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How will we fund our roads? A case of decreasing revenue from electric vehicles

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ABSTRACT

Annual expenditures for transportation infrastructure have recently surpassed the funding available through tax and fee collection. One large source of revenue generation for transportation infrastructure is use fees that are charged through taxes on gasoline both on a federal and state level. A massive adoption of electric vehicles (EVs) in the United States would result in significantly lower gasoline consumption and thus reduce the revenue collected to maintain the U.S. transportation infrastructure. We investigate how different vehicles will change the annual fee collected on a marginal basis. In addition, we assess the effects of adoption of alternative vehicles on revenues using several projections of alternative vehicles adoption, both on a state-by-state basis and at the national level. We find that baseline midsize and compact vehicles such as the Toyota Camry and Honda Civic generate approximately $2500–$4000 in tax revenue over their lifetime. Under the current funding structure, battery-electric vehicles (BEVs) such as the Nissan Leaf generate substantially less at $400–$1300, while plug-in hybrid electric vehicles (PHEVs) such as the Chevrolet Volt generate $1500–$2700. Even in states with high lifetime fees due to fuel taxes, such as California, revenue generation can be upwards of 50% lower than in states with high registration fees such as Colorado. Total annual revenue generation decreases by about $200 million by 2025 as a result of EV adoption in our base case, but in projections with larger adoption of alternative vehicles could lead to revenue generation reductions as large as $900 million by 2025. Potential schemes that charge user fees on alternative fuel vehicles to overcome the decrease in revenue include a flat annual registration fee at 0.6% of the vehicle's manufacturer suggested retail price (MSRP) or 22¢ per mile fee.

1. Introduction

The United States has a tremendously large road network with over 4 million miles of interstate highways, freeways, expressways, and local roads.[1] The transportation infrastructure is costly to build and even costlier to maintain: in 2010 approximately $4 billion was spent on the construction of new highways and bridges and $19 billion was spent on maintenance of existing highways and bridges by the federal government.[2] Similarly, state-level departments of transportation fund

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[1] U.S. Department of Transportation: Federal Highway Administration. Highway Statistics 2010, Table HM-20. http://www.fhwa.dot.gov/policyinformation/statistics/2010/hm20.cfm.

[2] U.S. Department of Transportation: Federal Highway Administration. Highway Statistics 2010, Table FA-10. http://www.fhwa.dot.gov/policyinformation/statistics/2010/fa10.cfm.

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transportation infrastructure projects and maintenance on a regional basis to the amount of about $90 billion in 2010.[3] Expansion of road networks and other transportation infrastructure means that these costs have increased historically, a trend that is likely to continue in the coming years. Fig. 1 shows the level of total federal revenue and spending from 1985 until 2012. Over the course of the last few years, expenditures have exceeded revenue generation.

The adoption of electric vehicles presents an interesting problem for revenue generation. In this work, we consider the following electric vehicles: plug-in hybrid electric vehicles (PHEVs) and full battery electric vehicles (BEVs). Since a relatively large portion of fees are collected through vehicle use by way of taxes on gasoline (about 50–70%), large-scale adoption of EVs would result in a decline in revenue generation since they use little to no gasoline as fuel. An estimate of the number of EVs sold in the future is required in order to estimate potential revenue losses.

Fig. 2 shows an increasing trend in both the quantity and availability of EVs since their first introduction into the automobile market in December of 2010. The most popular vehicles sold are the Chevrolet Volt (PHEV) and the Nissan Leaf (BEV) though the Toyota Prius (PHEV) and Tesla Model-S (BEV) have been recently gaining traction in sales as well. The variance in sales follows cyclical seasonal trends in vehicular sales, though the overall growth of many individual models far outpaces average vehicle model growth in the industry.

The importance of fuel tax revenue for road infrastructure funding was outlined in earlier works over two decades ago. Varma and Sinha describe state-to-state differences in revenue generation, the three-tiered charging system, and most importantly introduce a discussion of potential issues with revenue loss from alternative fuel vehicles (Varma and Sinha, 1990). Similarly, Berg describes issues of revenue generation for alternative fuels but for gasohol (gasoline blended with ethanol) and costs associated with the fuel type on the order of $480 million per year (Berg, 1990). While both studies are outdated, they are relevant in pointing out pervasive issues in the future of transportation. A number of reports have recently been produced by agencies such as the Congressional Budget Office and the American Society of Civil Engineers. These reports discuss the declining sources of funds for critical infrastructure, including trends in the transportation sector (Bradley et al., 2011; Congressional Budget Office, 2010; American Society of Civil Engineers, 2009; Coussan and Hicks, 2009). There are a number of works that highlight shortcomings of the gasoline use tax, particularly with decreased feasibility in funding opportunities as high fuel efficient vehicles are adopted (Krishen et al., 2010; Watts et al., 2012). In addition, there are important implications of different policy designs to generate revenue for transportation infrastructure in light of a host of issues facing the United States (Dutta and Patel, 2012; Schank and Rudnick-Thorpe, 2011).

Pricing schemes for fees such as congestion charging fees (Hensher and Puckett, 2007) and privatization using access toll roads (Swan and Belzer, 2010) have been studied and proposed. Unfortunately, there has not been much discussion to the issue of pricing schemes in response to the adoption of electric vehicles. While our work focuses on the quantification of revenue losses from electric vehicle adoption, we also provide an assessment of potential policies to address this issue, though we do not delve into issues of practical implementation.

Our work contributes to the body of literature by specifically quantifying the monetary impacts of electric vehicles (including plug-in hybrids (PHEVs) and fully battery electric vehicles (BEVs) adoption within the United States, both in the past as well into the future using projections from the Energy Information Agency (EIA). The remainder of the paper is organized as follows: in Section 2 we provide a description of the data we use to estimate the magnitude of EV adoption. In Section 2 we also provide an overview of the approach we use to calculate the cost figures. In Section 3 we provide the results and analysis and Section 4 ends with a presentation of the findings of our work and policy implications.

2. Materials and methods

In this section, we describe how we calculate lifetime fees for vehicles on a state-by-state basis, how we estimate future revenue gaps, and the approach we use to determine alternative policy strategies to overcome funding deficits due to EV adoption.

2.1. Lifetime fees for specific vehicle models on a state-by-state basis

Funding for transportation infrastructure is derived at three levels: federal, state, and local. The federal funding is specifically used for interstate highway construction and maintenance and comes from apportioned budgeting through Congress (such as funds from the stimulus package) as well as a use-fee flat tax on gasoline at 18.4¢ per gallon. State-level data are accumulated from states' respective department of transportations and legal rules for vehicle fees. These fees are used to fund state-level transportation projects, as well as local road construction and maintenance. State fees consist of a variety of use and fixed taxes. These include an additional gasoline tax, title fees, registration fees, and inspection fees. Registration fees are typically charged at an annual or biannual basis, and are typically flat or a function of vehicle weight or age. A description of state level charges can be found in Appendix, Table S1. We note that our estimates may be lower bounds as several states also have other fees (such as annual motor vehicle taxes) that could not be accounted for in this work.

[3] U.S. Department of Transportation: Federal Highway Administration. Highway Statistics 2010, Table SF-2. http://www.fhwa.dot.gov/policyinformation/statistics/2010/sf2.cfm.

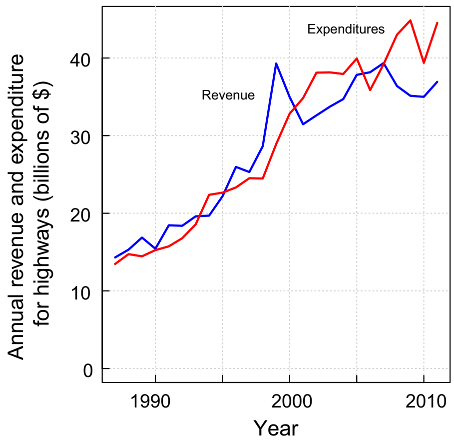

Fig. 1. Historical federal highway revenues and expenditures (real dollars) from 1985 to 2012. Figure produced by authors using data from the U.S. Department of Transportation Highway Statistics 2010.

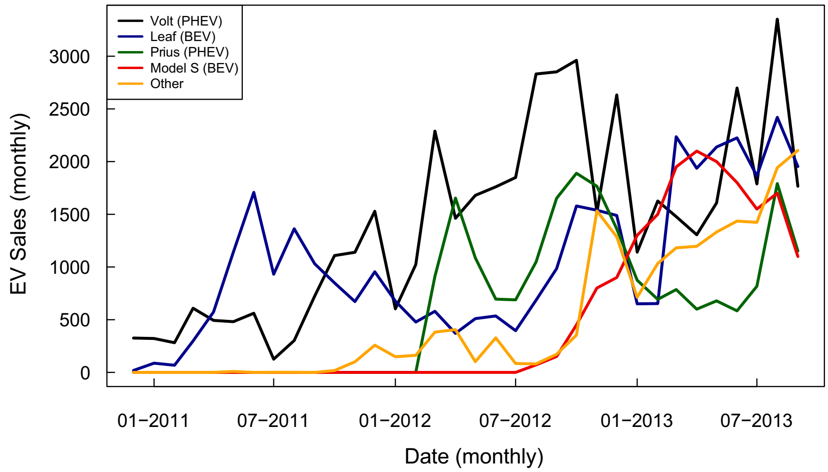

Fig. 2. Monthly sales figures for electric vehicles by model. Figure produced by the authors using data from http://www.hybridcars.com Hybrid Market Dashboard.

We estimate the total lifetime fees paid by a single vehicle model by aggregating the different components of fees outlined in Appendix in Table S1. The total lifetime fees, *lifefee*, by state index, *s*, over a vehicle's lifetime, *l*, can be calculated as:

$$lifefee_s = \sum_l \left[\frac{v}{FE} (tax^{fed} + tax_s^{state}) + regfee_{ls} + inspfee_{ls} \right] + titlefee \quad (1)$$

where registration fees over the lifetime of the vehicle and across all states is represented by $regfee_{ls}$, likewise inspection fees is represented as $inspfee_{ls}$, and the onetime titling fee is *titlefee*. Both registration fees and inspection fees vary between different states and can be a function of the vehicle's age, weight, manufacturer's suggested retail price (MSRP), drivetrain technology, or horsepower. For use-fees from gasoline taxes, we estimate the annual consumption of gasoline by dividing the annual miles travelled, v, by the vehicle's fuel efficiency, *FE*. We calibrate vehicle use behavior with a standardized annual vehicle miles travelled of 12,500 miles and a lifetime of 12 years[4] for all states in Table S1 in Appendix. The results are spatially portrayed on a state-by-state basis as well as broken down by components of funding sources in order to identify which fees are primarily responsible for decreases in overall revenue for EVs. Comparisons are based on fees calculated on a state-by-state basis using the characteristics in Table 1 as representative traditional internal combustion engine vehicles (ICVs), and EVs that progressively age in our analysis.

[4] Average values for vehicle use according to NHTSA report: Lu (2007).

Table 1
Vehicle characteristics inputs (MY 2013).

Vehicle model	Toyota camry	Honda civic	Ford F-150	Nissan leaf	Toyota prius	Chevrolet volt
MSRP [$]	22,235	18,165	24,070	21,300	32,000	34,185
Curb weight [lb]	3190	2740	4685	3291	3165	3786
Gas fuel efficiency [mi/gal]	28	32	20	NA	50	37
Technology	ICV	ICV	ICV	BEV	PHEV-10	PHEV-40
Horsepower	178	140	302	107	98	149

2.2. Assessing and projecting aggregated funding deficits

To calculate aggregate funding deficits, we use projected vehicle sales from the 2013 Annual Energy Outlook (AEO) from the Energy Information Administration (EIA) (EIA, 2013) report as seen in Fig. 3. Energy modelers generally use AEO reports from the EIA as baseline scenarios for system level models. However, we note that projections of sales by vehicle type are highly uncertain. For example, as shown in Fig. 3, the AEO report that was published in 2013 does not provide a good alignment with 2012 historical sales.

Alternative forecasts of electric vehicle adoption differ wildly based on differences in modeling, assumptions used, and year in which the forecast was performed. In Fig. 4 we have compiled several forecasts resulting from recent studies, and show the market share of electric vehicles over time and nationwide. As our paper attempts to avoid an exercise in forecasting vehicle adoption, we choose to the AEO 2013 forecasts as a middle-of-the-road level of adoption (at least through year 2025, which is the last year included in our analysis), and supplement our analysis with a sensitivity analysis. In the sensitivity analysis, we rely on the EPRI/NRDC, 2007 study through 2025 as an upper bound for our results.

We use the following representative vehicles: the Toyota Prius PHEV for the PHEV-10, the Chevrolet Volt for the PHEV-40, and the Nissan Leaf for the BEV-100. The proportion of time spent in electric drive mode is based on assumptions from the Environmental Protection Agency (EPA) with the Prius PHEV being 29% and the Chevrolet Volt being 66%.[5]

In order to distribute the projected sales over the 50 US states, we proxy sales based on average distributions of Toyota Prius (HEVs) over the past decade. The Prius serves as a superior representative to EV sales than the average vehicle model sold in the US on a monthly level. There is a substantial difference in state-level market share of Toyota Priuses compared to the average vehicle, and by proxying with the Prius we are better able to capture spatial consumer dynamics favoring "greeness". The total fees charged by a state, $totalfee_s$, are calculated as:

$$totalfee_s = lifefee_s \times p_s \times n \quad (2)$$

where $lifefee_s$ is calculated from Equation, p_s is the proportion of Priuses sold by state based on historical sales, and n is the projected sales of electric vehicles as provided by the 2013 AEO. We incorporate the uncertainty of p_s by drawing from the historical monthly distribution of Prius sales by state over the last 10 years in a Monte Carlo simulation with 10,000 draws.

In order to assess the change revenue with and without EVs, we assume a counterfactual scenario representing the baseline revenue generation where purchasers of electric vehicles instead choose to drive an average midsize vehicle. We chose a standard Toyota Camry to represent this vehicle. While we recognize this likely leads to inaccuracies in our counterfactual scenario, our results are meant to be order of magnitude estimates rather than an exercise in modeling vehicle sales.

2.3. Policy strategies to overcome the funding deficit arising from EV adoption

We estimate alternative policy options specifically for EVs that can help overcome the decreases in revenue generation in the status quo. The first option is charging an annual registration fee that is based on the percentage of MSRP of the vehicle. This strategy helps overcome decreases from use fee revenues, since EVs typically have a higher initial capital cost relative to traditional ICVs. We conduct an analysis across distribution of sales by state while parametrically varying the percentage of MSRP being charged. Similarly, we also consider a policy option that charges based on a use fee tax. We conduct an analogous sensitivity analysis by varying the dollars per mile charge. We incorporate ranges of values in our results based on differences in the distribution of historical Prius sales, which we use to allocate the projections of future electric vehicle sales.

3. Results and discussion

3.1. Breakdown of current revenues and expenditures by state

Figs. 5 and 6 break down the components of revenue generation and expenditures for transportation infrastructure in 2011, by state. The funds for the vehicle infrastructure come from a variety of sources including vehicle license and registration fees, toll road fees, inspections, titling, gasoline fuel taxes, and a number of other minor sources. Transportation departments are facing or will likely be facing deficits. We examine the effect of a changing vehicle fleet on the revenue

[5] 2013 Fuel Economy Datafile from the Office of Transportation & Air Quality from the US EPA at http://www.fueleconomy.gov/feg/download.shtml.

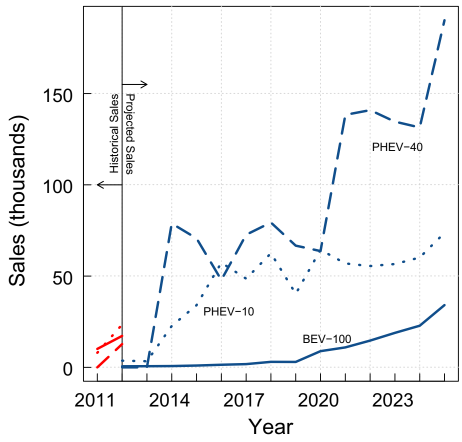

Fig. 3. Projections of electric vehicle sales through 2025 by the Energy Information Administration's Annual Energy Outlook 2013. Figure produced by the authors using data from the EIA (EIA, 2013).

generating capability of transportation departments in the United States. There is a potentially large decrease in gasoline tax revenue due to the increasing adoption of alternative fuel vehicles (AFVs) such as plug-in hybrids or full battery electric vehicles combined with the mandated fuel efficiency requirements from the Corporate Average Fuel Economy (CAFE) standards. Given the different tax and fee structures across states, as well as different vehicle fleet mixes, the revenues (and revenue losses) likely incurred by each state will differ widely. We estimate the lifetime fees associated with new alternative fuel vehicles across all 50 states in the US, as well as examine which state fee structures are most amenable to maintaining budgets amidst lower gasoline consumption at the margin.

3.2. Lifetime fees for specific vehicle models in each state

The results for revenue generation vary across the country because of differential state tax/fee policies. For standard midsize and compact vehicles (see Fig. 7 *top-left* and *top-right*), most states gain approximately $2000–$4000 in revenue over the lifetime of the vehicle. Typically over half of the fees are accrued from fuel taxes. For example, consider the states of California and Colorado: the former of has relatively high fees due to its fuel tax while Colorado has high fees due to its registration fee as a function of MSRP. The Camry fees are slightly higher for Colorado at $4600 compared to $4200 in California.

For less fuel-efficient vehicles, such as the light-duty F-150 truck seen in Fig. 7 (*bottom-left*), revenue generation is substantially higher from $3000 to $6000 over the lifetime of the vehicle. The share of revenue generation from fuel taxes typically increases across all states because of the large amount of gasoline consumption. For ICVs, most states generate at least half to two-thirds of their revenue from fuel taxes, a source of revenue that is significantly diminished for EVs.

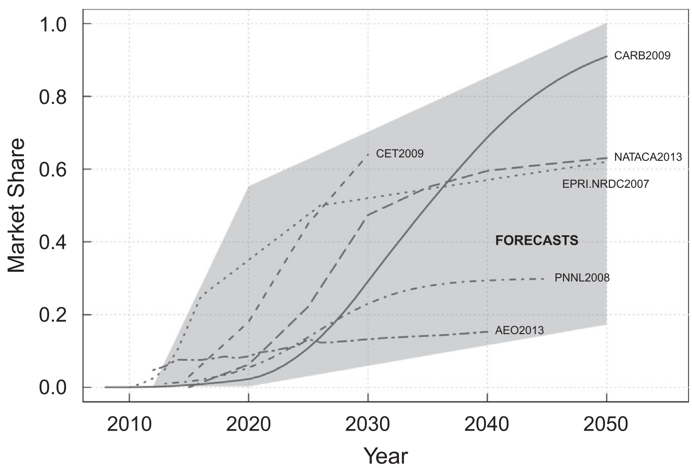

Fig. 4. Forecasts of electric vehicle adoption by market share. The forecasts shown are: CET2009 – (Becker et al., 2009), CARB2009 – (California Air Resources Board, 2009), NATACA2013 – (National Academy of Sciences, 2013), EPRI.NRDC2007 – (Electric Power Research Institute and Natural Resources Defense Council, 2007), PNNL2008 – (Balducci, 2008), AEO2013 – Annual Energy Outlook 2013.

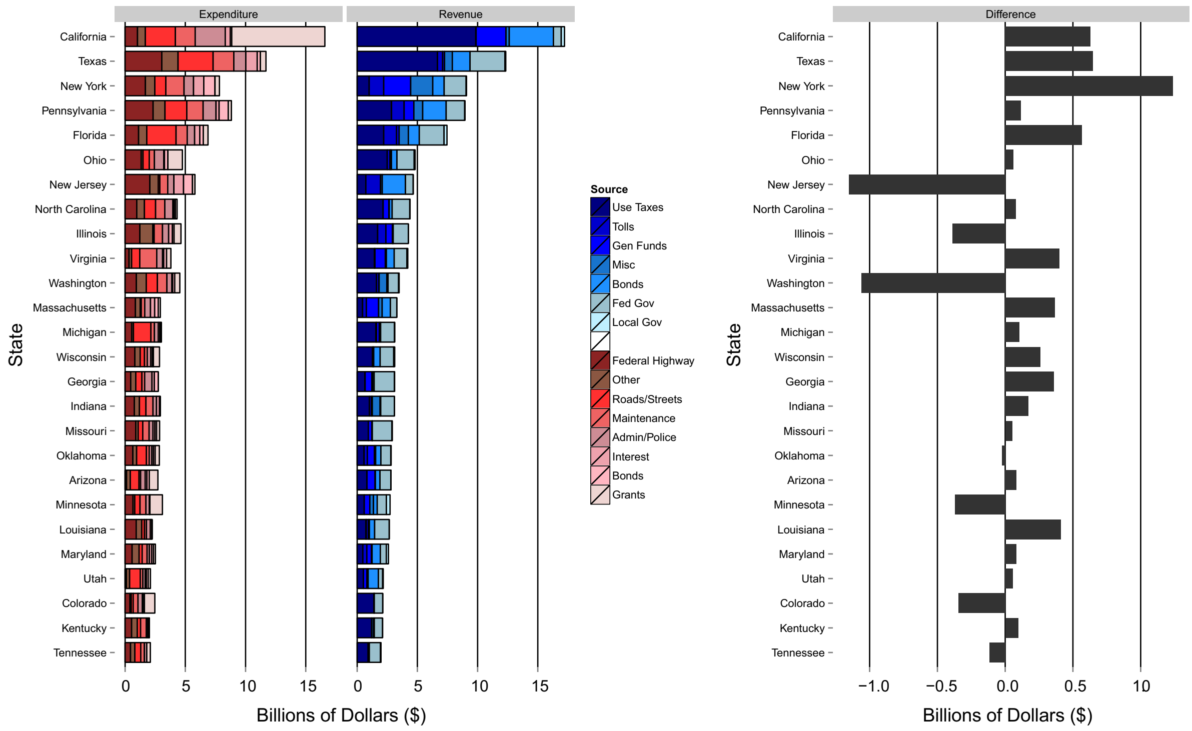

Fig. 5. Revenue and expenditures for 25 top grossing states in 2011 (highest revenue at approximately $15 billion). (*left*) Breakdown of revenues and expenditures, (*right*) Difference between revenue and expenditures, positive values indicate higher revenues than expenditures and negative values indicate higher expenditures than revenues.

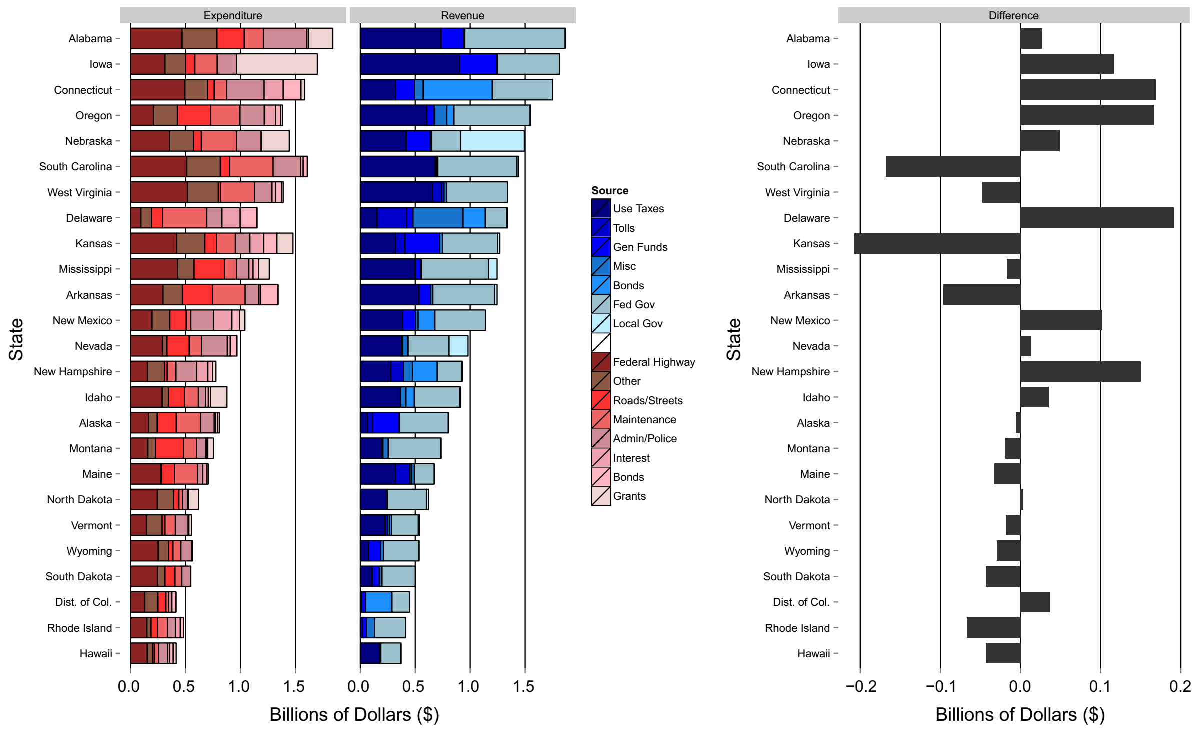

Fig. 6. Revenue and expenditures for 25 bottom grossing states in 2011 (highest revenue is ~$15 billion). *Left*: Breakdown of revenues and expenditures. *Right:* Difference between revenue and expenditures, positive values indicate higher revenues than expenditures. Negative values indicate higher expenditures than revenues.

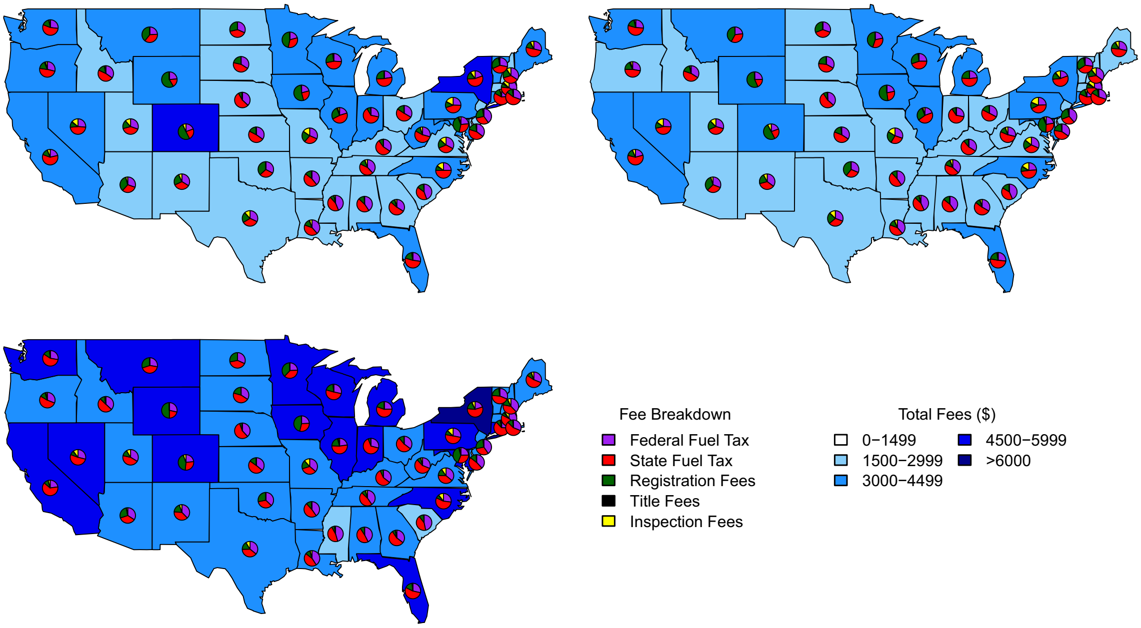

Fig. 7. Lifetime fees for ICVs by state. The color-code by state provides the total fees per vehicle over its lifetime while the pie charts highlight the breakdown of the fees by source. (*top-left*) Toyota Camry (Midsize ICV model), (*top-right*) Honda Civic (Compact ICV model), (*bottom-left*) Ford F150 (Light-duty truck ICV model). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The state fees in California and Colorado are quite similar, at about $5800 between both states, where the inefficient fuel economy in California compensates for the high registration fees in Colorado.

As shown in Fig. 8 (*top-left*), revenue generation from the Nissan Leaf is substantially lower than conventional ICVs with a range less than half of the Camry or Civic at around $400–$1300. Most noticeably from the breakdown of components of fees, there are no fuel taxes because of the fact that the electric drive in the Leaf does not consume any gasoline. Now the difference between California and Colorado are quite significant: California cannot rely on its high fuel taxes, resulting in a revenue collection of only $600 over the lifetime of the Nissan Leaf in comparison to $3100 in Colorado.

The revenue generation for PHEVs is higher than BEVs such as the Nissan Leaf, as seen in Figs. 8 (*top-right*) and 7 (*bottom-left*) with a range from $1500 to about $2700. This is still at the lower end of comparable ICVs. For these plug-in hybrid electric vehicles, the proportion of fees from fuel taxes is substantially lower because of operation of the electric drivetrain that does not require any gasoline. Once again, the decrease in revenue generation is substantially lower in states with MSRP based registration fees. Colorado's lifetime fees for the Prius and Volt are $4000 and $4800 respectively compared to California's fees of $2400 for both vehicles, representing around a 50% decrease in revenue generation for both vehicle models. An upper-bound decrease in revenue is estimated as the difference in revenue generation between the Ford F-150 and the Nissan Leaf (see Fig. 9).

In Fig. 10, we estimate the annual loss in future revenue generation due to decreases in fuel tax collections from electric vehicles. Using projections from the EIA AEO 2013 for vehicle sales and using the distributions of sales by state from Toyota Priuses as a proxy for future EV sales, we roughly estimate annual decreases in total revenue generation (as described in Section 2). Assuming the sales in the EIA reference scenario, over the next decade revenue from use fees for electric vehicles will decrease by around $200 million annually.

Similarly, we estimate the total revenue decrease by state due to EVs sold through 2025 (estimated using EIA 2013 AEO scenarios). The highest losses are a function of both the relative number of sales as well as each states' respective revenue-generation policies. While states with the highest populations expectedly have the greatest revenue loss, the magnitude of their losses is affected by their level of EV adoption as seen in Fig. 11. The high population states of California, Texas, Pennsylvania, and Florida all have total revenue decreases in excess of $70 million, cumulatively from 2011 to 2025. Other states with similar decreases include Wisconsin, Illinois, Virginia, North Carolina, and New York. Since the cumulative revenues in Fig. 11 are a function of both the state policies as well as the number of drivers, we also normalize these estimates by population to assess the effect of EV adoption per capita (see Fig. 12). The vertical axis in Fig. 11 displays such results in dollars per person. These monetary amounts per person have very small (on the order of $0–$20) due to the fact that relatively low adoption numbers are distributed across the entire population of the state.

3.3. Policies to overcome the funding deficit from EV adoption

In this section, we assess potential alternative strategies for revenue generation. An annual registration fee similar to Colorado or Wyoming wherein a fee is charged based on a percentage of the MSRP of the vehicle could be incorporated

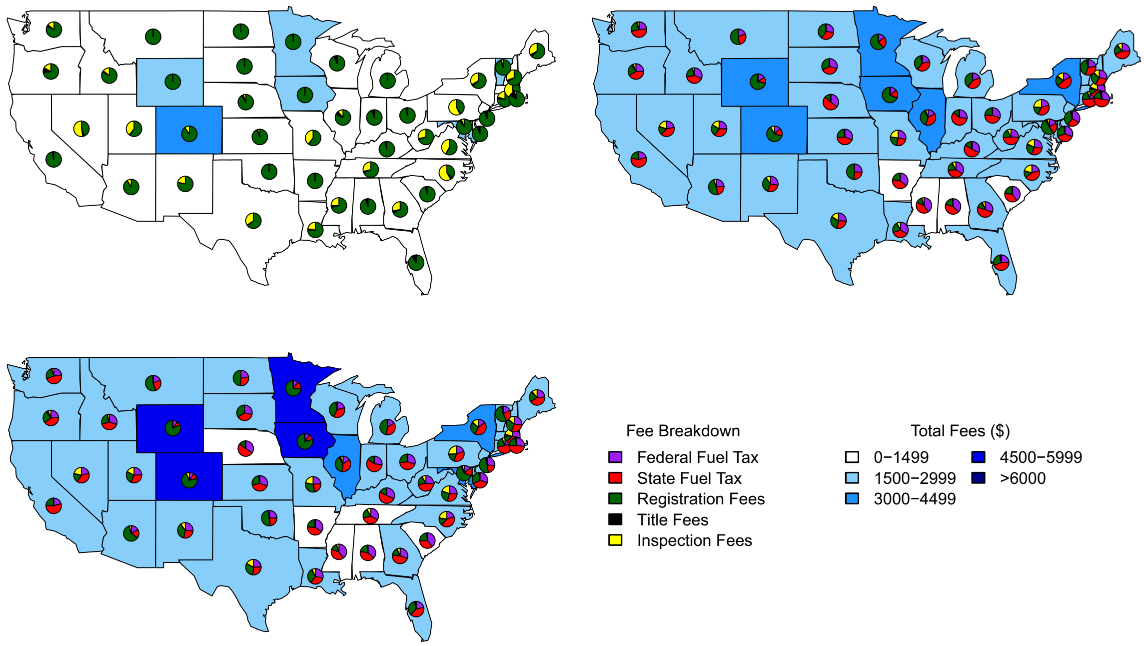

Fig. 8. Lifetime fees for EVs by state. The color-code by state provides the total fees per vehicle over its lifetime while the pie charts highlight the breakdown of the fees by source. (*top-left*) Nissan Leaf (BEV 100 model), (*top-right*) Toyota Prius (PHEV 10 model), (*bottom-left*) Chevrolet Volt (PHEV 40 model). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

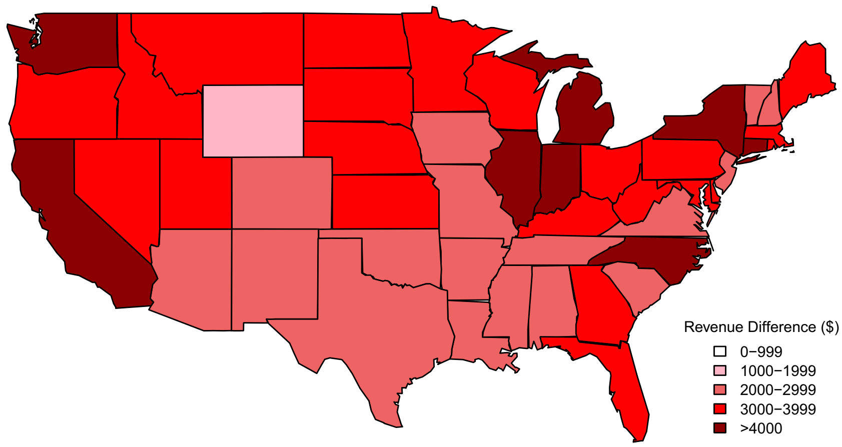

Fig. 9. Difference in lifetime fees between Ford F-150 and Nissan Leaf by state as an upper bound estimate of revenue decrease at the margin.

to make up the decrease in revenue generation from EVs. Fig. 13 demonstrates a fee of approximately 0.6% would breakeven the cumulative annual revenue generation overtime and even small increases over this amount can yield large increases in revenue (on the order of $1 billion to $2 billion). Similarly, instead of a use fee by taxing gasoline, a use fee on the mileage driven by the vehicle would also suffice as a replacement. At approximately 2¢ per mile, revenue generation from EVs would breakeven in comparison to comparable ICV replacements.

Alternatively, revenue neutrality can also be maintained by imposing a tax on electricity when charging an EV. The required fee would be approximately 4.5¢ per kW h when considering the efficiency of a Volt (35 kW h/100 miles). While this is a relatively small fee, we do not consider difficulties with policy implementation. Lastly, we also consider distribution of the revenue loss across all drivers in the US and roughly estimate that the total required tax would be a mere 0.02¢ per gallon of gas because of the relatively small number of EVs that would be sold in comparison to the ICV fleet. We display a short summary of fee increases on consumers that would be required to achieve revenue neutrality using different funding strategies in Table 2.

Table 2 demonstrates that for EV owners, bearing the cost of the fee increases can result in relatively large increases to their existing registration fees (or electricity bills). However, disaggregating the fees among the general population of drivers

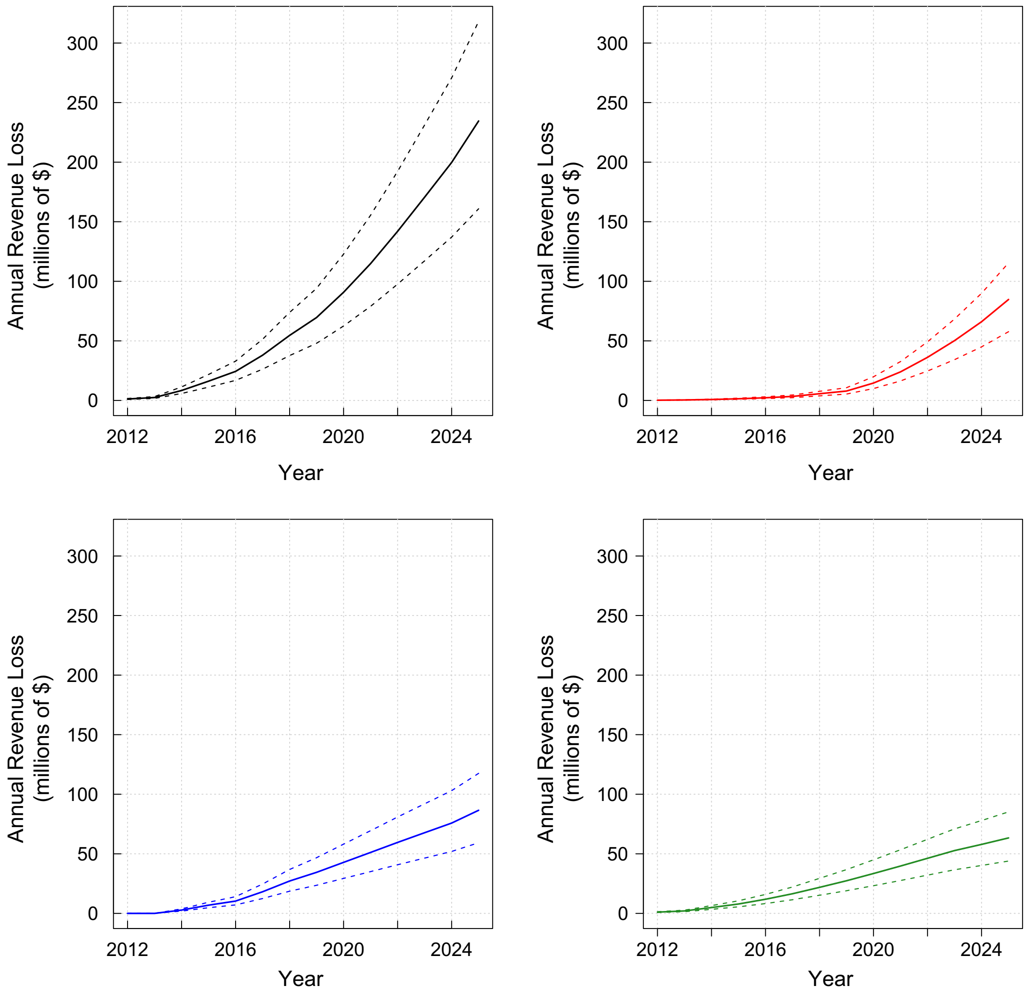

Fig. 10. Expected annual revenue loss for EVs with 95th percentile ranges of the distribution of historical Prius sales by state used to assign projected electric vehicles by state. Assumption of sales by vehicle type comes from AEO 2013 scenario estimates (see Fig. 3).

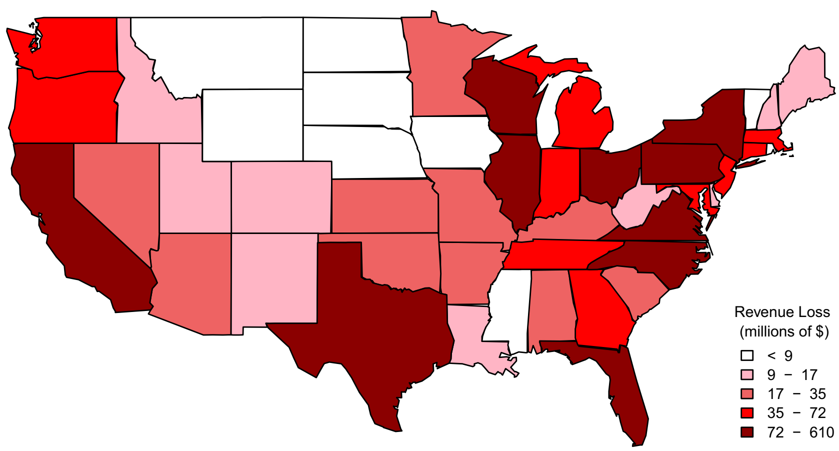

Fig. 11. Expected cumulative revenue loss through 2025 for EVs by state.

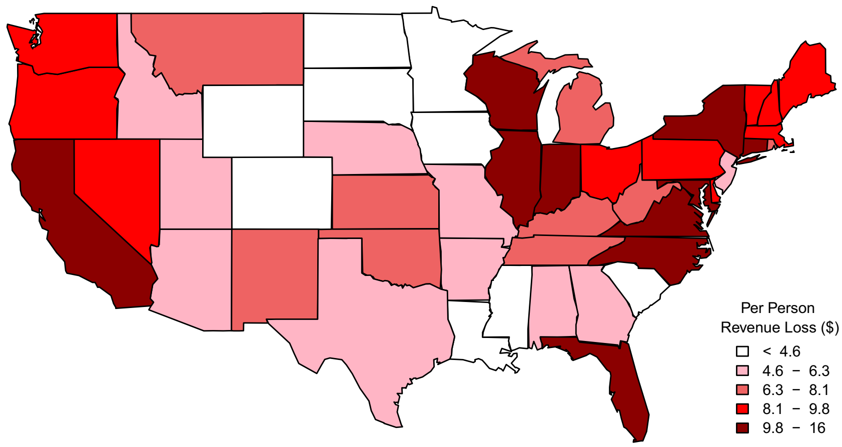

Fig. 12. Expected cumulative revenue loss through 2025 for EVs by state, normalized to 2012 population.

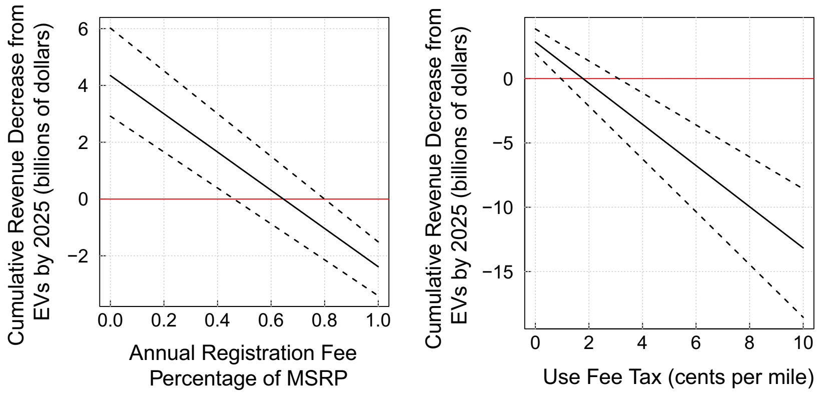

Fig. 13. Sensitivity analysis on alternative revenue generation policies with uncertainty from distribution of historical Prius sales by state used in allocating projections of electric vehicle sales.

Table 2
Absolute and relative increases in fees for two payee groups (depending on state).

Source	EV Owners		All vehicle owners	
	Absolute increase	Relative increase in annual bill (%)	Absolute increase	Relative increase in annual bill (%)
Annual registration fee	$200	60–1400	$1	0.5–7
Use fee	$0.045/kW h	100–266	$0.002/gal	0.05

leads to a negligible increase in gasoline fees paid by drivers: less than a penny per gallon. If the fees were switched to annual registration fees across all drivers, again the increase in negligible with approximately a $1 per year increase to registration fees.

Overall, the relative number of electric vehicles across a large number of projection scenarios is very small in comparison to the enormous number of traditional ICVs sold in the market. As a result, the increase in fees to compensate for revenue decreases from EV sales across the entire space of vehicles is much smaller than the variability that drivers would see in fluctuations of daily gas prices.

3.4. Effect of a larger adoption of EVs

Due to the conservative sales adoption of the AEO 2013 projections we use in the baseline scenario, we also examine an alternative and more aggressive adoption forecast that was produced by a report from EPRI/NRDC in 2007. Fig. 14 shows the baseline revenue loss scenario as well as the EPRI/NRDC scenario. If one assumes EPRI's EV sales projections, the increased adoption of electric vehicles would result in higher revenue loss, on the order of $900 million per year by 2025. This means that a revenue loss of roughly 3–4% of the annual revenue generation would be entailed.

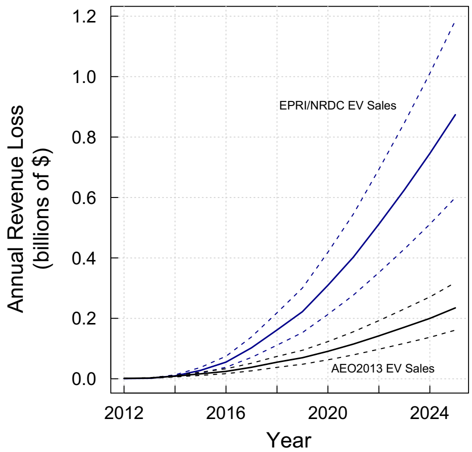

Fig. 14. Comparison of revenue loss from an upper-bound estimate based on optimistic projections of electric vehicle sales from an EPRI/NRDC study. Annual reduction in revenue is approximately four times higher at $900 million per year.

Given the large uncertainty about the future adoption of EVs, policy makers should consider addressing this potential revenue loss. The distribution of revenue decrease is now larger and would result in an approximate 1¢ per gallon tax, which would progressively increase over time as more electric vehicles are adopted.

4. Conclusion

While the decrease in annual revenue generation of $200 million is a relatively small amount of total national revenue generation (∼1%), the decrease represents part of a larger issue where expenditures have over taken revenue generation in the recent past. Future strategies to increase revenue generation should accommodate the increasing adoption of EVs in the market. Our analysis provides a monetary strategy to overcome the impact of EV adoption on revenue generation for transportation infrastructure, but there are still several unresolved issues. Firstly, implementation of our proposed strategies has been traditionally difficult. Political backlash against increased fees could prevent such policies from being adopted despite the fact that the majority of vehicles (ICVs) would see no effective increase in fees. Moreover, a use fee tax by mileage could present implementation challenges, as odometer readings would be required. Secondly, increasing fees for EVs works in stark opposition to incentives for alternative fuel vehicles adoption that both federal and state governments have made (e.g. tax credits). A targeted increase in fees for EVs would be an inefficient mechanism that may hinder the promotion of adoption strategies. Nevertheless, decreasing revenue generation from EVs represents a small but growing problem that should be considered in future strategies to increase revenue for transportation infrastructure funding.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tra.2015.02.004.

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