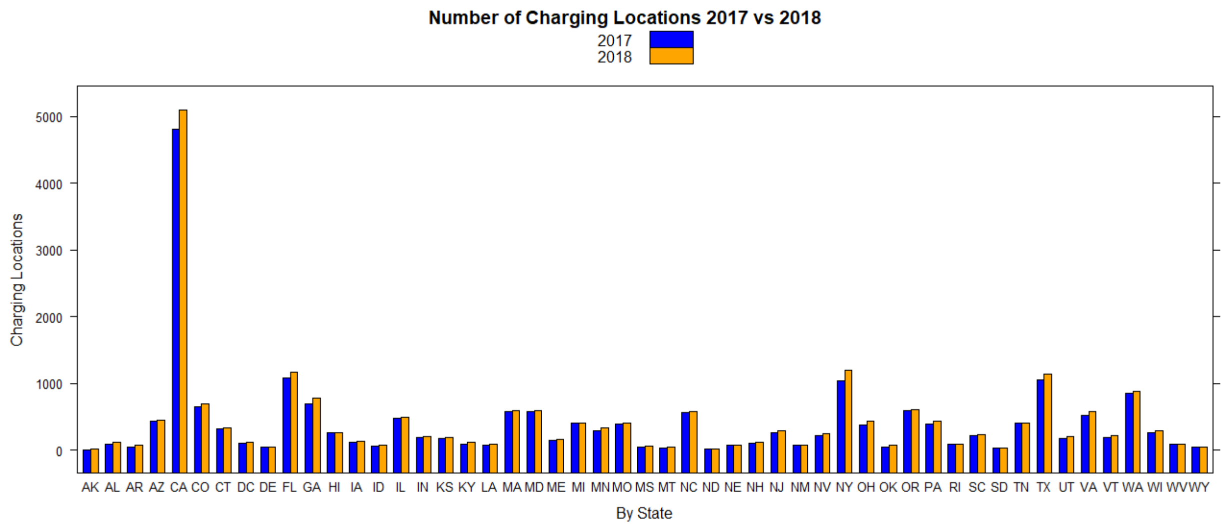

Figure 1 Depicting Number of Public Charging Locations Comparing 2017 and 2018.

Aside from the number of charging locations impacting the sale of EVs the "type of infrastructure" is equally important when considering the length of time taken to re-charge an EV, the amount of voltage required for an EV to be fully re-charged, and the daily maintenance cost of this activity compared to gas operated vehicles (Harper, et. al, 2019). The three most common types of charging infrastructures are Level 1, Level 2, and DC Fast Charging. Level 1 is most prevalent for household outlets when re-charging an EV and emits "120V" of electricity (Harper, et. al, 2019). Level 1 charging takes the longest amount of time requiring "18-22 hours" to fully re-charge an EV compared to the other two types of charging infrastructures (Harper, et. al, 2019). Level 2 charging is the most common for public charging locations and provides twice the voltage as Level 1. However, the re-charge completion time varies depending on the make and BEV model which is typically "25 miles of range per hour" (Harper, et. al, 2019). EV owners are encouraged to install Level 2 charging outlets in their homes, but the cost is substantially higher to upgrade, "averaging approximately $2,000" (Saxman, 2016). To incentivize EV owners to utilize Level 2 over Level 1 charging, state and federal rebates to consumers have been enacted to maintain a stronger balance of cost effectiveness and electrical efficiency. Figure 2 depicts the number of charging outlets across all 50 states with California residents reaching almost 20,000 as a benchmark in 2018 compared to an estimated 17,000 in 2017 (retrieved from the EV Adoption website).

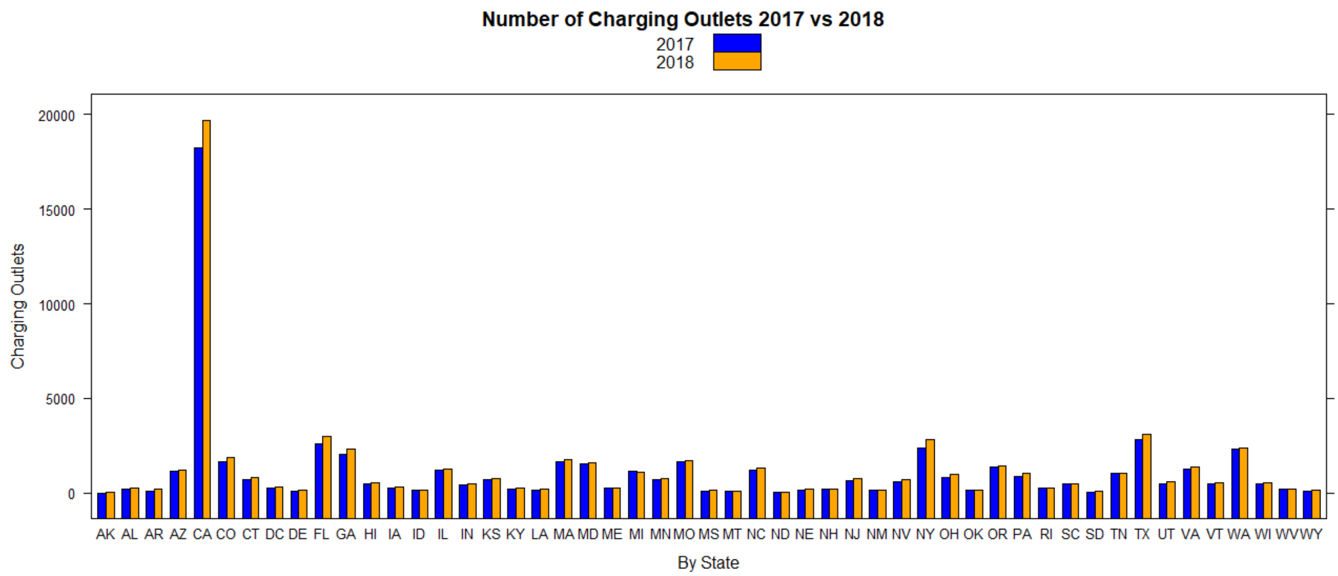

Figure 2 Showing Number of Public Charging Outlets Comparing 2017 and 2018.

DC Fast Charging requires "50 to 350kW" of electricity and is the most expedient method for re-charging (Harper, et. al, 2019). This type of charging will not be available for regular household outlet usage and is intended strictly for public real estate, as DC Fast Charging is the "most expensive" form of re-charging. Using the Nissan LEAF as an example, a "50kW charge" of electricity will take "approximately 30 minutes" to restore the EV's charge to "80 percent" (Harper, et. al, 2019). Figure 3 depicts the rising installation of charging outlets relative to building additional charging locations.

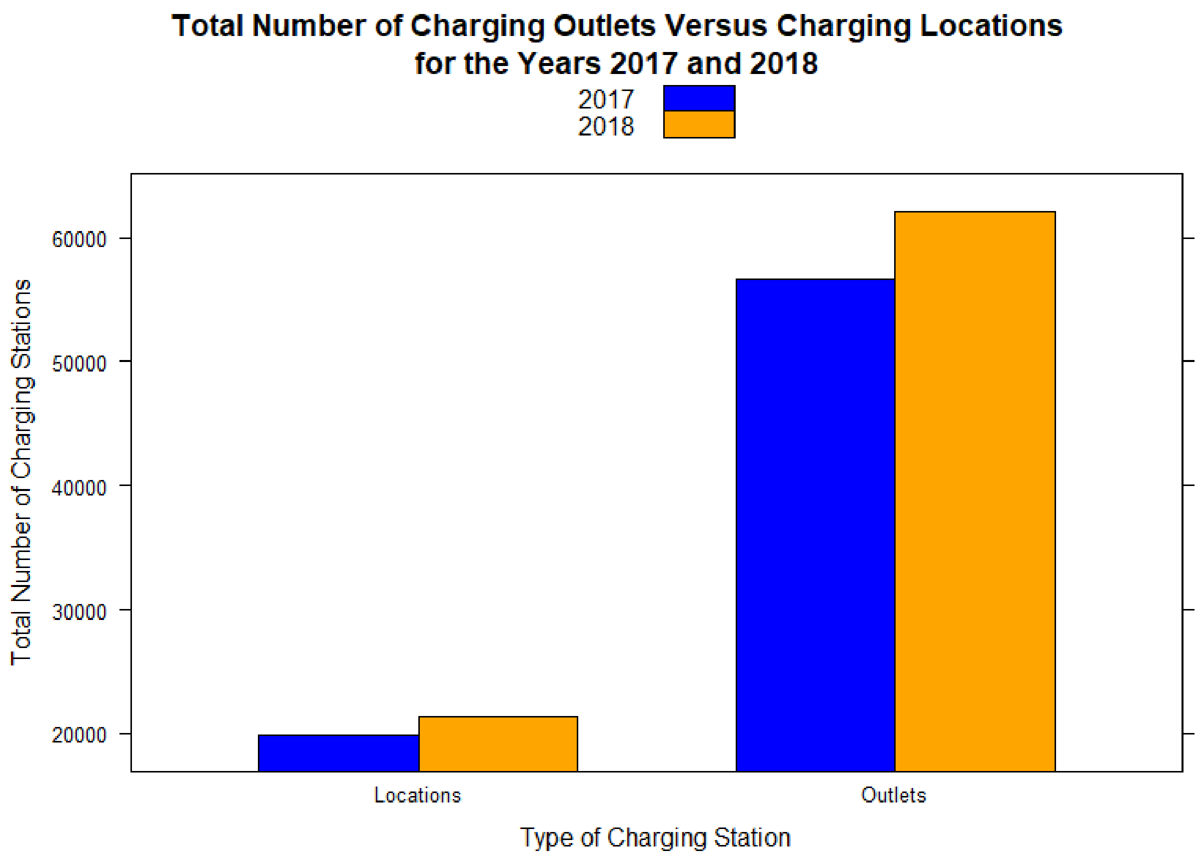

Figure 3 Comparing the Total Number of Charging Outlets to Charging Locations for the Years 2017 Versus 2018.

The time sensitivity in charging an EV is essential to both consumers and utility companies throughout the country when taking into account the impact of increased charging on the electrical grids and how that will be accommodated with continued EV market growth. To stay ahead of the electrical curve on EV charging, two recommendations that have been implemented in progressive states, like California, that are fueling charging location development are the offering of "Time Of Use (TOU) Rates" and flexible "Real Time Pricing (RTP)" (Harper, et. al, 2019). Adopting a "smart charging" model like these promotes an environment where consumers capitalize on financial incentives for charging their EVs during "off-peak times" which alleviates the pressure on utility companies to improvise on "spikes" of electrical usage since this strategy provides "grid flexibility" (Harper, et. al, 2019).

TOU Rates, the more commonly implemented method of the two options, are designed to offer a sliced-time structure to EV owners where charging rates are driven by "time of day, season, and day type (i.e. weekdays, weekends/holidays)" (Harper, et. al, 2019). The financial incentive is for consumers to charge their vehicles at the specified times provided by utility companies where electrical usage for re-charging is the least intrusive to the electrical grid. RTP, in contrast, offers an à la carte approach to EV consumers where the cost structure implementation is pay-per-usage. The onus is passed on to the consumer to control electrical usage on an hourly basis as rates charged can fluctuate depending on demand. Utility companies argue that this method is better than TOU Rates as pricing is more accurately assessed to the EV consumer's electrical usage. However, both strategies are flawed because they are "whole-home mandated", whereby the pricing is not differentiated between EV re-charging and household use, which is undesirable to low-earning EV consumers who inadvertently could be paying more to re-charge their vehicles (Harper, et. al, 2019). California has instituted "EV submetering" for residential owners of EVs where EV load monitoring is conducted using resources such as "charging stations, vehicle telematics, or third-party hardware" for tracking consumer behaviors (Harper, et. al, 2019). California's pilot of this enactment circumvents the necessity to charge for "whole-home" usage and is a more "cost effective" solution over installing a "second meter" at households which promotes more accurate cost analysis and "EV-specific" billing to EV consumers (Harper, et. al, 2019). Thus, EVs can be cost-efficient to the consumer, but only a few states are employing some means to recover the additional use of electricity. With the growing sales of EVs, states need to consider not only the electricity costs and how the lost revenue might be recouped.

Projected US EV Sales

Growth of US EV Sales

The exponential climb of EV sales in the United States is showing no sign of plateauing within the automobile industry or among consumers over the next nine years, and as such, provides an excellent starting point for predictive data analysis to determine the potential gas tax revenue loss for the states. According to the EV Adoption website, the growth potential of the EV market segment is slated to see dramatic increases by 500,000 in two to three-year intervals from 2019 to 2028. This is largely driven by a consumer market which is more inclined to purchase an EV as a result of being ecologically and economically minded. Figure 4 depicts the projected forecast for US sales of EVs manufactured by automakers.

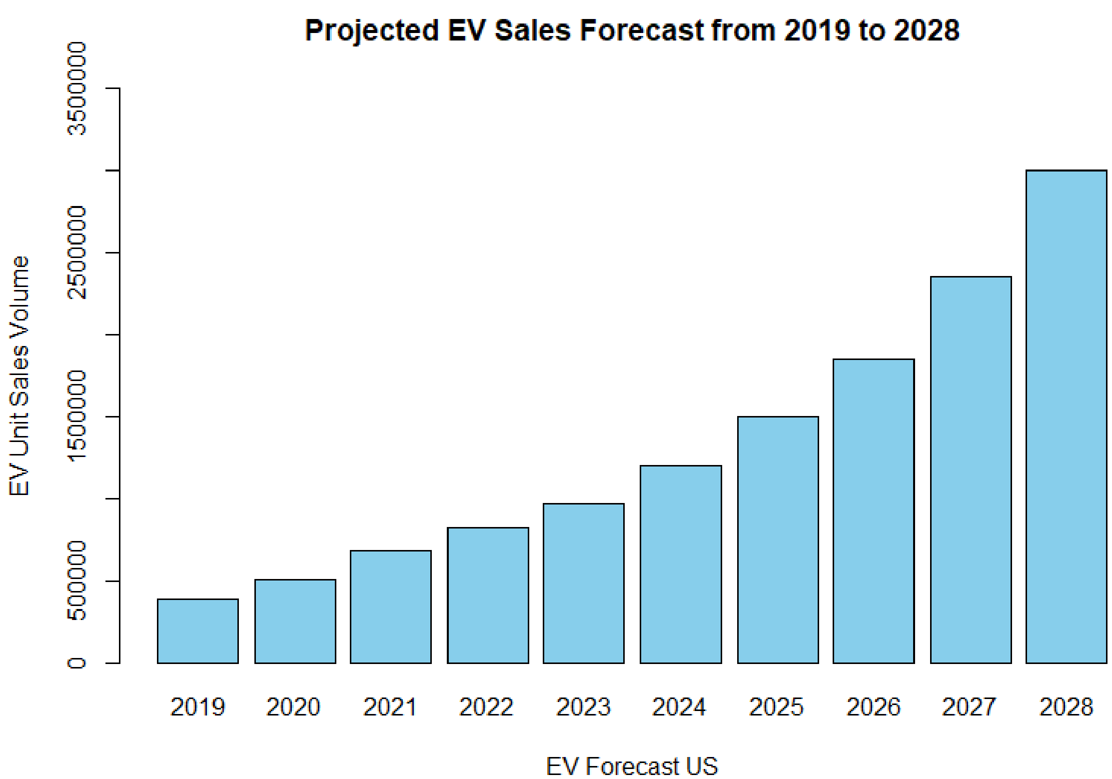

Figure 4 Showing EV Unit Sales Volume in the US Over the Next Nine Years.

The strong preference of EVs over ICE vehicles by consumers has enabled the United States to rank third world-wide in their progressiveness in manufacturing and selling this type of vehicle at an astounding “32% in the first quarter of 2018”, following Europe which has “39%” of the EV market share and China as the dominant country in promoting EVs with “113% growth” (EEI, 2018). The EV Adoption website (2020) shows a year-over-year (YOY) percentage increase in market share growth by “63.33%” in the United States exhibiting the same positive correlation with sales at “74.54%” from 2017 to 2018. This is attributed to the progressiveness of certain states, like California, where “Californians are noted for their love of nice cars” (EV Adoption, 2020). Figure 5 below and also enlarged in Appendix B shows the EV market share breakdown, by state, with California, Texas, and Florida in the top tier for purchasing EVs which will drive the overall sales volume in the US referenced above.

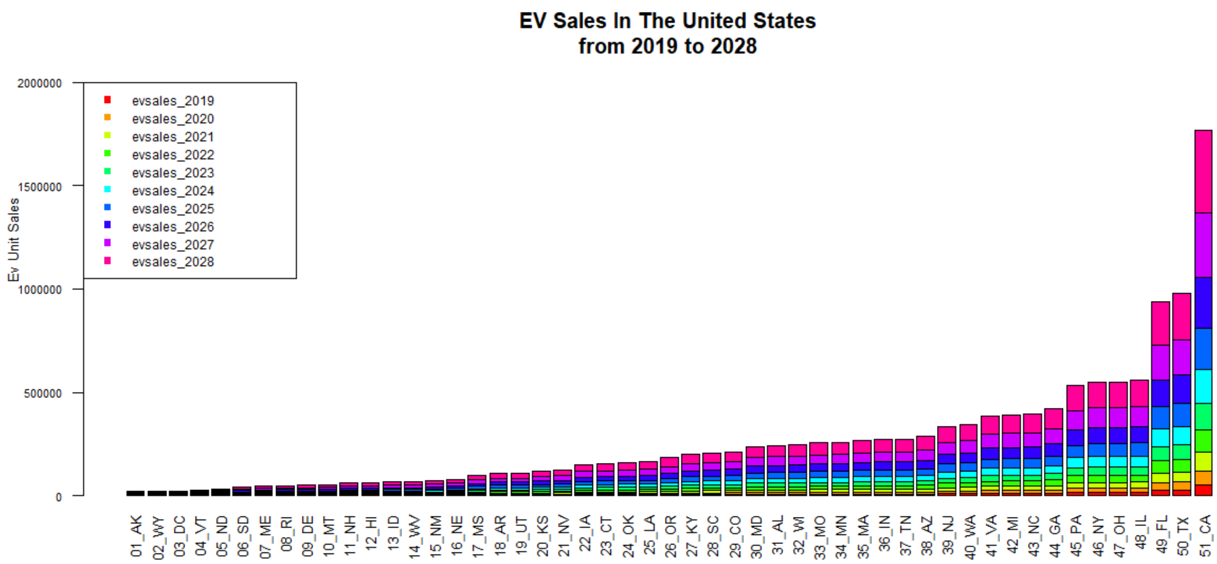

Figure 5 Depicting all 50 States in Ascending Order by EV Unit Sales in the US Projected Over the Next Nine Years.

Using California as an example, Figure 5 depicts total EV sales at approximately 1,765,956 cumulatively from 2019 to 2028. The growth per year is computed by taking the difference of total sales for the current year from the previous year, for example, the growth in 2028 (399,186) is computed by subtracting the total of all years 2019-2027 (1,366,770) from total sales for all years 2019-2028 (1,765,956). This is illustrated in the formula that follows:

EV Sales by Year $_{n}$ = EV Sales Total $_{n}$ – EV Sales Total $_{(n-1)}$

EV Sales by Year$_{2028}$ = EV Sales Total$_{2028}$ – EV Sales Total$_{2027}$

For California, Year 2028 EV Sales are: 399,186 = 1,765,956 - 1,366,770

The remaining years are computed in a similar manner with data extracted for California from Appendix A as shown in Table 1.

Table 1: EV Sales in California for Years 2019 to 2028

Year	**Legend**	**EV Sales Total**	**EV Sales by Year**
2028	Pink	1,765,956	399,186
2027	Purple	1,366,770	312,696
2026	Deep Blue	1,054,074	246,165
2025	Blue	807,909	199,593
2024	Light Blue	608,316	159,674
2023	Green	448,642	129,143
2022	Light Green	319,499	109,650
2021	Yellow	209,849	91,340
2020	Orange	118,509	67,557
2019	Red	50,952	50,952

Analyzing the data over this time period in California shows that as time progresses from 2019 through 2028, the sales volume of EVs increases substantially each year by 2.89% to 22.60%, respectively.

Tesla, which has 80.60% of the market share, is the outlier in outpacing other EV manufacturers. Two other automakers, BMW and Volvo combined, “have the highest share of

EV sales of all new cars sold for the first half of 2018" comprising of "11.10%" (EEI, 2018). The sales objective of both of these automobile manufacturers, as well as Daimler, which ranks behind BMW and Volvo in EV sales at "1.40%", is committed to increase their share of the EV market segment to "15-25%" over the next five years (EEI, 2018). Nissan LEAF, had 1.0% of EV shares of all cars sold in the first half of 2018. Many of the top-selling US automobile makers of EVs are racing to the finish line to be the leader in production, quality, and efficiency. It will only be a matter of time before that same ambition extends even more to the global EV market segment.

Automobile Registrations in the US

The number of automobile registrations in each state is also a key factor in projecting EV sales across the US over the next nine years. Vehicle registration is "required by all states" in order to legally operate a vehicle and is assessed annually or bi-annually depending on state residency (Car Registration Fees By State, 2020). The percentage of registrations per state relative to the projected EV sales for the entire country can be used to estimate EV sales by state. Figure 6 shows the percentage of all registrations across the US in ascending order by state.

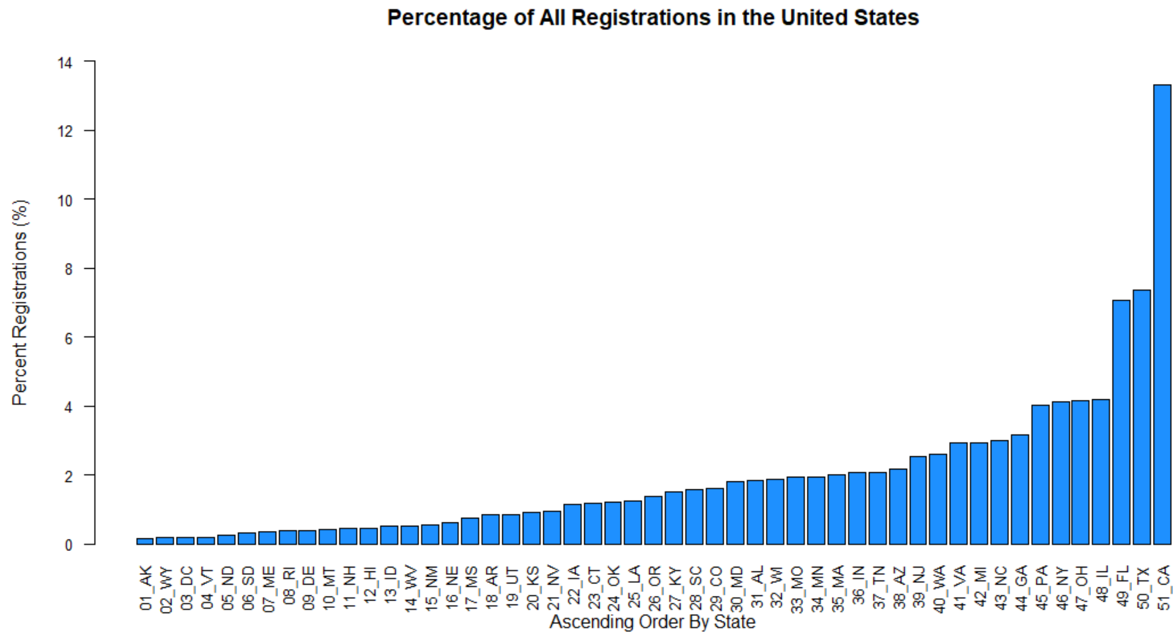

Figure 6 Consisting of Automobile Registration Percentages Across the Entire Country.

Using California as an example, the percentage of registrations in 2019 are approximately 13.30% of the total US registrations. This value was derived by calculating the number of automobile registrations reported in 2017, provided by *Car Ownership Statistics (2020)*, which is "14,615,499" for California divided by the total of 109,839,701 across all 50 states. Taking this percentage and multiplying it by the projected sales for the country in 2019 "382,920", as shown earlier in Figure 4, results in 50,952 sales in California for that year, as shown earlier in Figure 5 (EV Adoption, 2020). This is illustrated in the formula that follows:

$\text{EV State Sales by Year}_{n} = (\text{Registrations}_{state} / \text{Registrations}_{US}) \times \text{Projected EV Sales Total}_{US}$

For California, Year 2019 EV Sales are: (14,615,499 / 109,839,701) x 382,920 = 50,952

With data extracted for California from Appendix A, the same computations were employed for determining California's role in the promotion of EV sales for the remaining time period (using 13.30% as a constant value for each year). Table 2 depicts the product of California's percentage of automobile registrations by the projected EV sales across the country to correlate with the forecasted total EV sales in CA.

Table 2: California's EV Sales from 2019 to 2028

Column 1 Year	**Column 2 Legend**	**Column 3 Projected Sales in US**	**Column 4 EV Sales in CA (13.30% of Column 3)**
2019	Red	382,920	50,952
2020	Orange	507,710	67,557
2021	Yellow	686,450	91,340
2022	Light Green	824,050	109,650
2023	Green	970,550	129,143
2024	Light Blue	1,200,000	159,674
2025	Blue	1,500,000	199,593
2026	Deep Blue	1,850,000	246,165
2027	Purple	2,350,000	312,696
2028	Pink	3,000,000	399,186

California's strong progressiveness as being the leading state for EV sales followed by Texas and Florida, shows a positive correlation for all three states having the highest percentages of registrations as shown in Figure 6.

As this trend continues and automobile manufacturers penetrate deeper into the EV market segment, all of the states continue to become negatively impacted by the large reductions in state fuel tax across the US. Addressing this shortfall requires peer reviewed insights of the problem that will generate feasible solutions in preventing the states from incurring persistent deficits over the next decade.

Gasoline Tax Revenue

Past Gasoline Tax Revenue by State

From the mid-1990s, the stagnated growth of state fuel taxes across the 50 states was unable to make up the shortfall in lost gas tax revenues. The required independent granular data analysis for every state is beyond the scope of this paper; however, selected peer review sources are used to identify the problem among sampled states to represent the entire population.

Stagnating gas tax revenues across the country have had the largest disparate impact on the transportation industry, whereby these revenues were used for “road construction, maintenance, and repairs” (Loughead, 2018). The gas taxes per gallon by state have remained constant for “nearly two decades” resulting in a gas tax deficit, as state and federal legislatures alike have not implemented paralleling “inflation” bump ups in state fuel taxes for “two-thirds of the states” (Vock, 2015). The only options feasible for state and federal legislators in circumventing larger, incurred deficits across the country was to either universally “raise state fuel taxes” or consider other revenue sources that would facilitate breaking-even or returning to a surplus status for transportation funding (Vock, 2015).

Certain states, such as “Georgia, Iowa, South Dakota, and Utah,” had been progressive by increasing their state fuel taxes to ensure their transportation spending moved to the black which was still not aggressive enough because their state fuel funding did not correlate with “gas price” trends (Vock, 2015). Two states, “Minnesota and South Carolina” had not acknowledged favoring or disfavoring “hiking” state fuel taxes (Vock, 2015). Major reasons state and federal legislatures did not support increasing state fuel taxes could be because they were adverse to re-election. Also, there was the misconception that as the US population continued to grow, there would be additional cars purchased to consume more gasoline; however, this only widened the gap to recoup incurred losses on gas tax revenue.

The transportation budget deficit was severe for Rhode Island, which "dwindled the most and now has half [of its] purchasing power in 2014 as it did in 1994" (Vock, 2015). Alaska ranks second in "dropping off at a third" of its purchasing power for transportation funding (Vock, 2015). New Mexico and Illinois each tied third in "bringing in less than a quarter" of their respective purchasing power from the same time frame (Vock, 2015). According to the Tax Policy Center, if states, such as the ones listed above, raised their state fuel taxes "to inflation in 1993" each state would be reaping the benefits of a net revenue surplus where "tax rates would have increased by more than 10 cents per gallon [each year] in 41 states (plus the District of Columbia)" and the transportation funding would have subsequently increased "by 50 percent in 16 states" dependent on consumer purchasing behaviors (Vock, 2015). Sampling certain states provided insights on their position relative to the overall gas tax revenue crisis across the US.

Some states were doing better than others in handling the losses associated with gas tax revenue. California was the most progressive state where it completely transformed its transportation funding initiatives "in 2011" (Vock, 2015). California was keeping lock-step with inflation which made the state "more reliant on gas taxes" (Vock, 2015). This temporary solution to a wider-ranged problem was more appealing from a state than federal level. This was the result of legislatures being more willing to raise gas taxes as a state request versus a federal one, because "policymakers spend that money locally"; whereas, at the federal level, policymakers pooled money across all 50 states (Vock, 2015). Kentucky increased its state fuel taxes to match inflation. Kentucky was able to accomplish this as a result of its state fuel taxes being tied to "fuel prices" versus "per-gallon taxes" like most states (Vock, 2015). This was beneficial only when gas prices rose because state fuel taxes followed suit. However, the caveat to this strategy was that when there was a downward trend in gas prices, transportation funding also declined. New Jersey, on the other hand, was one of the states that was in worse shape regarding the recovery of lost gas tax revenue. The state had gone "even longer than the federal government" in not increasing state fuel taxes (Vock, 2015). The negative correlation between New Jersey's net revenue in assessed gas taxes relative to inflation was astounding, resulting in "a loss of nearly a quarter of the real dollars those taxes generated over the last two decades" (Vock, 2015). Legislatures had made attempts at addressing the issue by "raising gas taxes" but received strong resistance by the reigning Governor Chris Christie. Looking at the current gas tax by state compared to the history in shortfall of gas tax revenue provides further insights on how this existing problem is being perpetuated across the US.

Current Gasoline Tax Revenue by State

States have three methodical approaches in leveraging transportation funding which consists of: taxes per gallons of gas purchased, fuel tax "on the purchase of gasoline", and wholesaler taxes that are "passed on to the consumer" at a markup rate (Loughead, 2018). For the purposes of this paper, the primary focus will be taxes on gallons of gas purchased which vary broadly by state. Figure 7 depicts, as a constant value from 2019 to 2028, the taxes per gallon by state in the US in ascending order from the lowest (Alaska $0.1465) to highest tax rate (Pennsylvania $0.5870) assessment.

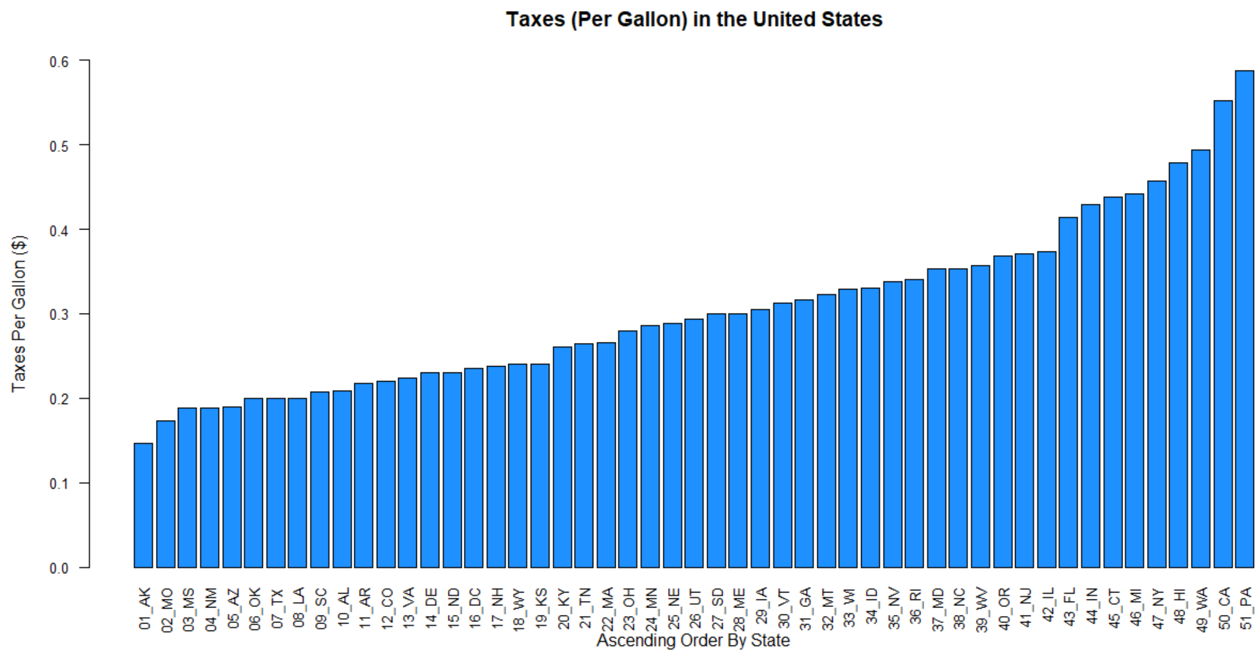

Figure 7 Charting Taxes per Gallon by State Across the Entire Country.

Pennsylvania has the highest tax per gallons of gas purchased quoted at "$0.5870" (Loughead, 2018). The second highest is California with a tax rate of "$0.5522" (Loughead, 2018). The third highest state, to cap off the top charging taxes per gallon tier, is Washington at "$0.4940" (Loughead, 2018). However, on the opposite spectrum, the three lowest tier charging states of taxes per gallon are Alaska, Missouri, and Mississippi with tax rates assessed as "$0.1465, $0.1735, and $0.1879", respectively (Loughead, 2018). Analyzing the variances in tax rate assessments across the entire country showcases the importance of this initiative, as it is considered the dominant revenue generating source for ensuring consistent road maintenance upkeep. A pitfall to this, as identified in the previous section regarding the attributing factors to the shortfall in gas tax revenue, is that per-gallon taxes by state are not "indexed for inflation" meaning the "current value" of state fuel taxes is not maintaining a positive correlation with inflation, which is negatively impacting transportation budgets in the US (Loughead, 2018). As a result, if the indexed inflation strategy is not implemented, states have no other option but to resort to tapping into other, higher generating sources of revenue for “infrastructure maintenance” (Loughead, 2018).

Gas Mileage Consumption Per Gallon

The average combined city and highway gas mileage consumption per gallon in the US was reported at “24.7 in 2016” whereby many automakers were faced with the issue of purchasing more “credits to meet federal requirements” due to the failure of meeting fuel efficiency standards (Shepardson and Carey, 2018). This lower than expected gas mileage per gallon continues to manifest as regulators explore the option of “revising fuel efficiency requirements” (Shepardson and Carey, 2018). When President Trump was elected into office in 2016, one of his goals was to initiate a thorough “review” of the existing “fuel efficiency standards” but received strong opposition from progressive states such as “California” for scrutinizing these policies (Shepardson and Carey, 2018). The onus is being pushed down to the automakers to develop innovative strategies in manufacturing more efficient vehicles that require less gas consumption per mile.

Increasing gas mileage reduces greenhouse gas emissions, as less gas is burned per mile and therefore the exhaust has fewer emissions. One of the strategies used by each manufacturer to actually increase the gas mileage rating is to apply a “greenhouse gas emission surplus” from previous years (Shepardson and Carey, 2018). During 2018 for example, the CO^2 target value was set at “185 grams/mile” (Cornell Law School, n.d.). Instead of increasing gas mileage, which would have resulted in reducing greenhouse gas emission, each automaker capitalized on a greenhouse gas emission surplus from previous years which resulted in later applying this surplus toward a “9 gram per mile deficit” [194 grams/mile] (Shepardson and Carey, 2018). Automakers are resorting to using roll-over credits they earned in previous years, such as “Fiat

Chrysler falling 28 grams per mile short", [213 grams/mile] to cover their newly incurred debt (Shepardson and Carey, 2018). Automakers such as "Volvo and Jaguar Land Rover" are in worse shape and do not have prior credit to default to in covering their existing debts (Shepardson and Carey, 2018). Instead, both automakers are given "three years" by the United States Environmental Protection Agency (EPA) to become "compliant" with "emission standards" (Shepardson and Carey, 2018). One of the ways Jaguar Land Rover is looking to move out of the red in emission requirements is re-designing their vehicles with reduced "engine sizes" which helps compensate for the overall weight of the vehicle (Shepardson and Carey, 2018). Strategies like this should mitigate the need to use previous credits acquired to cover current deficits or resort to purchasing additional credits from other automakers, like Tesla who specializes in the manufacturing of EVs, to cover their shortfalls.

Becoming the "fuel economy champion" of all US automakers comes with a hefty price in regard to meeting customer demand, satisfaction, and loyalty (Shepardson and Carey, 2018). The two largest US automakers, General Motors and Ford Company, reportedly had the worst gas mileage per gallon of all of their vehicle models. Their rationale was that consumer demand for "trucks and SUVs" was a strategic move away from "passenger vehicles" and contributed to the increased "miles per gallon" which paralleled a rebounding economy (Shepardson and Carey, 2018). Both automakers and their initial introduction into the EV market segment also contributed to setting them apart from their competition; however, their predominant focus is still on building ICE vehicles. Automakers, in general, are striving to balance improvements in gas consumption per mile with emission requirements in their ICE vehicles to ensure their models are the most optimal choice for consumers. The disappointing fuel efficiency ties very closely to the average miles Americans drive per year and its impact from a consumer standpoint regarding desired new technology vehicles such as the EV.

Average Miles Driven Per Year in the US

Driving a personally operated vehicle is the most prevalent form of transportation in the US and is relied on more heavily "than in other countries" (Drive Safely, 2020). The average number of miles driven per American for all age groups and genders in the US "comes out to 13,476 in 2018" (Drive Safely, 2020).

States that reportedly have the highest average miles of range driven in the US consist of "Wyoming, Georgia, and Oklahoma" at "21,821 miles, 18,920 miles, and 18,891 miles", respectively (Drive Safely, 2020). "Arkansas", on the other hand, ranks "the lowest at 9,915 miles driven per year" (Drive Safely, 2020). The progressive states such as: "California, Florida, and New York" also practice lower "average rates of miles driven per year due to their denser populations" (Drive Safely, 2020). The average miles driven in these states comes out to "14,435 miles, 11,836 miles, and 11,871 miles", respectively (Drive Safely, 2020). Overall, most of the states are seeing a rise in the average number of miles driven per year across the entire country.

As shown in Table 3, Age Group 1 below, due to many teenagers postponing their first issued license in recent years there are fewer teenagers driving than those in Age Groups 2 through 4. There is a similar drop off at the opposite end of the spectrum for 65+ individuals in Age Group 5.

Table 3: Yearly Percentage US Miles Driven by Gender and Age

Age Group	Ages	Males (%)	Females (%)
1	16-19	12%	16%
2	20-34	25%	28%
3	35-54	26%	27%
4	55-64	22%	18%
5	65+	14%	11%

Although gas consumption has increased due to more people driving, the impact of deficient gas tax revenues will be quantified.

Projected Loss in Gas Tax Revenue by State

To gauge the impact on unrealized gas tax revenues by the states over a ten-year period from 2019 through 2028, future projections of EV sales were forecasted relative to current automobile registrations by state. The EV sales by state projected against the average miles driven per year (13,476) divided by the average miles per gallon (24.7) provided the gallons of gas not required for purchase. Lost gas tax revenue per year by state was a function of the tax rate that would have been applied to the unpurchased gallons of gas. This lost gas tax revenue per year by state can be overcome in all 50 states by imposing a yearly EV surcharge.

Overview of Calculations

Using the following constants of 24.7 miles per gallon current average vehicle fuel efficiency, 13,476 average miles driven per year, and 109,839,701 total vehicle registrations for the US, an example of the projected gas tax revenue loss for California in 2021 is provided in Table 4 Steps 1 through 7. Steps 8 and 9 illustrate the necessary surcharge to break-even and also generate a surplus revenue. The constant of 550 is a valid computed multiplier that when applied to the current state gas tax can be used to provide an approximate necessary yearly surcharge to compensate for lost gas tax revenue.

Table 4: Overview of Example Calculations to Determine Projected Loss of California 2021 Gas Tax Revenue

Step	**California 2021 Projections**	**Formula (Constants: 24.7 mpg, 13,476 avg mile per year, and 109,839,701 US registrations)**
1	Percent Registrations	Percent of Registrations/State $_{\%}$ = (Registrations $_{state}$ / Registrations $_{US}$) California Registrations $_{2021}$ = (14,615,499 / 109,839,701) = 13.30%
2	Sales	EV Sales by $_{state}$ = (Percent of Registrations/State $_{\%}$ x Projected Sales for Country $_{Year}$) California EV Sales $_{2021}$ = (13.30% x 686,450) = 91,340
3	Mile Driven	Total Miles Driven $_{EV\ Vehicles/state}$ = (Year EV Sales $_{by\ state}$ x Avg Miles/Year) Total Miles Driven $_{EV\ Vehicles/California}$ = (2021 EV Sales $_{by\ California}$ x Avg Miles/Year) California Miles Driven $_{2021}$ = (91,340 x 13,476) = 1,230,904,097
4	Number of Gallons Not Purchased	Number of Gallons Not Purchased $_{state}$ = (Total Miles Driven $_{EV\ Vehicles/state}$ /Avg Miles Per Gallon) Number of Gallons Not Purchased $_{California/2021}$ = (Total Miles Driven $_{EV\ Vehicles/California}$ / Avg Miles Per Gallon) Number of Gallons Not Purchased $_{California/2021}$ = (1,230,904,097 / 24.7) = 49,834,174
5	Gross Revenue Loss	Gross Revenue Loss ($) $_{Year}$ = (Number of Gallons Not Purchased $_{state}$ x Taxes per gallon $_{by\ state}$) Gross Revenue Loss ($) $_{2021}$ = (Number of Gallons Not Purchased $_{California}$ x Taxes per gallon $_{by\ California}$) Gross Revenue Loss ($) $_{2021}$ = (49,834,174 x 0.5522) = $27,518,431
6	Net Revenue Loss/Gain	Net Revenue Loss/Gain $_{Year}$ = (Gross Revenue Loss ($) $_{2021}$ – Total Surcharges $_{by\ state}$) Net Revenue Loss/Gain $_{2021}$ = (Gross Revenue Loss ($) $_{2021}$ – Total Surcharges $_{by\ California}$) Net Revenue Loss/Gain $_{2021}$ = ($27,518,431 - $9,134,046) = $18,384,384 $_{Net\ Loss}$
7	Avg Revenue Lost Per EV	Average Revenue Lost/EV $_{state}$ = (Gross Revenue Loss ($) $_{Year}$ / Year EV Sales $_{by\ state}$) Average Revenue Lost/EV $_{California}$ = (Gross Revenue Loss ($) $_{2021}$ / 2021 EV Sales $_{by\ California}$) Average Revenue Lost/EV $_{California}$ = ($27,518,431 / 91,340) = $301
8	Break-Even Surcharge	Break-Even Surcharge $_{California}$ = Average Revenue Lost/EV $_{California}$ = $301 Alternate Calculation: (Constant 550 x Constant Taxes per gallon $_{by\ California}$) Break-Even Surcharge $_{California}$ = (550 x $0.5522) ≈ $301
9	Surplus Revenue Surcharge	Typical example adding $5.00 to the Surcharge: Average Revenue Lost/EV $_{California}$ = (550 x Taxes per gallon $_{by\ California}$) + $5.00 Average Revenue Lost/EV $_{California}$ = (550 x $0.5522) + $5.00 ≈ $306

Registration Percentages by State

The percentage of registrations per state, as referenced in Appendix A, is a constant value implemented in the calculations over the time period 2019-2028. Determining the constant percentage value for future computations requires taking the number of registrations per state and dividing it by the total number of registrations for the entire country. The formula for this calculation is illustrated below:

Percent of Registrations/State $_{\%}$ = (Registrations $_{state}$ / Registrations $_{US}$)

Using California as an example, the percent of registrations for this state is:

Percent of Registrations/State $_{California =}$ (14,615,499 / 109,839,701) = 13.30%.

New EV Sales Per Year by State

Assuming EVs are equally popular across the country, the percentage of registrations in a state serves as a baseline for determining EV sales by state by multiplying this constant value by the projected sales for the entire country in that given year (provided in Table 2). For example, using the year 2021 for California, the formula for this calculation is shown below:

EV Sales by $_{state}$ = (Percent of Registrations/State $_{\%}$ x Projected Sales for Country $_{Year}$)

EV Sales $_{by\ California}$ = (13.30% x 686,450) = 91,340

Miles Driven Per Year by State

The total miles driven per year by state for EV consumers is computed by the product of the new EV sales by state for the 2019 – 2028 time period and the average miles driven per year (13,476 miles identified in Appendix A as a constant value). Using the year 2021 for California as an example, the formula for this calculation is shown below:

Total Miles Driven $_{\text{EV Vehicles/state}}$ = (Year EV Sales $_{\text{by state}}$ x Avg Miles/Year)

Total Miles Driven $_{\text{EV Vehicles/California}}$ = (2021 EV Sales $_{\text{by California}}$ x Avg Miles/Year)

Total Miles Driven $_{\text{EV Vehicles/California}}$ = (91,340 x 13,476) = 1,230,904,097

Average Miles Per Gallon Not Consumed by New EVs

For the time period 2019-2028 by state, the total miles driven by year divided by the average miles per gallon typically driven, (i.e. 24.7 miles identified in Appendix A as a constant value), provides the number of gallons not being purchased by EV consumers annually. Using the year 2021 as an example, the formula for this calculation is shown below:

Number of Gallons Not Purchased $_{\text{state}}$ = (Total Miles Driven $_{\text{EV Vehicles/state}}$ /Avg Miles/Gallon)

Number of Gallons Not Purchased $_{\text{California/2021}}$ = (Total Miles Driven $_{\text{EV Vehicles/California}}$ /Avg Miles/Gallon)

Number of Gallons Not Purchased $_{\text{California/2021}}$ = (1,230,904,097 / 24.7) = 49,834,174

Figure 8 shows the gallons of gas not purchased in the US with California as the number one state impacted. Of the total 963.48 million gallons of gas not purchased in California for 2019-2028, the stacked barplot depicts 49,834,174 (49.83 million) gallons of gas not purchased in 2021 for California (yellow-green stack third from the bottom).

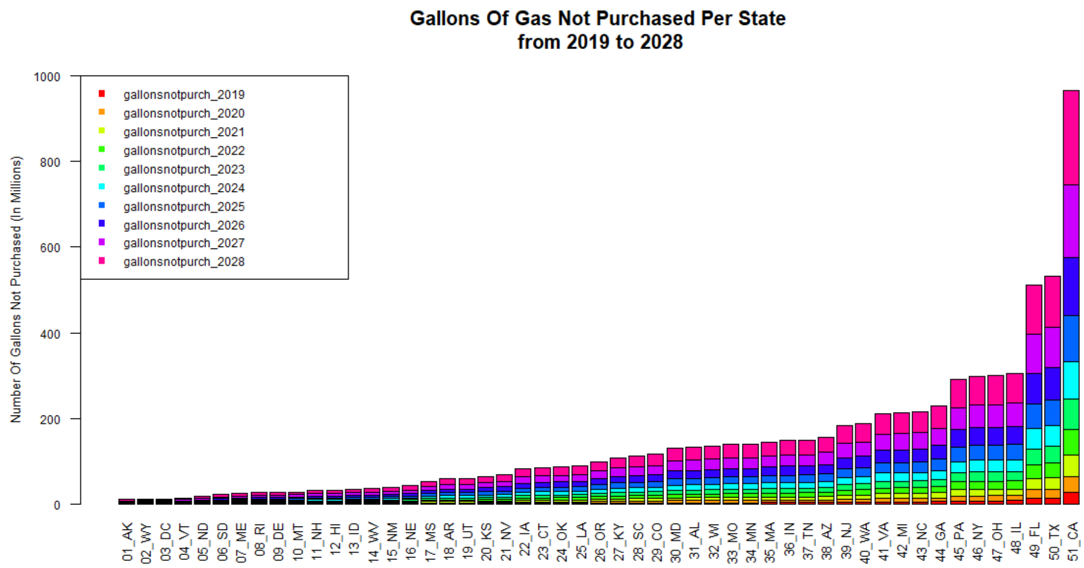

Figure 8 Showing Gallons of Gas Not Purchased (in Millions) Over the Next Nine Years.

Gas Tax Revenue Lost

The gas tax per gallon on each state was computed using data retrieved from the American Petroleum Institute as cited by Katherine Loughead *(2018)* in her article *State Gasoline Tax Rates as of July 2018*. These values remain constant for calculating the gross revenue loss across all 50 states for the referenced time period in Figure 8. Continuing with California as an example, the gross revenue loss per state for a given year is determined by multiplying the number of gallons not purchased by the taxes per gallon by state. Using the year 2021 as an example, the formula for this calculation is shown below:

Gross Revenue Loss ($) $_{\text{Year}}$ = (Number of Gallons Not Purchased $_{\text{state}}$ x Taxes per gallon $_{\text{by state}}$)

Gross Revenue Loss ($) $_{2021}$ = (Number of Gallons Not Purchased $_{\text{California}}$ x Taxes per gallon $_{\text{by California}}$)

Gross Revenue Loss ($) $_{2021}$ = (49,834,174 x 0.5522) = $27,518,431

Figure 9 depicts this loss along with the other 50 states due to projected increase of EV purchases. Of the total $532.03 million gross revenue lost for California in 2019-2028, the stacked barplot depicts $27,518,431 ($27.52 million) lost California gas tax revenue for the year 2021 (yellow-green stack third from the bottom).

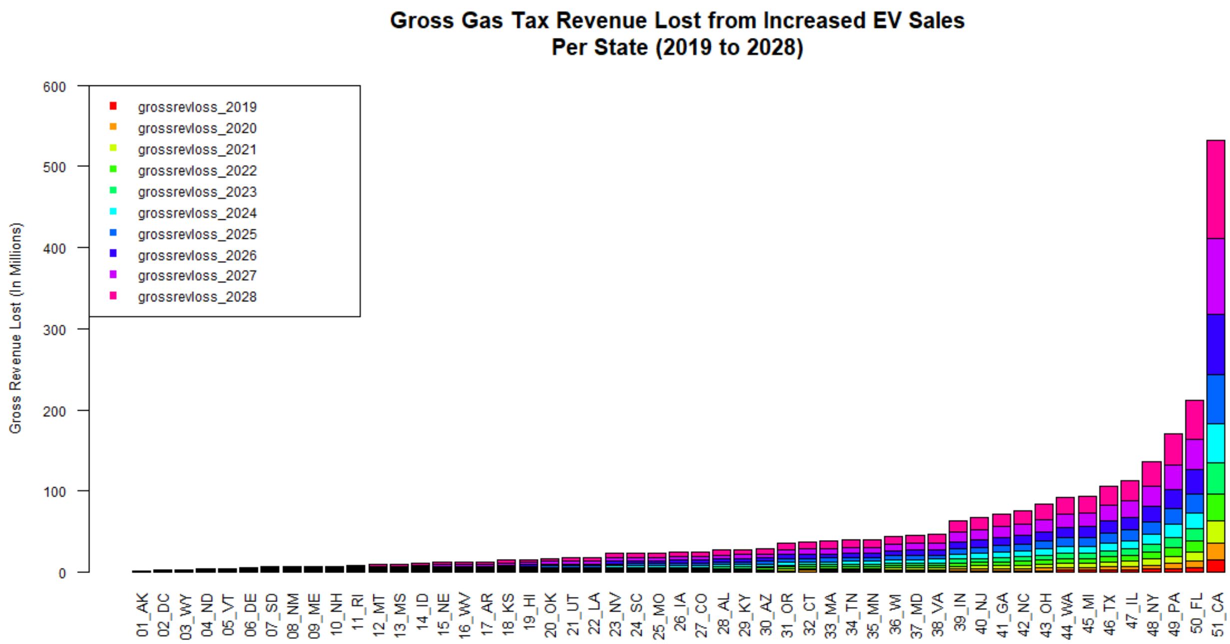

Figure 9 Charting Gas Tax Revenue Loss Across All 50 States with California As the Highest Reported State (in Millions).

Net Revenue Losses or Gains

Some states have been progressive in implementing an EV surcharge to reduce the shortfall in state fuel taxes. Currently, "21 states" impose an EV surcharge with Georgia and West Virginia at the forefront assessing state residents "$200 annually" to drive an EV (Gorzelany, 2019; Iowa Department of Transportation, 2018). Indiana, Mississippi, and Washington represent the second highest tier in EV surcharges assessing their state residents "$150 annually" (Gorzelany, 2019; Iowa Department of Transportation, 2018). Further developments on this topic show states, such as California and Oregon, assessing surcharges on

EV owners at the start of 2020 in the amounts of “$100” and $110” per year, respectively to cover their transportation funding deficits (Gorzelany, 2019; Iowa Department of Transportation, 2018).

While more states are also implementing EV surcharges, currently only three out of the 21 states have a net revenue surplus. Those states are Georgia, Mississippi, and West Virginia ranked in order from highest to lowest earners as identified in Appendix A. The other 18 states are not assessing state residents enough to cover their net revenue losses incurred each year. Even worse, the remaining 30 states do not have any EV surcharge structure in place to begin recouping yearly losses. Figure 10 shows the net revenue gains and losses (in millions of dollars) for all the states showing gains for Georgia, Mississippi and West Virginia at $11.62, $4.70, and $0.35 million respectively, and a loss of $360.54 million for California for 2019-2028.

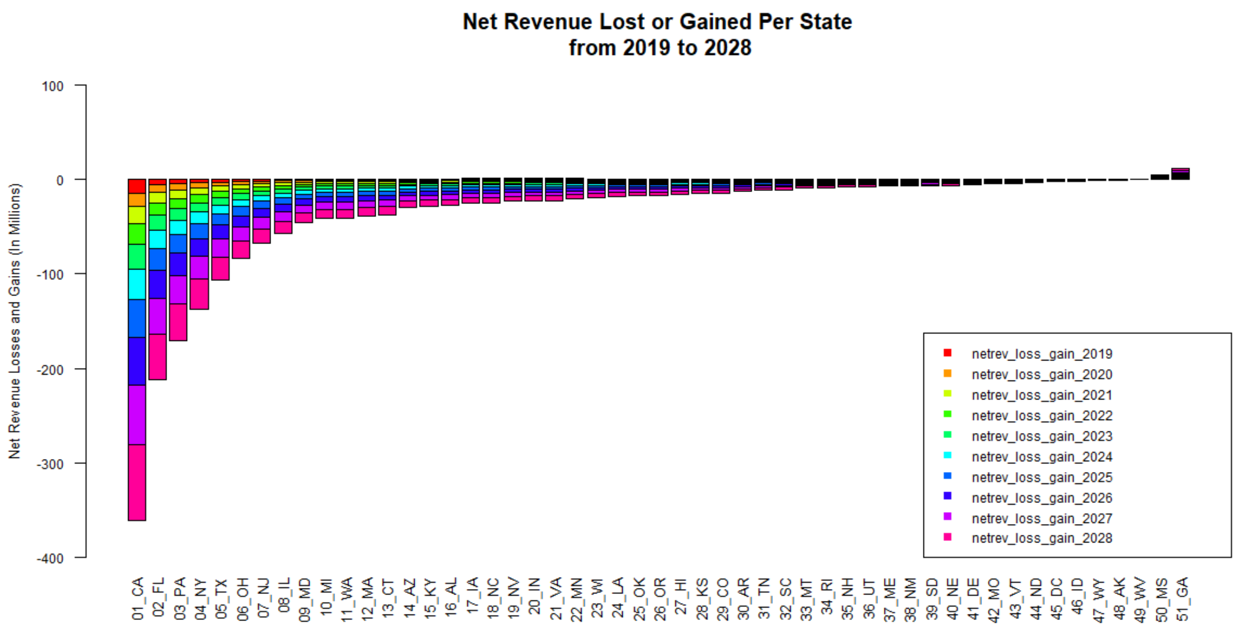

Figure 10 Depicting Net Revenue Losses or Gains per State (in Millions).

Presently, California is assessing state residents only $100 per EV. The formulae below compute the current total surcharge in California in 2021 and the amount the state receives in Net Revenue relative to the gross gas tax revenue loss that would be reported:

$$\text{Net Revenue Loss/Gain}_{\text{Year}} = (\text{Gross Revenue Loss (\$)}_{2021} – \text{Total Surcharges}_{\text{by state}})$$

$$\text{Net Revenue Loss/Gain}_{2021} = (\text{Gross Revenue Loss (\$)}_{2021} – \text{Total Surcharges}_{\text{by California}})$$

$$\text{Net Revenue Loss/Gain}_{2021} = (\$27{,}518{,}431 - \$9{,}134{,}046) = \$18{,}384{,}384_{\text{Net Loss}}$$

For those states with no EV surcharge plan in place, an approximation for the constant yearly EV surcharge can be obtained by dividing the state's yearly gross revenue loss by the number of EV sales for the state for that given year. For example, using the year 2021 for California, the formula for this calculation is shown below:

$$\text{Average Revenue Lost/EV}_{\text{state}} = (\text{Gross Revenue Loss (\$)}_{\text{Year}} / \text{Year EV Sales}_{\text{by state}})$$

$$\text{Average Revenue Lost/EV}_{\text{California}} = (\text{Gross Revenue Loss (\$)}_{2021} / \text{2021 EV Sales}_{\text{by California}})$$

$$\text{Average Revenue Lost/EV}_{\text{California}} = (\$27{,}518{,}431 / 91{,}340) = \$301$$

This value, $301, represents not only the average revenue loss carried over each year in the state of California but also the optimal EV surcharge that should be assessed to reach a break-even status. Continuing with the trend of assessing the $100 EV surcharge (where this value multiplied by Year EV Sales $_{\text{by state}}$ or 91,340 equals the $9,134,046 referenced above) is not a viable solution for the state of California or most of the states for that matter. Another practicable option must be explored to secure consistent net revenue surpluses for all the states in the US.

Current Proposed Solutions to Cover the Offset in Gasoline Tax Revenue

Proposed Solution 1

Proposed solutions to ensure a constant source of revenue for all 50 states will be evaluated in this section of the paper as well as the most optimal proposal that will return all states to a revenue surplus status. As previously noted, states can recover from the loss in gas tax revenue by implementing a yearly EV surcharge. Since 21 of the 50 states have implemented this surcharge, it would be reasonable for the remaining 30 states to institute this surcharge on an annual or bi-annual basis. The precise surcharge for all of the states to return to a break-even status was computed in the previous section by dividing the gross revenue lost per year by the number of EVs sold per year. Returning to the example with California for the year 2021, the state's projected gross revenue loss was estimated to be $27,518,431 while the total number of EV sales projected for that year was determined to be 91,340. Dividing the gross revenue loss for California by the EV sales projected for 2021 equals the $301 in average revenue lost per EV sold computed in the previous section. If California increased its yearly EV surcharge to this amount, the state would recoup all the anticipated gross gasoline tax revenue that would be lost in 2021. Analyzing this value further also shows that the $301 assessment in California is approximately 550 times greater than the current gasoline tax per gallon ($0.5522), which is also a valid multiplier for other states in the study. The formula is shown below:

$$\text{Average Revenue Lost/EV}_{\text{California}} = (550 \times \text{Taxes per gallon}_{\text{by California}})$$

$$\text{Average Revenue Lost/EV}_{\text{California}} = (550 \times \$0.5522) \approx \$301$$

The value "550" is a representative multiplier of the taxes per gallon for all states in implementing this recommendation. Using Pennsylvania in 2021 as another example for demonstrating this computation shows identical results below:

$$\text{Average Revenue Lost/EV}_{\text{Pennsylvania}} = (550 \times \text{Taxes per gallon}_{\text{by Pennsylvania}})$$

$$\text{Average Revenue Lost/EV}_{\text{Pennsylvania}} = (550 \times \$0.5870) \approx \$320$$

This value represents not only the average revenue loss for each year in the state of Pennsylvania but also the optimal EV surcharge that should be assessed to reach a break-even status. Other states that are not imposing a surcharge would also need to analyze a newly proposed surcharge that is approximately 550 times more than their current assessed taxes per gallon. Minimally, to ensure break-even, states currently imposing an EV surcharge per year would take credence comparing it to the proposed EV surcharge calculation and adjusting it accordingly.

Proposed Solution 2

A better option would be to increase the proposed EV surcharge by an additional amount, such as $5.00 per EV for states currently implementing a net loss or break-even surcharge. Figure 11 shows the net revenue surpluses that would benefit all states if a recommended additional $5.00 were added to the calculated EV surcharge:

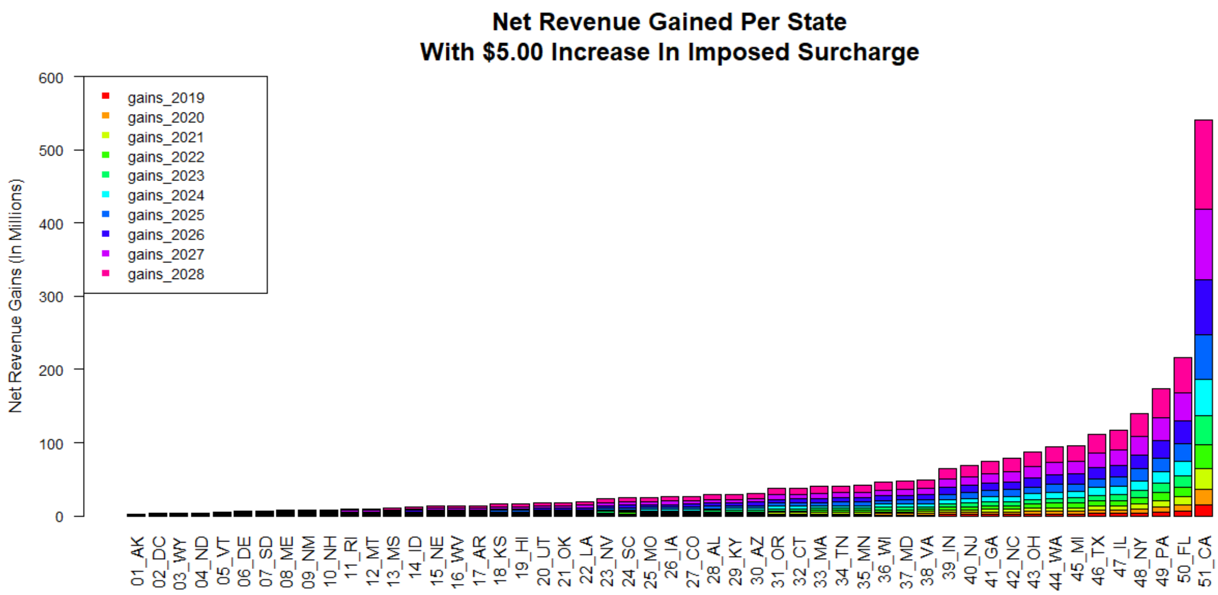

Figure 11 Depicting the Net Revenue Gains (in Millions) With A $5.00 Increase to the Proposed EV Surcharge.

All 50 states would realize the benefit of net revenue surpluses under this proposed recommendation with California, Florida, and Pennsylvania listed as the top-tier revenue earning states with total net revenues of $540.86, $216.30, and $173.51 million respectively. These three states would model themselves after states such as: Georgia, Mississippi, and West Virginia that are already assessing EV surcharges and are leaders in perpetuating a formula that works.

For California, adding $5.00 to the current calculated EV surcharge would be as follows:

$\text{Average Revenue Lost/EV}_{\text{California}} = (550 \times \text{Taxes per gallon}_{\text{by California}}) + \$5.00$

$\text{Average Revenue Lost/EV}_{\text{California}} = (550 \times \$0.5522) + \$5.00 \approx \$306$

Similarly, for Pennsylvania and Florida, adding $5.00 to the current calculated EV surcharge would be as follows:

$$\text{Average Revenue Lost/EV}_{\text{Pennsylvania}} = (550 \times \text{Taxes per gallon}_{\text{by Pennsylvania}}) + \$5.00$$

$$\text{Average Revenue Lost/EV}_{\text{Pennsylvania}} = (550 \times \$0.5870) + \$5.00 \approx \$325$$

$$\text{Average Revenue Lost/EV}_{\text{Florida}} = (550 \times \text{Taxes per gallon}_{\text{by Florida}}) + \$5.00$$

$$\text{Average Revenue Lost/EV}_{\text{Florida}} = (550 \times \$0.4136) + \$5.00 \approx \$231$$

In summary, states can compensate for the lost gas tax revenue most states would incur due to EV sales can be achieved through diligent application of surcharges that are evaluated yearly to ensure a minimum break-even position.

Conclusion

The projected loss of state gas tax revenue as a result of rising sales of EVs can be overcome in all 50 states by imposing a yearly EV surcharge. This conclusion was based on a very promising increase in demand in future years for ecologically friendly EVs due to increased charging port construction with additional outlets, extended EV mileage resulting from faster and larger charging battery capacities, off-hour economic home charging rates from power companies, additional auto maker market entries with anticipated lower pricing, and lower operating costs compared to gas operated vehicles.

As previously stated in Projected Gas Tax Lost By State, to gauge the impact on unrealized gas tax revenues by the states over a ten-year period from 2019 through 2028, future projections of EV sales were forecasted relative to current automobile registrations by state. The EV sales by state projected against the average miles driven per year (13,476) divided by the average miles per gallon (24.7) provided the gallons of gas not required for purchase. Lost gas tax revenue per year by state was a function of the tax rate that would have been applied to the unpurchased gallons of gas.

It was demonstrated that recouping the lost gas tax revenue could easily be achieved with a yearly EV surcharge. As shown in Table 4, currently, only three states, Georgia (GA), Mississippi (MS), and West Virginia (WV), have EV imposed surcharges that are higher than the calculated proposed break-even surcharge proposed for the remaining states. This provides additional revenues above break-even.

Table 5: GA, MS, and WV Imposed Surcharge vs Proposed Surcharge

Column 1 State	**Column 2 Current Imposed Surcharge/Yr**	**Column 3 Proposed EV Surcharge/Yr**	**Column 4 Percentage (%) Improvement (Column 2 vs Column 3)**
GA	$200.00	$172.00	14.00%
MS	$150.00	$103.00	31.34%
WV	$200.00	$195.00	2.50%

The proposed surcharge on each EV per year is approximately 550 times the current gas tax per gallon for each state. For the remaining 47 states, layering an additional $5.00 to this annual surcharge would extend revenues collected beyond break-even to yield a surplus. This surplus could then be used to cover the shortfall in gas tax revenues from previous years for new road construction as well as maintenance and repairs for the current transportation system.

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Appendix A

Supplementary Data Files

Description:

The accompanying *.csv files

Number of Charging Locations 2017 vs 2018 (cluster_chart_eport_locations.csv)	
Data Item	**Data Description**
twoyrstate	State Abbreviations.
year	Year – identifies each of the two years (2017 and 2018) applicable to the number of charging locations.
charginglocations	Charging Locations – number of charging locations for each year.
Number of Charging Outlets 2017 vs 2018 (cluster_chart_outlets.csv)	
Data Item	**Data Description**
twoyrstate2	State Abbreviations.
year2	Year2 – identifies each of the two years (2017 and 2018) applicable to the number of charging outlets.
chargingoutlets	Charging Outlets - number of charging outlets for each year.
Number of Charging Outlets Versus Charging Locations for the Years 2017 and 2018 (totals_outlets_locations.csv)	
Data Item	**Data Description**
sttotals	State Totals – outlets and locations.
yrs	Years – lists years 2017 and 2018.
yrtotals	Year Totals – total outlets and locations.
Projected EV Sales Forecast from 2019 to 2028 (evmarketshare.csv)	
Data Item	**Data Description**
evUSA	EV USA – identifies the years 2019 through 2028 for EV sales in the US.
salesvolume	Sales Volume – the number of EVs sold by year.
sharetotalmarket	Share of Total Market – percent share of the total US sales for that year.
EV Sales in the United States from 2019 to 2028 (stEVSales2.csv)	
Data Item	**Data Description**
stevsales	State Abbreviations in ascending order.

evsales_20XX	EV Sales 2019 through 2028 – provides a separate column for each of the stated years showing the projected sales volume by state for that year.
Percentage of All Registrations in the United States (forcsortreg.csv)	
Data Item	**Data Description**
percregstates	Percent States Registration – name of states across the US in ascending order.
percreg2019_2028	Percent Registrations for Years 2019 through 2028 – shows a constant value of the percent registrations for each state relative to the total US registrations for the time period from year 2019 through 2028.
Taxes (Per Gallon) in the United States (txgalst.csv)	
Data Item	**Data Description**
statetaxes	State Taxes - lists all of the states plus Washington DC.
txgal_2019_2028	Taxes per Gallon for Years 2019 through 2028 – lists the constant value of the current taxes per gallon in ascending order for the respective state.
Gallons of Gas Not Purchased Per State from 2019 to 2028 (in Millions) (galnotpurch_copy.csv)	
Data Item	**Data Description**
ntpurchsts	Not Purchased States - lists all of the states in ascending order including Washington DC.
galntpurch_20XX	Gallons Not Purchased - millions of gallons of gas not purchased in the state for years 2019 through 2028, where XX = 19 – 28.
Gross Gas Tax Revenue Lost from Increased EV Sales Per State (2019 to 2028) (gross_revloss2_copy.csv)	
Data Item	**Data Description**
StateRevLoss	State Revenue Loss - lists all of the states plus Washington DC in ascending order.
GrossRevLostXX	Gross Revenue Lost – in millions of dollars, the gross gas tax revenue lost due to the sale of EVs from years 2019 through 2028, where XX = 19 – 28.
Net Revenue Lost or Gained Per State from 2019 to 2028 (net_rev2_copy.csv)	
Data Item	**Data Description**
netstate	Net State - lists all of the states plus Washington DC in ascending order.

net_rev_loss_gn_20XX	Net Revenue Lost – in millions of dollars, the net gas tax revenue lost, less revenue recouped via surcharges, due to the sale of EVs from years 2019 through 2028, where XX = 19 – 28.
Net Revenue Gained Per State with $5.00 Increase in Imposed Surcharge (gain2.csv)	
Data Item	**Data Description**
gainstate	Gain State - lists all of the states plus Washington DC in ascending order.
gain_20XX	Gain - in millions of dollars, the gas tax revenue recovered from a surcharge plus additional $5.00, from years 2019 through 2028, where XX = 19 – 28.

Excel spreadsheet contains the following data items:

States Alpha Order.xlsx – tabs Registered Cars 2017_XX (where XX = 19 – 28)	
Data Item	**Data Values**
State	State Name
The number of registered automobiles	Constant Value for the years 2019 to 2028
Percentage of registrations/state	Constant value calculated by taking the number of registrations for each state and dividing it by the total number of registrations across the United States
Year Projected Sales for Country	The value forecasted for the given year in the United States (e.g. 2021)
Year EV Sales by State	Computed by taking the product of the percentage of registrations for each state by the projected sales for the entire country to perform a predictive analysis on EV sales volume for that given year (e.g. 2021)
Average Miles/Year	Constant value 13,476 miles used for predictive analysis that was retrieved from the *Drive Safely (2020)* website
Total Miles Driven of EV Vehicles/State	Computed by taking the product of EV sales by state for each year by average miles driven per year
Average Miles/Gallon	Constant value retrieved from the *2018* article *U.S. vehicle fuel economy rises to record 24.7 mpg: EPA* as cited by authors Shepardson and Carey
Number of Gallons Not Purchased	Calculated taking the total miles driven for EV vehicles by state and dividing it by the average miles per gallon driven

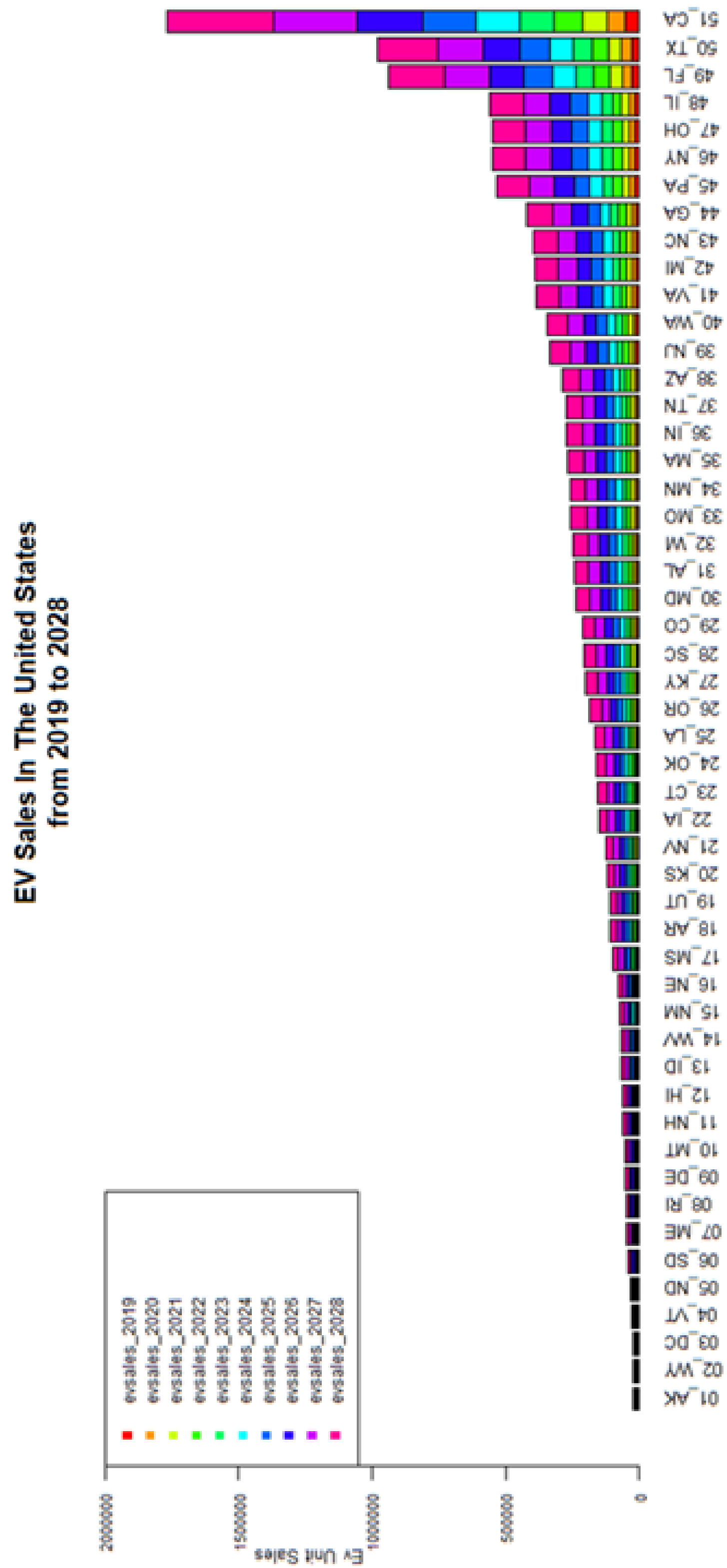
Taxes/Gallon by State	Constant value reported by the American Petroleum Institute as cited by Katherine Loughead *(2018)* in her article *State Gasoline Tax Rates as of July 2018*
Gross Revenue Lost Each Year	Computed by taking the product of the number of gallons not purchased for a specified year (e.g. 2021) by the taxes per gallon by state
EV Surcharge by State	Constant value enacted by 21 of the 50 states (plus the District of Columbia) retrieved from the *Iowa Department of Transportation (2018)* and as cited by Gorzelany *(2019)* in *States That Charge Extra Fees to Own an Electric Vehicle*
Total Surcharges by State	Computed by taking the product of EV sales by state for that specified year (e.g. 2021) by the EV surcharge by state (where applicable)
Net Revenue Lost (Gained) Each Year	Calculated by taking the difference of gross revenue lost in a specified year (e.g. 2021) from the total surcharge by state (where applicable)
Average Revenue Lost/EV	Computed by dividing the gross revenue lost in a specified year (2021) by the EV sales by state for the same year
Proposed EV Surcharge/Year	The approximate value calculated by multiplying the gas tax for that year by the constant value 550.
Gas Tax Revenue Recovered from Surcharge	The Proposed EV Surcharge/Year multiplied by the EV Sales by State.
EV Surcharge Plus 5.00	The Proposed EV Surcharge/Year plus $5.00.
Gas Tax Revenue Recovered from New Surcharge	The EV Surcharge Plus 5.00/Year multiplied by the EV Sales by State.

Workbook tabs not uniquely defined in the data dictionary actually provide line item input as follows:
State Gas Tax 2018 per Gallon - in dictionary as Taxes/Gallon by State
Projected Sales 2019 - 2028 - in dictionary as Year Projected Sales for Country
Avg Miles Per Yr - in dictionary as Average Miles/Year
2018 Avg Miles Per Gallon - in dictionary as Average Miles/Gallon
Regist & EV Surcharge by State - in dictionary as The number of registered automobiles and EV Surcharge by State

Also, the Charging Ports by State tab is split-out into three .csv files:
cluster_chart_eport_locations.csv,
cluster_chart_outlets.csv, and
totals_outlets_locations.csv

Appendix B

Enlarged Figure 5



Appendix C

R Script

```
# Analytics Capstone
# Thesis on Electric Vehicles (Final R Script - v1.0)

# Chart #1 - Cluster Barplot for Number of Charging Locations 2017 vs 2018----

charginglocations <- read.csv("cluster_chart_eport_locations.csv")
charginglocations

library(lattice)

colors = c("blue", "orange") #ADA Compliant Colors


barchart(
  # Input the data in
  data = charginglocations,

  # y axis by x axis
  charginglocations ~ twoyrstate,

  # Set the groups
  # This is what the x axis is grouped by
  group = year,
  xlab = "By State",
  ylab = "Charging Locations",
  main = "Number of Charging Locations 2017 vs 2018",
  auto.key = TRUE,
  par.settings = list(superpose.polygon = list(col = colors))
)

# Chart #2 - Cluster Barplot for Number of Charging Outlets 2017 vs 2018----

coutlets <- read.csv("cluster_chart_outlets.csv")
coutlets

library(lattice)

colors = c("blue", "orange") #ADA Compliant Colors

barchart(
  # Input the data in
  data = coutlets,

  # y axis by x axis
  chargingoutlets ~ twoyrstate2,
```

```
  # Set the groups
  # This is what the x axis is grouped by
  group = year2,
  xlab = "By State",
  ylab = "Charging Outlets",
  main = "Number of Charging Outlets 2017 vs 2018",
  auto.key = TRUE,
  par.settings = list(superpose.polygon = list(col = colors))
)

# Chart #3 - Totals Cluster Barplot for Total Number of Charging Outlets Relative to Charging Locations for the Years 2017 and 2018----

totalscocl <- read.csv("totals_outlets_locations.csv")
totalscocl

library(lattice)

colors = c("blue", "Orange") #ADA Compliant Colors

barchart(
  # Input the data in
  data = totalscocl,

  # y axis by x axis
  yrtotals ~ sttotals,

  # Set the groups
  # This is what the x axis is grouped by
  group = yrs,
  xlab = "Type of Charging Station",
  ylab = "Total Number of Charging Stations",
  main = "Total Number of Charging Outlets Versus Charging Locations\nfor the Years 2017 and 2018",
  auto.key = TRUE,
  par.settings = list(superpose.polygon = list(col = colors))
)

# Chart #4 - Projected EV Sales Forecast from 2019 to 2028----

evforecasting <- read.csv("evmarketshare.csv")
evforecasting

evUSA <- evforecasting[, c(1)]
evUSA

salesvolume <- evforecasting[, c(2)]
salesvolume

sharetotalmarket <- evforecasting[, c(3)]
sharetotalmarket
```

```
evforecast2 <- data.frame(evUSA, salesvolume, sharetotalmarket)
evforecast2

barplot(evforecast2$salesvolume ~ evforecast2$evUSA, ylim = c(0, 3500000), xlab = "EV Forecast US",
ylab = "EV Unit Sales Volume", main = "Projected EV Sales Forecast from 2019 to 2028", col =
"skyblue") #ADA Compliant Colors

# Chart #5 - Stacked Barplot Depicting EV Sales By State from 2019 to 2028----

st_EVSales2 <- read.csv("stEVSales2.csv")
st_EVSales2

library(data.table)

# Create Vectors Out of Imported Data Set to Create a Data.Frame Out of The Data

st_EVSales2[, 1]
st_EVSales2[, 2]

sales_stev2 <- st_EVSales2[, c(1)]
sales_stev2

evsales_2019 <- st_EVSales2[, c(2)]
evsales_2019

evsales_2020 <- st_EVSales2[, c(3)]
evsales_2020

evsales_2021 <- st_EVSales2[, c(4)]
evsales_2021

evsales_2022 <- st_EVSales2[, c(5)]
evsales_2022

evsales_2023 <- st_EVSales2[, c(6)]
evsales_2023

evsales_2024 <- st_EVSales2[, c(7)]
evsales_2024

evsales_2025 <- st_EVSales2[, c(8)]
evsales_2025

evsales_2026 <- st_EVSales2[, c(9)]
evsales_2026

evsales_2027 <- st_EVSales2[, c(10)]
evsales_2027

evsales_2028 <- st_EVSales2[, c(11)]
evsales_2028
```

```
stev <- data.frame(evsales_2019, evsales_2020, evsales_2021, evsales_2022, evsales_2023,
evsales_2024, evsales_2025, evsales_2026, evsales_2027, evsales_2028)
stev

library(data.table)

tdata3 <- transpose(stev)
tdata3

rownames(tdata3) <- colnames(stev)
colnames(tdata3) <- sales_stev2
tdata3

cbind(tdata3[,1], tdata3[,2], tdata3[,3], tdata3[,4], tdata3[,5], tdata3[,6], tdata3[,7], tdata3[,8], tdata3[,9],
tdata3[,10], tdata3[,11], tdata3[,12], tdata3[,13],tdata3[,14], tdata3[,15], tdata3[,16], tdata3[,17],
tdata3[,18], tdata3[,19], tdata3[,20], tdata3[,21], tdata3[,22], tdata3[,23], tdata3[,24], tdata3[,25],
tdata3[,26], tdata3[,27], tdata3[,28], tdata3[,29], tdata3[,30], tdata3[,31], tdata3[,32], tdata3[,33],
tdata3[,34], tdata3[,35], tdata3[,36], tdata3[,37], tdata3[,38], tdata3[,39], tdata3[,40], tdata3[,41],
tdata3[,42], tdata3[,43], tdata3[,44], tdata3[,45], tdata3[,46], tdata3[,47], tdata3[,48], tdata3[,49],
tdata3[,50], tdata3[,51])
cbind

op <- par(ps = 10, cex.axis = 1.1, cex.main = 1.1, las = 1, mai=c(0.7, 1, 1, 1))
plot3 <- barplot(cbind(tdata3[,1], tdata3[,2], tdata3[,3], tdata3[,4], tdata3[,5], tdata3[,6], tdata3[,7],
tdata3[,8], tdata3[,9], tdata3[,10], tdata3[,11], tdata3[,12], tdata3[,13],tdata3[,14], tdata3[,15], tdata3[,16],
tdata3[,17], tdata3[,18], tdata3[,19], tdata3[,20], tdata3[,21], tdata3[,22], tdata3[,23], tdata3[,24],
tdata3[,25], tdata3[,26], tdata3[,27], tdata3[,28], tdata3[,29], tdata3[,30], tdata3[,31], tdata3[,32],
tdata3[,33], tdata3[,34], tdata3[,35], tdata3[,36], tdata3[,37], tdata3[,38], tdata3[,39], tdata3[,40],
tdata3[,41], tdata3[,42], tdata3[,43], tdata3[,44], tdata3[,45], tdata3[,46], tdata3[,47], tdata3[,48],
tdata3[,49], tdata3[,50], tdata3[,51]))

plot3 <- barplot(cbind(tdata3[,1], tdata3[,2], tdata3[,3], tdata3[,4], tdata3[,5], tdata3[,6], tdata3[,7],
tdata3[,8], tdata3[,9], tdata3[,10], tdata3[,11], tdata3[,12], tdata3[,13],tdata3[,14], tdata3[,15], tdata3[,16],
tdata3[,17], tdata3[,18], tdata3[,19], tdata3[,20], tdata3[,21], tdata3[,22], tdata3[,23], tdata3[,24],
tdata3[,25], tdata3[,26], tdata3[,27], tdata3[,28], tdata3[,29], tdata3[,30], tdata3[,31], tdata3[,32],
tdata3[,33], tdata3[,34], tdata3[,35], tdata3[,36], tdata3[,37], tdata3[,38], tdata3[,39], tdata3[,40],
tdata3[,41], tdata3[,42], tdata3[,43], tdata3[,44], tdata3[,45], tdata3[,46], tdata3[,47], tdata3[,48],
tdata3[,49], tdata3[,50], tdata3[,51]), col = rainbow(10), las = 2, pch = 4, ylim = c(0, 2000000), cex = 1,
cex.axis = 0.85, cex.label = 0.75, cex.main = 1.5, xlab = NA, ylab = "                    Ev Unit Sales", main
= "EV Sales In The United States\nfrom 2019 to 2028", names.arg = colnames(tdata3))

legend("topleft", bty = "1", pch = 15, cex = 0.88, col = rainbow(10), legend = rownames(tdata3))

# Chart #6 - Barplot Depicting Percentage of Registrations in the US (Static Number from 2019 to 2028)-
---

forcsort <- read.csv("forcsortreg.csv")
forcsort

percregstates2 <- forcsort[, c(1)]
```

```
percregstates2

percreg2019_2028_2 <- forcsort[, c(2)]
percreg2019_2028_2

str(forcsort)

forcsort[, 1]
forcsort[, 2]

sortstates <- data.frame(percregstates2, percreg2019_2028_2)
sortstates

barplot(sortstates$percreg2019_2028_2 ~ sortstates$percregstates2, type = "o", las = 2, cex = 0.8,
cex.axis = 0.8, ylim = c(0, 14), xlab = "Ascending Order By State", ylab = "Percent Registrations (%)",
main = "Percentage of All Registrations in the United States", col = "dodgerblue") #ADA Compliant
Colors

# Chart #7 - Barplot Depicting Taxes Per Gallon By State (Static Number from 2019 to 2028)----

tx_gal_st <- read.csv("txgalst.csv")
tx_gal_st

statetaxes <- tx_gal_st[, c(1)]
statetaxes

txgal_2019_2028 <- tx_gal_st[, c(2)]
txgal_2019_2028

str(tx_gal_st)

tx_gal_st[, 1]
tx_gal_st[, 2]

taxgals <- data.frame(statetaxes, txgal_2019_2028)
taxgals


barplot(taxgals$txgal_2019_2028 ~ taxgals$statetaxes, type = "o", las = 2, cex = 0.8, cex.axis = 0.8, ylim
= c(0.0, 0.6), xlab = "Ascending Order By State", ylab = "Taxes Per Gallon ($)", main = "Taxes (Per
Gallon) in the United States", col = "dodgerblue") #ADA Compliant Colors

# Chart #8 - Number of Gallons Not Purchased in the US from 2019 to 2028----

library(data.table)

glntpur <- read.csv("galnotpurch_copy.csv")
glntpur

notpurchst <- glntpur[, c(1)]
notpurchst
```

```
gallonsnotpurch_2019 <- glntpur[, c(2)]
gallonsnotpurch_2019

gallonsnotpurch_2020 <- glntpur[, c(3)]
gallonsnotpurch_2020

gallonsnotpurch_2021 <- glntpur[, c(4)]
gallonsnotpurch_2021

gallonsnotpurch_2022 <- glntpur[, c(5)]
gallonsnotpurch_2022

gallonsnotpurch_2023 <- glntpur[, c(6)]
gallonsnotpurch_2023

gallonsnotpurch_2024 <- glntpur[, c(7)]
gallonsnotpurch_2024

gallonsnotpurch_2025 <- glntpur[, c(8)]
gallonsnotpurch_2025

gallonsnotpurch_2026 <- glntpur[, c(9)]
gallonsnotpurch_2026

gallonsnotpurch_2027 <- glntpur[, c(10)]
gallonsnotpurch_2027

gallonsnotpurch_2028 <- glntpur[, c(11)]
gallonsnotpurch_2028

galsdata <- data.frame(gallonsnotpurch_2019, gallonsnotpurch_2020, gallonsnotpurch_2021,
gallonsnotpurch_2022, gallonsnotpurch_2023, gallonsnotpurch_2024, gallonsnotpurch_2025,
gallonsnotpurch_2026, gallonsnotpurch_2027, gallonsnotpurch_2028)
galsdata

tgalsdata <- transpose(galsdata)
tgalsdata

rownames(tgalsdata) <- colnames(galsdata)
colnames(tgalsdata) <- notpurchst
tgalsdata

cbind(tgalsdata[,1], tgalsdata[,2], tgalsdata[,3], tgalsdata[,4], tgalsdata[,5], tgalsdata[,6], tgalsdata[,7],
tgalsdata[,8], tgalsdata[,9], tgalsdata[,10], tgalsdata[,11], tgalsdata[,12], tgalsdata[,13],tgalsdata[,14],
tgalsdata[,15], tgalsdata[,16], tgalsdata[,17], tgalsdata[,18], tgalsdata[,19], tgalsdata[,20], tgalsdata[,21],
tgalsdata[,22], tgalsdata[,23], tgalsdata[,24], tgalsdata[,25], tgalsdata[,26], tgalsdata[,27], tgalsdata[,28],
tgalsdata[,29], tgalsdata[,30], tgalsdata[,31], tgalsdata[,32], tgalsdata[,33], tgalsdata[,34], tgalsdata[,35],
tgalsdata[,36], tgalsdata[,37], tgalsdata[,38], tgalsdata[,39], tgalsdata[,40], tgalsdata[,41], tgalsdata[,42],
tgalsdata[,43], tgalsdata[,44], tgalsdata[,45], tgalsdata[,46], tgalsdata[,47], tgalsdata[,48], tgalsdata[,49],
tgalsdata[,50], tgalsdata[,51])
```

```
plot8 <- barplot(cbind(tgalsdata[,1], tgalsdata[,2], tgalsdata[,3], tgalsdata[,4], tgalsdata[,5], tgalsdata[,6],
tgalsdata[,7], tgalsdata[,8], tgalsdata[,9], tgalsdata[,10], tgalsdata[,11], tgalsdata[,12],
tgalsdata[,13],tgalsdata[,14], tgalsdata[,15], tgalsdata[,16], tgalsdata[,17], tgalsdata[,18], tgalsdata[,19],
tgalsdata[,20], tgalsdata[,21], tgalsdata[,22], tgalsdata[,23], tgalsdata[,24], tgalsdata[,25], tgalsdata[,26],
tgalsdata[,27], tgalsdata[,28], tgalsdata[,29], tgalsdata[,30], tgalsdata[,31], tgalsdata[,32], tgalsdata[,33],
tgalsdata[,34], tgalsdata[,35], tgalsdata[,36], tgalsdata[,37], tgalsdata[,38], tgalsdata[,39], tgalsdata[,40],
tgalsdata[,41], tgalsdata[,42], tgalsdata[,43], tgalsdata[,44], tgalsdata[,45], tgalsdata[,46], tgalsdata[,47],
tgalsdata[,48], tgalsdata[,49], tgalsdata[,50], tgalsdata[,51]), col = rainbow(10), las = 2, pch = 4, ylim =
c(0, 1000), cex = 1, cex.axis = 0.9, cex.label = 1, cex.main = 1.5, xlab = NA, ylab = "Number Of Gallons
Not Purchased (In Millions)", main = "Gallons Of Gas Not Purchased Per State\n from 2019 to 2028",
names.arg = colnames(tgalsdata))

legend("topleft", bty = "1", pch = 15, cex = 0.88, col = rainbow(10), legend = rownames(tgalsdata))

# Chart #9 - Gross Revenue Lost from 2019 to 2028 Due to Increase in EV Purchases----

grosslos <- read.csv("gross_revloss2_copy.csv")
grosslos

grossstloss <- grosslos[, c(1)]
grossstloss

grossrevloss_2019 <- grosslos[, c(2)]
grossrevloss_2019

grossrevloss_2020 <- grosslos[, c(3)]
grossrevloss_2020

grossrevloss_2021 <- grosslos[, c(4)]
grossrevloss_2021

grossrevloss_2022 <- grosslos[, c(5)]
grossrevloss_2022

grossrevloss_2023 <- grosslos[, c(6)]
grossrevloss_2023

grossrevloss_2024 <- grosslos[, c(7)]
grossrevloss_2024

grossrevloss_2025 <- grosslos[, c(8)]
grossrevloss_2025

grossrevloss_2026 <- grosslos[, c(9)]
grossrevloss_2026

grossrevloss_2027 <- grosslos[, c(10)]
grossrevloss_2027

grossrevloss_2028 <- grosslos[, c(11)]
```

```
grossrevloss_2028

grossdata <- data.frame(grossrevloss_2019, grossrevloss_2020, grossrevloss_2021, grossrevloss_2022,
grossrevloss_2023, grossrevloss_2024, grossrevloss_2025, grossrevloss_2026, grossrevloss_2027,
grossrevloss_2028)
grossdata

tgrossdata2 <- transpose(grossdata)
tgrossdata2

rownames(tgrossdata2) <- colnames(grossdata)
colnames(tgrossdata2) <- grossstloss
tgrossdata2

cbind(tgrossdata2[,1], tgrossdata2[,2], tgrossdata2[,3], tgrossdata2[,4], tgrossdata2[,5], tgrossdata2[,6],
tgrossdata2[,7], tgrossdata2[,8], tgrossdata2[,9], tgrossdata2[,10], tgrossdata2[,11], tgrossdata2[,12],
tgrossdata2[,13],tgrossdata2[,14], tgrossdata2[,15], tgrossdata2[,16], tgrossdata2[,17], tgrossdata2[,18],
tgrossdata2[,19], tgrossdata2[,20], tgrossdata2[,21], tgrossdata2[,22], tgrossdata2[,23], tgrossdata2[,24],
tgrossdata2[,25], tgrossdata2[,26], tgrossdata2[,27], tgrossdata2[,28], tgrossdata2[,29], tgrossdata2[,30],
tgrossdata2[,31], tgrossdata2[,32], tgrossdata2[,33], tgrossdata2[,34], tgrossdata2[,35], tgrossdata2[,36],
tgrossdata2[,37], tgrossdata2[,38], tgrossdata2[,39], tgrossdata2[,40], tgrossdata2[,41], tgrossdata2[,42],
tgrossdata2[,43], tgrossdata2[,44], tgrossdata2[,45], tgrossdata2[,46], tgrossdata2[,47], tgrossdata2[,48],
tgrossdata2[,49], tgrossdata2[,50], tgrossdata2[,51])

plot9 <- barplot(cbind(tgrossdata2[,1], tgrossdata2[,2], tgrossdata2[,3], tgrossdata2[,4], tgrossdata2[,5],
tgrossdata2[,6], tgrossdata2[,7], tgrossdata2[,8], tgrossdata2[,9], tgrossdata2[,10], tgrossdata2[,11],
tgrossdata2[,12], tgrossdata2[,13],tgrossdata2[,14], tgrossdata2[,15], tgrossdata2[,16], tgrossdata2[,17],
tgrossdata2[,18], tgrossdata2[,19], tgrossdata2[,20], tgrossdata2[,21], tgrossdata2[,22], tgrossdata2[,23],
tgrossdata2[,24], tgrossdata2[,25], tgrossdata2[,26], tgrossdata2[,27], tgrossdata2[,28], tgrossdata2[,29],
tgrossdata2[,30], tgrossdata2[,31], tgrossdata2[,32], tgrossdata2[,33], tgrossdata2[,34], tgrossdata2[,35],
tgrossdata2[,36], tgrossdata2[,37], tgrossdata2[,38], tgrossdata2[,39], tgrossdata2[,40], tgrossdata2[,41],
tgrossdata2[,42], tgrossdata2[,43], tgrossdata2[,44], tgrossdata2[,45], tgrossdata2[,46], tgrossdata2[,47],
tgrossdata2[,48], tgrossdata2[,49], tgrossdata2[,50], tgrossdata2[,51]), col = rainbow(10), las = 2, pch = 4,
ylim = c(0, 600), cex = 1, cex.axis = 0.9, cex.label = 1, cex.main = 1.5, xlab = NA, ylab = "Gross
Revenue Lost (In Millions)", main = "Gross Gas Tax Revenue Lost from Increased EV Sales\nPer State
(2019 to 2028)", names.arg = colnames(tgrossdata2))

legend("topleft", bty = "1", pch = 15, cex = 0.88, col = rainbow(10), legend = rownames(tgrossdata2))

# Chart #10 - Net Revenue Losses/Gains from 2019 to 2028 in the US----

cnetrev <- read.csv("net_rev2_copy.csv")
cnetrev

cnetst <- cnetrev[, c(1)]
cnetst

netrev_loss_gain_2019 <- cnetrev[, c(2)]
netrev_loss_gain_2019

netrev_loss_gain_2020 <- cnetrev[, c(3)]
```

```
netrev_loss_gain_2020

netrev_loss_gain_2021 <- cnetrev[, c(4)]
netrev_loss_gain_2021

netrev_loss_gain_2022 <- cnetrev[, c(5)]
netrev_loss_gain_2022

netrev_loss_gain_2023 <- cnetrev[, c(6)]
netrev_loss_gain_2023

netrev_loss_gain_2024 <- cnetrev[, c(7)]
netrev_loss_gain_2024

netrev_loss_gain_2025 <- cnetrev[, c(8)]
netrev_loss_gain_2025

netrev_loss_gain_2026 <- cnetrev[, c(9)]
netrev_loss_gain_2026

netrev_loss_gain_2027 <- cnetrev[, c(10)]
netrev_loss_gain_2027

netrev_loss_gain_2028 <- cnetrev[, c(11)]
netrev_loss_gain_2028

cnetrevdata <- data.frame(netrev_loss_gain_2019, netrev_loss_gain_2020, netrev_loss_gain_2021,
netrev_loss_gain_2022, netrev_loss_gain_2023, netrev_loss_gain_2024, netrev_loss_gain_2025,
netrev_loss_gain_2026, netrev_loss_gain_2027, netrev_loss_gain_2028)
cnetrevdata

tcnetrevdata <- transpose(cnetrevdata)
tcnetrevdata

rownames(tcnetrevdata) <- colnames(cnetrevdata)
colnames(tcnetrevdata) <- cnetst
tcnetrevdata

cbind(tcnetrevdata[,1], tcnetrevdata[,2], tcnetrevdata[,3], tcnetrevdata[,4], tcnetrevdata[,5],
tcnetrevdata[,6], tcnetrevdata[,7], tcnetrevdata[,8], tcnetrevdata[,9], tcnetrevdata[,10], tcnetrevdata[,11],
tcnetrevdata[,12], tcnetrevdata[,13],tcnetrevdata[,14], tcnetrevdata[,15], tcnetrevdata[,16],
tcnetrevdata[,17], tcnetrevdata[,18], tcnetrevdata[,19], tcnetrevdata[,20], tcnetrevdata[,21],
tcnetrevdata[,22], tcnetrevdata[,23], tcnetrevdata[,24], tcnetrevdata[,25], tcnetrevdata[,26],
tcnetrevdata[,27], tcnetrevdata[,28], tcnetrevdata[,29], tcnetrevdata[,30], tcnetrevdata[,31],
tcnetrevdata[,32], tcnetrevdata[,33], tcnetrevdata[,34], tcnetrevdata[,35], tcnetrevdata[,36],
tcnetrevdata[,37], tcnetrevdata[,38], tcnetrevdata[,39], tcnetrevdata[,40], tcnetrevdata[,41],
tcnetrevdata[,42], tcnetrevdata[,43], tcnetrevdata[,44], tcnetrevdata[,45], tcnetrevdata[,46],
tcnetrevdata[,47], tcnetrevdata[,48], tcnetrevdata[,49], tcnetrevdata[,50], tcnetrevdata[,51])

plot9 <- barplot(cbind(tcnetrevdata[,1], tcnetrevdata[,2], tcnetrevdata[,3], tcnetrevdata[,4],
tcnetrevdata[,5], tcnetrevdata[,6], tcnetrevdata[,7], tcnetrevdata[,8], tcnetrevdata[,9], tcnetrevdata[,10],
```

```
tcnetrevdata[,11], tcnetrevdata[,12], tcnetrevdata[,13],tcnetrevdata[,14], tcnetrevdata[,15],
tcnetrevdata[,16], tcnetrevdata[,17], tcnetrevdata[,18], tcnetrevdata[,19], tcnetrevdata[,20],
tcnetrevdata[,21], tcnetrevdata[,22], tcnetrevdata[,23], tcnetrevdata[,24], tcnetrevdata[,25],
tcnetrevdata[,26], tcnetrevdata[,27], tcnetrevdata[,28], tcnetrevdata[,29], tcnetrevdata[,30],
tcnetrevdata[,31], tcnetrevdata[,32], tcnetrevdata[,33], tcnetrevdata[,34], tcnetrevdata[,35],
tcnetrevdata[,36], tcnetrevdata[,37], tcnetrevdata[,38], tcnetrevdata[,39], tcnetrevdata[,40],
tcnetrevdata[,41], tcnetrevdata[,42], tcnetrevdata[,43], tcnetrevdata[,44], tcnetrevdata[,45],
tcnetrevdata[,46], tcnetrevdata[,47], tcnetrevdata[,48], tcnetrevdata[,49], tcnetrevdata[,50],
tcnetrevdata[,51]), col = rainbow(10), las = 2, pch = 4, ylim = c(-400, 100), cex = 1, cex.axis = 0.9,
cex.label = 1, cex.main = 1.5, xlab = NA, ylab = "Net Revenue Losses and Gains (In Millions)", main =
"Net Revenue Lost or Gained Per State\n from 2019 to 2028", names.arg = colnames(tcnetrevdata))

legend("bottomright", bty = "1", pch = 15, cex = 0.88, col = rainbow(10), legend =
rownames(tcnetrevdata))

# Chart #11 - Stacked Barplot Depicting Net Revenue Gains After Adding $5.00 to Suggested Surcharge
Per State----

g2 <- read.csv("gain2.csv")
g2

gainst <- g2[, c(1)]
gainst

gains_2019 <- g2[, c(2)]
gains_2019

gains_2020 <- g2[, c(3)]
gains_2020

gains_2021 <- g2[, c(4)]
gains_2021

gains_2022 <- g2[, c(5)]
gains_2022

gains_2023 <- g2[, c(6)]
gains_2023

gains_2024 <- g2[, c(7)]
gains_2024

gains_2025 <- g2[, c(8)]
gains_2025

gains_2026 <- g2[, c(9)]
gains_2026

gains_2027 <- g2[, c(10)]
gains_2027
```

```
gains_2028 <- g2[, c(11)]
gains_2028

gdata <- data.frame(gains_2019, gains_2020, gains_2021, gains_2022, gains_2023, gains_2024,
gains_2025, gains_2026, gains_2027, gains_2028)
gdata

tga <- transpose(gdata)
tga

rownames(tga) <- colnames(gdata)
colnames(tga) <- gainst
tga

cbind(tga[,1], tga[,2], tga[,3], tga[,4], tga[,5], tga[,6], tga[,7], tga[,8], tga[,9], tga[,10], tga[,11], tga[,12],
tga[,13],tga[,14], tga[,15], tga[,16], tga[,17], tga[,18], tga[,19], tga[,20], tga[,21], tga[,22], tga[,23],
tga[,24], tga[,25], tga[,26], tga[,27], tga[,28], tga[,29], tga[,30], tga[,31], tga[,32], tga[,33], tga[,34],
tga[,35], tga[,36], tga[,37], tga[,38], tga[,39], tga[,40], tga[,41], tga[,42], tga[,43], tga[,44], tga[,45],
tga[,46], tga[,47], tga[,48], tga[,49], tga[,50], tga[,51])

plot7 <- barplot(cbind(tga[,1], tga[,2], tga[,3], tga[,4], tga[,5], tga[,6], tga[,7], tga[,8], tga[,9], tga[,10],
tga[,11], tga[,12], tga[,13],tga[,14], tga[,15], tga[,16], tga[,17], tga[,18], tga[,19], tga[,20], tga[,21],
tga[,22], tga[,23], tga[,24], tga[,25], tga[,26], tga[,27], tga[,28], tga[,29], tga[,30], tga[,31], tga[,32],
tga[,33], tga[,34], tga[,35], tga[,36], tga[,37], tga[,38], tga[,39], tga[,40], tga[,41], tga[,42], tga[,43],
tga[,44], tga[,45], tga[,46], tga[,47], tga[,48], tga[,49], tga[,50], tga[,51]), col = rainbow(10), las = 2, pch
= 4, ylim = c(0, 600), cex = 1, cex.axis = 0.9, cex.label = 1, cex.main = 1.5, xlab = NA, ylab = "Net
Revenue Gains (In Millions)", main = "Net Revenue Gained Per State\nWith $5.00 Increase In Imposed
Surcharge", names.arg = colnames(tga))

legend("topleft", bty = "1", pch = 15, cex = 0.88, col = rainbow(10), legend = rownames(tga))

# Using California As An Example
# gains_2028 (pink) 541M - 419M = 122M
# gains_2027 (purple) 419M - 323M = 96M
# gains_2026 (deeper blue) 323M - 248M = 75M
# gains_2025 (medium blue) 248M - 187M = 61M
# gains_2024 (light blue) 187M - 138M = 49M
# gains_2023 (green) 138M - 98M = 40M
# gains_2022 (light green) 98M - 64M = 34M
# gains_2021 (greenish-yellow) 64M - 36M = 28M
# gains_2020 (orange) 36M - 15M = 21M
# gains_2019 (red) 15M - 15M = 0M
```

Footnotes

[1] Harper, C., McAndrews, G., & Byrnett, D. S. (2019). Electric Vehicles: Key Trends, Issues, and Considerations for State Regulators. *National Association of Regulatory Utility Commissioners*, p. 7.