Impact of Eliminating the Alternative-Fuel Vehicle Tax Exemption on the Washington State Economy

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Securing America's Future Energy and
The Electrification Coalition

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EXECUTIVE SUMMARY

Washington currently offers an exemption of its motor vehicle sales and use taxes for all-electric vehicles. The exemption has played a significant role in boosting Washington's all-electric vehicle penetration rate to one of the highest rates in the country—1.2 percent of all new light duty-vehicle sales in 2014. This study, commissioned by Securing America's Future Energy (SAFE) in partnership with the Electrification Coalition, examines the economic effects of a possible elimination of the sales tax exemption on the Washington state economy.

The study evaluates two scenarios – a "baseline" scenario in which Washington's tax exemption remains in place through 2019 and a "policy shock" scenario in which the tax exemption is eliminated starting in July 2015. It quantifies the impact on state GDP of removing the exemption by comparing the two scenarios. The study starts with an accounting of the household-level response to the removal of the tax exemption and aggregates up to the state-level. The study's micro-level consumer cost model is based on the Electric Power Research Institute's (EPRI) 2013 and 2014 reports on the economics of EV ownership, which provide detailed estimates of the cost of owning and operating electric vehicles (EVs) relative to a comparison set of conventional vehicles. The study's macroeconomic modeling of the state-level impacts relies on a 70-sector model of Washington's economy developed by REMI, Inc., a leading supplier of regional economic models.

The study finds that the elimination of Washington's sales tax exemption would reduce Washington's real GDP (or aggregate state income) each year between 2015 and 2030.

- The cumulative 5-year loss in Washington's GDP is $25 million, and the cumulative 16-year loss totals $68 million, assuming that consumers respond to the elimination of the tax exemption by purchasing conventional internal combustion engine vehicles instead of EVs. This overall loss of Washington GDP occurs despite the repurposing of "saved" EV funds on other forms of state government spending.
- Further, the study finds that without the sales tax exemption, Washington car owners would pay an additional $40 million in gasoline bills over the next five years and an additional $191 million through 2030 (only partially offset by saving $46 million in electricity bills).
- Additionally, it finds that if the EV tax exemption were eliminated, Washington would be giving up a type of future economic insurance policy for its consumers. If the exemption were eliminated (and there were fewer EVs on Washington roads) and gasoline prices then spiked by $1.50 a gallon in 2020 due to an oil shock, Washington drivers would have to spend an additional $7 million per year for fuel beyond the numbers cited above.

Two key factors account for the reduction in state GDP. With significantly fewer EVs on the road in the absence of the tax exemption, state drivers would have to pay more for transportation fuel over the coming years, because EVs are cheaper to operate than conventional vehicles. This would cause reduced spending on other Washington-produced goods and services. Second, the elimination of the state's exemption would reduce current cash inflows to Washington households from the federal $7,500 EV income tax credit.

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I. INTRODUCTION

In an effort to increase electric vehicle penetration, the Washington state government currently offers a sales tax exemption to individuals who purchase or lease a new all-electric vehicle (also known as battery electric vehicles, or BEVs). This Alternative Fuel Vehicle (AFV) tax exemption only applies to vehicles that run exclusively on a clean alternative fuel; therefore, only all-electric vehicles qualify for the exemption, while plug-in hybrids (PHEVs) do not. Specifically, purchasers of BEVs are exempt from the 6.5% state sales tax and the 0.3% motor vehicle use tax.[1] The AFV exemption has played a significant role in boosting Washington's BEV penetration rate to one of the highest rates in the country—1.2 percent of all new light duty-vehicle sales in 2014.[2]

Washington's AFV tax exemption is currently scheduled to expire on July 1, 2015, although several state lawmakers are calling for an extension. Proponents of the exemption stress the environmental and household benefits associated with increased EV ownership, while opponents stress the budgetary pressures facing the state. This study, commissioned by Securing America's Future Energy (SAFE) in partnership with the Electrification Coalition, quantifies the economic impact of a possible elimination of Washington's AFV sales tax exemption on the state economy. It asks what the likely impact would be on Washington's economy if people currently purchasing all-electric vehicles in response to the state tax exemption purchased conventional vehicles instead.

The study adopts a detailed consumer model of the economics of electric vehicle ownership and operation conducted by the Electric Power Research Institute's (EPRI) in 2013 and 2014. For the macroeconomic modeling component, the study relies on a 70-sector model of Washington's economy developed by REMI, Inc., a leading supplier of regional economic models.

The report is organized as follows: Section II provides policy context behind the rationale behind the current discussion regarding tax incentives for EVs; Section III outlines the study's technical approach and core assumptions; Section IV describes the study's main findings; and Section V offers key conclusions from the modeling exercise. Four technical appendices present the study's detailed results, a full list of its modeling assumptions, a description of the model used to conduct the study, and references.

II. POLICY CONTEXT

Over the past five years, car manufacturers have begun to introduce more electric vehicles (EVs) into the American light-duty vehicle market. The potential advantages of increased EV ownership are numerous: electric vehicles provide an opportunity to reduce household spending on transportation over the long-run, insulate consumers from gas price fluctuations,

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[1] The dollar-value of the tax exemption will of course vary based on the make and model of vehicle purchased.
[2] Polk Automotive, Vehicle Sales by State, January 2011 – October 2014

improve U.S. energy diversification, and emit minimal to zero tailpipe pollutants.[3] Despite these benefits, EVs account for only a small segment of U.S. vehicle purchases each year. One likely reason for this is that EVs can still be considered an "infant industry". In other words, EVs represent a relatively new technology that may have difficulty gaining market share in an industry dominated by an older technology (in this case, the traditional internal combustion engine). This may be due to a variety of factors, including entrenched consumer habits, an extensive conventional infrastructure (like fueling infrastructure), and the relatively higher cost of younger technologies, which typically lack the economies of scale in production enjoyed by older technologies.

Given these factors, and in light of the benefits associated with increased EV penetration, the federal government has established an income tax credit of $7,500 in order to incentivize the uptake of EVs. Because policymakers expect the EV industry to mature over time and compete with conventional internal combustion engine (ICE) vehicles without government support as economies of scale improve and costs decline, the federal credit is available for the purchase of the first 200,000 EVs sold by each auto manufacturer and is set to phase out once sales quotas are reached.

At the state level, lawmakers can amplify the effect of the federal credit by offering their own incentives, such as a tax credit or sales tax exemption. This can allow states to capture the immediate economic benefits associated with federal funds flowing into the state as well as the long-term, sustained benefits of higher EV penetration. More state residents driving EVs translates into reduced overall spending on transportation fuels and vehicle maintenance, which frees up a larger share of household budgets to be spent on other goods and services. In Washington, policymakers have attempted to capture these benefits by establishing a state sales tax exemption for alternative fuel vehicles, including BEVs, which has been highly effective at increasing the state's EV penetration rate. While critics of the tax exemption emphasize its cost to the state budget, proponents assert that the benefits of reduced gasoline consumption create positive ripple effects throughout Washington's economy.

III. METHODOLOGY

3.1 TECHNICAL APPROACH

This study evaluates two core scenarios – a "baseline" scenario in which Washington's AFV sales tax exemption remains in place through 2019 and a "policy shock" scenario in which the tax exemption is eliminated, as scheduled, in July 2015 – and quantifies the impact on state GDP of removing the tax exemption, relative to the baseline. The study considers a 16-year time horizon, which spans the five years during which the state tax exemption is assumed to be available and is intended to coincide with the average lifetime of new vehicles (i.e., vehicles purchased in the program's fifth and final year are assumed to be taken off the road in the last year of the modeling time horizon).

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[3] Congressional Budget Office (2012). "Effects of Federal Tax Credits for the Purchase of Electric Vehicles."

The study begins with a "bottom up" approach, starting with an accounting of the household-level response to the removal of the tax exemption and aggregating up to the state-level. The study's micro-level consumer cost model is based on the Electric Power Research Institute's (EPRI) 2013 and 2014 reports on the economics of EV ownership, which provide detailed estimates of the cost of owning and operating electric vehicles relative a set of comparison alternate vehicles. To perform the macroeconomic analysis the study relies on a 70-sector model of Washington's economy developed by REMI, Inc., which is based on a U.S. Bureau of Economic Analysis input-output database that captures the specific structure of the Washington state economy and captures the inter-industry flows in activity within the state.

Finally, given the inherent uncertainty in any modeling exercise, this study considers the impacts of eliminating Washington's AFV tax exemption under several different scenarios. First, the study includes high and low gas price scenarios in addition to its "baseline" gas price assumption. Second, the study adopts the EPRI study's approach and reports two sets of results: one that assumes would-be EV purchasers buy a conventional ICE vehicle when the state tax exemption is eliminated, and another that assumes they buy a hybrid ICE vehicle.

3.1.1 Micro-Level Washington Consumer Model

Removing Washington's AFV sales tax exemption will cause a number of consumers who would have purchased a BEV to purchase an ICE vehicle instead. This behavioral shift in response to the change in the incentive structure regarding BEVs will increase the share of consumers' budgets spent on gasoline (net of electricity outlays), leaving less disposable income to be spent on other goods and services throughout the state. It will also reduce the number of Washington households receiving the $7,500 federal EV tax credit, which can be applied to the cost of a new EV purchase, or to purchasing additional "other" goods and services.

In order to quantify these changes, this study develops a consumer cost model that represents an individual, "average" Washington consumer. The consumer model quantifies the impact on the average Washington consumer's household budget of owning and operating a conventional or hybrid ICE vehicle, instead of an all-electric vehicle. The development of the consumer model relies heavily on EPRI's 2013 and 2014 reports on the economics of EV ownership. Specifically, the consumer cost model is built around four key cost drivers: vehicle purchase price; electricity cost; gasoline cost; and operating and maintenance costs.

In order to translate the impact of the policy shock on a single consumer's budget into state-level macroeconomic impacts, the study multiplies the results of the consumer model by the number of Washington residents who would likely be affected by the elimination of the sales tax exemption. In order to determine the number of Washington consumers impacted by this policy shock, the study evaluates EV penetration rates in Washington and its neighboring states and applies 2014 sales numbers and consumer behavior to the baseline and policy shock scenarios.

Currently, Washington has one of the nation's highest penetration rates for all-electric vehicles in new vehicle sales. In 2014, 1.2 percent of all vehicle sales were BEVs, well-above the national average of just 0.2 percent. Specifically, BEV sales in Washington totaled approximately 3,396 in 2014, and the baseline scenario assumes that this level of sales continues for the modeled duration of the tax exemption, until 2019. Conversely, the policy shock scenario assumes that the tax exemption's expiration would result in 2,134 fewer BEV sales annually through 2019, a roughly 63% reduction in sales. The expected shift in EV purchase patterns in Washington is assumed to be proxied half by current EV sales patterns in the neighboring state of Oregon and half by current EV sales patterns in the average U.S. state that does not have any special EV tax incentives.[4]

3.1.2 Macro-Level Washington State Model

The results of the consumer cost model, scaled up to account for the number of Washington consumers affected by the presence of the state sales tax exemption in the baseline scenario and the absence of the exemption in the policy shock scenario, were used as the first of two key inputs for the study's macroeconomic model:

(1) **Consumer Spending:** The REMI model uses the aggregate change in the amount and distribution of consumer spending – the output of the micro-level Washington consumer model – to calculate the impact of the policy shock on Washington's economic output. The modeling assumes that household budgets are fixed. That is, increases or decreases in specific spending categories (e.g., gasoline) are offset by reciprocal increases or decreases in other spending. An exception to this assumption is the treatment of the federal tax credit and state tax exemption. Because these tax incentives are, in effect, additional income to consumers, they result in spending increases — primarily on motor vehicles — which are not offset by a decrease in other spending. For this reason, the elimination of the Washington tax exemption results in a net reduction in consumer spending.

(2) **Government Spending:** The second key assumption for the macroeconomic modeling is the change in Washington state government spending as a result of the tax exemption's expiration. This study assumes that the elimination of the EV tax exemption allows the state of Washington to ramp up its purchases of other goods and services by the same amount as the newly "retained" sales tax receipts. That is, the study explicitly assumes that the net budget position of state of Washington is unchanged with or without the AFV sales tax exemption.[5]

Based upon these two key assumptions and a range of other assumptions (discussed briefly below and more fully in Appendix B), the macro model is used to estimate the impact of eliminating Washington's AFV tax exemption on state economic output annually from 2015 through 2030.

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[4] See Appendix B for a more detailed discussion of the methodology surrounding the Washington consumer's demand-response to the elimination of the tax exemption.

[5] Note: Washington currently imposes a $100 per year fee on BEV drivers in order to make up for lost gas tax revenue. With respect to the fee, fewer BEVs sold would reduce government revenue. However, we assume that reduced government revenue from the BEV fee has no net effect on the state budget. Given that the intention of the EV fee is to replace lost gas tax revenue due to BEV ownership, this study assumes that the increase in gas tax revenues when the exemption is eliminated is the equivalent of the lost EV fees.

3.2 CORE TECHNICAL ASSUMPTIONS

The results of both the micro-level consumer model and the macro-level state model are dependent upon a set of core assumptions regarding vehicle characteristics, consumer behavior, and economic and price variables.

Regarding vehicle characteristics and the costs of vehicle ownership and operation, most of the study's assumptions are taken from the EPRI's 2013 and 2014 studies on the total cost of EV ownership, which provide detailed estimates of the capital, fuel, and maintenance costs of electric vehicles and a group of comparator conventional and hybrid ICE vehicles. However, this study makes several adjustments to EPRI's assumptions in order to incorporate more recent information regarding the characteristics of EVs and vehicle and fuel prices. A review of the study's core assumptions is included below and a more detailed discussion is contained in Appendix B.

Vehicle Model: As a simplifying assumption, this study takes the price and characteristics of the Nissan Leaf as representative of BEVs sold in Washington during the modeling period. The study does not assume a particular model for conventional or hybrid ICE vehicles, but rather relies on the average vehicle characteristics for EPRI's comparator groups of conventional and hybrid vehicles.

Vehicle Lifetime & Miles Driven: This study assumes that all vehicle types – electric vehicles, hybrids, and conventional vehicles – have a 12-year lifetime. This assumption is based on EPRI's assumption of 150,000 lifetime miles for all vehicle types, and data from the Oak Ridge National Laboratory's 2014 Transportation Energy Data Book suggesting that vehicles travel an average of 12,500 miles per year. Vehicle lifetime is important in the context of the study because it affects the amount of money that consumers must spend to fuel their vehicles over time, and therefore the relative affordability of operating BEV versus ICE vehicles.

Gasoline Prices: Gasoline price assumptions are based on regional historical prices reported in the Energy Information Administration's (EIA) January 2015 Short-Term Energy Outlook (STEO), and regional price forecasts reported in the EIA's 2014 Annual Energy Outlook (AEO). This approach grounds the model in recent gasoline price trends while allowing prices to increase gradually over time. The study assumes a gasoline price of $2.62 per gallon in 2015, $3.21 in 2020, $3.74 in 2025, and $4.26 in 2030.

Acknowledging the uncertainty and volatility inherent in predicting gasoline prices, the study also conducts sensitivity analysis around the gasoline price assumption. A high gasoline price scenario adds $1 to the reference case gasoline price assumption for each year, while the low price scenario subtracts $1 each year. Under the low price scenario, prices peak at $3.26 per gallon in 2030, while under the high price scenario gasoline prices reach $5.26 in 2030.

Electricity Prices: Electricity price assumptions are based on state-specific historical prices reported in the EIA's December 2014 Monthly Electricity Review (MER) and regional price forecasts reported in the EIA's 2015 Short-Term Energy Outlook (STEO) and 2014 Annual Energy Outlook (AEO). Specifically, state-specific prices from the MER were used as the jumping-off point and were increased gradually over time according the regional forecast growth rates in the STEO and AEO. This approach accounts for the significant variation in electricity prices across states, due to different generation sources, while allowing prices to fluctuate over time.

Tax Benefit "Capture": For several reasons, this study assumes that Washington consumers who purchase a BEV capture 100% of both the federal tax credit and the state sales tax exemption. First, survey data indicate that the vast majority of national EV purchasers have household incomes that result in federal tax liabilities above $7,500 — the threshold needed to capture the full federal tax credit.[6] Second, because Washington's EV incentive is a tax exemption rather than a tax credit, consumers do not face the hurdle of having to file income taxes in order to receive the full incentive amount. Finally, the tax exemption also applies to leases of qualifying vehicles.[7] It is, of course, possible that some BEV purchasers may not receive the full federal tax credit or sales tax exemption amount.

Consumer Behavior: It is assumed that all EV purchasers put the full $7,500 federal tax credit toward the vehicle purchase, and that most Washington households apply the amount of their sales tax exemption toward the cost of the BEV purchase. However, the study assumes that a subset of Washington consumers spends a portion of their tax exemption on goods and services other than the vehicle, and save the remainder. This reflects the demand response assumption that roughly one-third of Washington consumers would purchase an EV without the existence of the state tax exemption (see Appendix B), and that some households therefore treat the tax exemption as additional income rather than a necessary incentive to purchase an EV.

IV. RESULTS

The study finds that the expiration of Washington's sales tax exemption would reduce Washington's real GDP each year between 2015 and 2030. Specifically, it finds that the cumulative 5-year GDP loss to the state economy is $25 million, and the cumulative 16-year loss totals $68 million, assuming that consumers respond to the elimination of the tax exemption by purchasing conventional internal combustion engine vehicles instead of electric vehicles. This overall loss of Washington GDP occurs despite the re-application of "retained" sales tax receipts to other forms of state government spending. It also occurs under all gas price scenarios, and regardless of whether consumers choose to purchase a conventional or hybrid vehicle instead of an all-electric vehicle.

Two key factors account for this reduction in state GDP, both of which also contribute to a net decline in aggregate consumer spending. With significantly fewer EVs on the road in the absence of the state tax exemption, Washington drivers would have to pay more for transportation fuel over the coming years, given that conventional vehicles cost more to operate than BEVs. Second, the elimination of the state's sales tax exemption would cause a substantial reduction in the number of electric vehicles sold in Washington, which would reduce cash inflows to state households from the $7,500 federal income tax credit.

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[6] The EV Project (August 2013). "Who are the Participants in the EV Project?" http://www.theevproject.com/cms-assets/documents/128842-80098.devproj.pdf
[7] http://www.nissanusa.com/ev/media/pdf/incentives/nissan-leaf-incentive-54.pdf

The sections below report these results in more detail. Section 4.1 describes the results of the consumer model (i.e., the impact of removing Washington's AFV sales tax exemption on consumer and government spending), and section 4.2 describes the results of the macro model (i.e., the impact on state GDP). Note that all results reported below are consistent with a scenario in which Washington consumers purchase conventional ICE vehicles instead of BEVs when the exemption is removed. The core finding that state GDP declines every year as a result of the exemption's elimination does not change depending upon whether consumers purchase a conventional or a hybrid vehicle instead of a BEV, although the scale of the GDP-impact differs somewhat. Appendix A provides complete results tables that report results for both conventional and the hybrid alternate vehicle scenarios.

4.1 CONSUMER MODEL RESULTS: IMPACT ON SPENDING

4.1.1 Changes in Consumer Spending

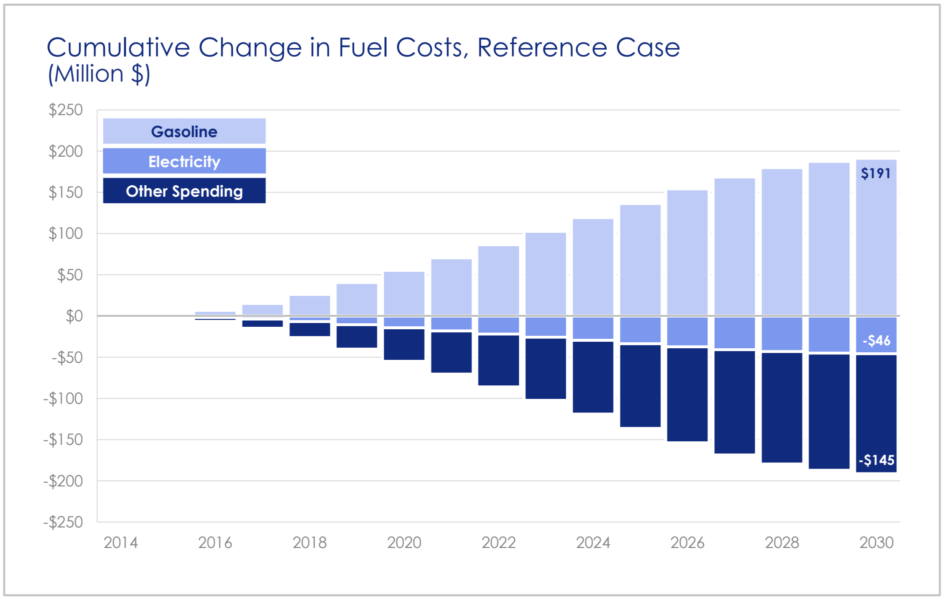
Shifts in Washington consumer spending in response to the elimination of the tax exemption and the differences between EVs and alternative vehicles affect several major spending categories:

- **Motor Vehicles:** Spending on motor vehicles declines by roughly $21 million each year between July of 2015 and 2019, resulting in a cumulative $94 million drop in motor vehicle spending. This shift accounts for the "would-be" BEV purchasers who decide to buy a conventional ICE vehicle in the absence of the state sales tax exemption, as the purchase price of a conventional vehicle is lower than that of an EV.

- **Motor Fuel:** Spending on electricity falls by a total of $46 million over the modeling period, while gasoline spending increases by $191 million. These spending shifts reflect lower fuel costs for BEVs than for conventional vehicles. With the elimination of Washington's AFV tax exemption, consumers would spend more on gasoline and less on other goods and services (given the study's fixed household budget assumption). Importantly, if the state sales tax exemption is removed, Washington households would spend more on motor fuel regardless of the future trajectory of gas prices. According to the study's low gas price scenario, total spending on gasoline increases by $137 million; under the high price scenario, spending increases by $246 million.

- **Vehicle Maintenance & Operation:** Reflecting higher maintenance costs for conventional vehicles compared to BEVs, spending on motor vehicle maintenance increases by $51 million over the modeling period, while general spending declines by a reciprocal $51 million. However, based on the assumption that BEV owners must pay to rent a replacement vehicle on days that require a greater driving range than the BEV is able to provide, the elimination of the tax exemption lowers this "replacement" cost to BEV consumers by a total of $52 million, freeing up $52 million for general consumer spending.

Figure 1. Shifts in Washington Motor Fuel Spending

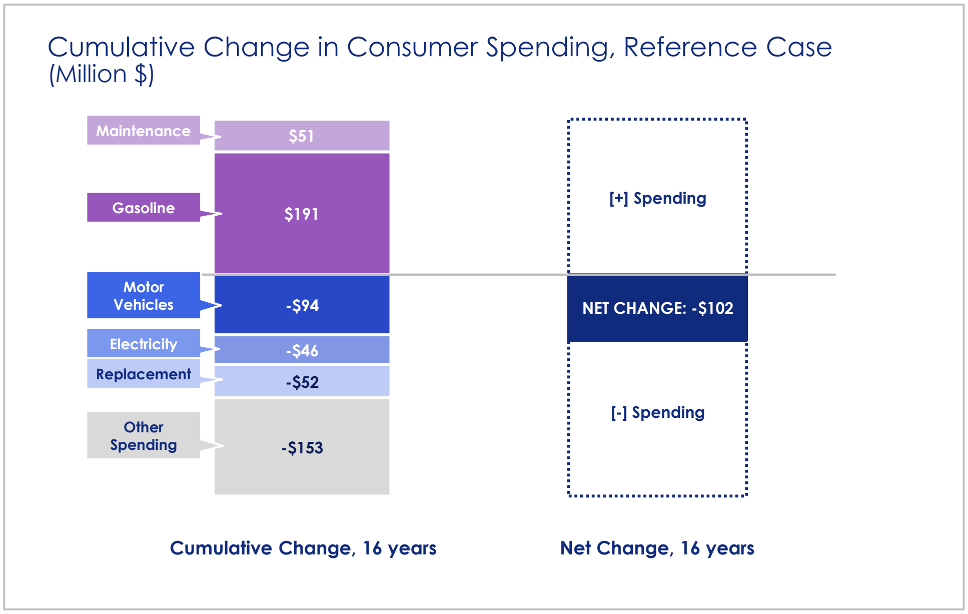


- **Other Consumer Spending:** Finally, because the consumer model assumes that Washington household budgets are fixed, shifts in motor-vehicle related spending necessarily impact a household's ability to spend on "other" items. In the case of Washington consumers, eliminating the state sales tax exemption would have the effect of reducing "other" household spending by $153 million over the modeling period, predominantly (although not exclusively) through having to compensate for significantly higher spending on gasoline.

The Impact of an Oil Price Shock

In addition to the low and high gas price scenarios, the study also examined the impact of an oil price shock on gasoline spending. In the event that unforeseen economic or political events prompt a severe and sustained oil supply shock – simulated in this study as a sudden $1.50 spike in gas prices in 2020 and 2021 – Washington consumers would spend an additional $7 million per year on fuel. This $7 million is *on top of* the roughly $15 million in additional gasoline spending as a result of the removal of the sales tax exemption under more typical gas prices. In essence, removing the exemption would take approximately 9,600 BEVs off Washington roads by 2019, thereby giving up a type of future economic insurance policy against oil price spikes for its consumers.

Figure 2. Net Change in Consumer Spending



4.1.2 Changes in Government Spending

The removal of the state sales tax exemption gives the state a small revenue boost through sales taxes that it would have otherwise not collected, and this revenue allows the government to increase its spending on other programs. Specifically, government purchases increase by nearly $4 million in 2015 and approximately $8 million in each subsequent year through 2019, totaling $34 million over the 5-year period. This result reflects the study's "balanced budget" assumption for state government spending.

Table 1. Impact on Consumer & Government Spending, Reference Case (Million $)

Impact on Spending	1 Year	5 Years	16 Years
Household-Level			
Motor Vehicle Spending	-$10	-$94	-$94
Electricity Spending	$0	-$11	-$46
Gasoline Spending	$1	$40	$191
Maintenance Spending	$0	$8	$51
Replacement Spending	$0	-$11	-$52
Other Consumer Spending	-$2	-$35	-$153
State-Level			
Government Spending	$4	$34	$34

4.2 MACRO MODEL RESULTS: IMPACT ON THE STATE ECONOMY

The study finds that the elimination of the state sales tax exemption would reduce Washington's real GDP each year between 2015 and 2030. Note that real GDP is equal to aggregate state income and also equal to total state economic output, adjusted for inflation. The cumulative 5-year GDP loss to the state economy is $25 million, and the cumulative 16-year loss totals $68 million.

The effect of the tax exemption's elimination on aggregate consumer spending is actually larger than the GDP impact. Specifically, if the exemption were to be removed aggregate consumer spending would fall by $117 million over a 5-year period, and by $204 million over the full 16-year modeling period. The reason for the much larger impact on aggregate spending is that spending on motor-vehicle related purchases and on motor vehicles in particular (including their multiplier effects), is often spent on goods and services produced outside of the state of Washington. This is because Washington is not a hub of vehicle manufacturing, and goods and services produced outside of the state do not count toward Washington's GDP.

Table 2. Impact on State Economy, Reference Case (Million $)

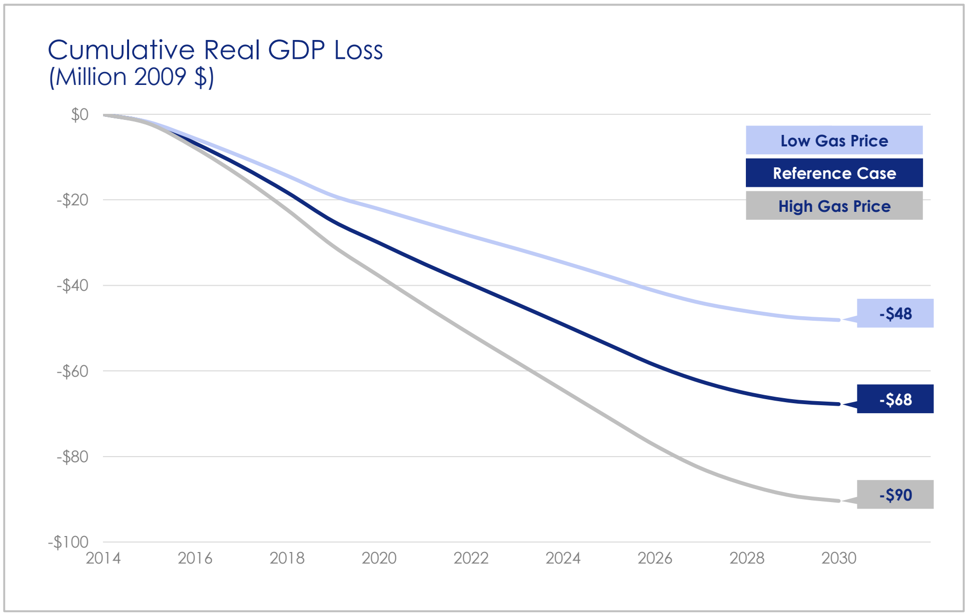
Impact on State Economy	1 Year	5 Years	16 Years
Aggregate Consumer Spending (2009 $)	-$12	-$117	-$204
Real GDP (2009 $)	-$2	-$25	-$68

The two most important changes in Washington consumer spending relative the decline in Washington's GDP include foregone fuel savings, and lost after-tax income from the federal tax credit and state sales tax exemption. First, would-be BEV purchasers lose the additional after-tax income from the federal tax credit and state tax exemption, most of which would have been spent on motor vehicles, but some of which would have been spent on other spending categories. This additional spending would have had ripple effects throughout the state economy. Second, would-be BEV purchasers will spend significantly more on motor fuel when the exemption is removed, which takes away from their ability to spend on other goods and services. Given that petroleum is predominately imported from outside Washington, and much of the foregone spending would have been on goods and services produced within the state, this negatively affects state GDP. This overall decline in Washington GDP occurs despite the increase in sales tax receipts and reciprocal increase in state government spending.

The study's core finding — that the elimination of the AFV sales tax exemption results in a GDP loss in each of the 16 years — remains intact under all gasoline price scenarios and regardless of whether Washington consumers purchase conventional or hybrid vehicles instead of BEVs. In the low gasoline price scenario, GDP falls by a cumulative $19 million in the first five years and by $48 million over the 16-year horizon. In the high gasoline price scenario, GDP declines by $31 million over five years and by $90 million over 16 years.

While consistently negative, the economic impact of the tax exemption's removal is relatively modest, compared to Washington's roughly $408 billion economy. This finding is expected, given that EVs are a new technology and that they play a modest role in the overall state economy.

Figure 3. Washington Real GDP Loss



V. CONCLUSION

Eliminating the AFV sales tax exemption in the state of Washington would reduce state GDP by $68 million over the period from 2015 to 2030. This result would be slightly more negative if gasoline prices were to increase substantially over the next 16 years, and slightly less negative if gasoline prices were to decline further. However, state GDP would be steadily reduced each year over the next 16 years for any plausible gasoline price profile.

There are two key channels through which elimination of the state's AFV sales tax exemption would hurt the economy. First, without the exemption there would be substantially fewer EVs on Washington roads, and Washington households would have to spend substantially more each year for their transportation fuel because conventional gasoline vehicles cost more to operate per mile driven than electric vehicles. Second, without the exemption fewer EVs would be purchased by Washington households, which would mean significantly reduced inflows of the $7,500 federal tax credit to state residents.

Given the state of play in Washington and the likely impacts of significantly reducing the number of electric vehicles sold in the state over the next five years, policymakers must weigh a number of factors as they seek to craft an effective policy concerning EVs. These include the degree to which the electric vehicle industry has traditional "infant industry" qualities; the degree to which the state will benefit from leveraging existing federal incentive programs; the degree to which electric vehicles provide an opportunity to reduce household spending on gasoline, and the degree to which they might view the attractiveness of insulating consumers from potential future oil price volatility.

APPENDIX A: DETAILED MODELING RESULTS

Reference Gasoline Price Case (Million $)

BEV vs. Conventional ICE	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Model Inputs																
Motor Vehicle Spending	-$9.8	-$20.1	-$20.7	-$21.3	-$22.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	-$0.4	-$1.5	-$2.2	-$3.0	-$3.7	-$3.8	-$3.8	-$3.8	-$3.8	-$3.9	-$3.9	-$4.0	-$3.2	-$2.5	-$1.7	-$0.9
Gasoline	$1.2	$5.5	$8.3	$11.2	$14.3	$14.8	$15.2	$15.7	$16.2	$16.7	$17.2	$17.7	$14.5	$11.1	$7.6	$3.9
Maintenance	$0.0	$0.8	$1.5	$2.4	$3.3	$4.2	$4.4	$4.5	$4.6	$4.8	$4.9	$5.0	$4.2	$3.2	$2.2	$1.1
Replacement	-$0.3	-$1.4	-$2.2	-$3.0	-$3.9	-$4.0	-$4.1	-$4.3	-$4.4	-$4.5	-$4.7	-$4.8	-$4.0	-$3.1	-$2.1	-$1.1
Government Spending	$3.8	$7.6	$7.6	$7.6	$7.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Other Consumer Spending	-$2.1	-$6.0	-$7.4	-$9.0	-$10.7	-$11.2	-$11.7	-$12.1	-$12.6	-$13.1	-$13.5	-$13.9	-$11.5	-$8.8	-$6.1	-$3.1
Macro Results																
Real GDP (2009 $)	-$2.0	-$4.7	-$5.4	-$6.0	-$6.6	-$5.1	-$5.0	-$4.7	-$4.6	-$4.8	-$4.7	-$4.6	-$3.8	-$2.8	-$1.9	-$0.8
Aggregate Consumer Spending (2009 $)	-$11.5	-$24.5	-$25.8	-$26.8	-$28.3	-$9.6	-$9.7	-$9.4	-$9.4	-$9.8	-$9.5	-$9.6	-$7.9	-$5.8	-$4.2	-$2.1

BEV vs. Hybrid ICE	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Model Inputs																
Motor Vehicle Spending	-$3.3	-$6.8	-$7.0	-$7.2	-$7.4	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	-$0.4	-$1.5	-$2.2	-$3.0	-$3.7	-$3.8	-$3.8	-$3.8	-$3.8	-$3.9	-$3.9	-$4.0	-$3.2	-$2.5	-$1.7	-$0.9
Gasoline	$0.8	$3.7	$5.6	$7.5	$9.6	$10.0	$10.3	$10.6	$11.0	$11.3	$11.6	$11.9	$9.8	$7.5	$5.1	$2.6
Maintenance	$0.0	$0.2	$0.5	$0.8	$1.1	$1.4	$1.4	$1.5	$1.5	$1.6	$1.6	$1.7	$1.4	$1.1	$0.7	$0.4
Replacement	-$0.3	-$1.4	-$2.2	-$3.0	-$3.9	-$4.0	-$4.1	-$4.3	-$4.4	-$4.5	-$4.7	-$4.8	-$4.0	-$3.1	-$2.1	-$1.1
Government Spending	$3.8	$7.6	$7.6	$7.6	$7.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Other Consumer Spending	-$8.2	-$17.1	-$17.4	-$17.9	-$18.4	-$3.6	-$3.8	-$4.0	-$4.3	-$4.5	-$4.7	-$4.8	-$4.0	-$3.0	-$2.1	-$1.1
Macro Results																
Aggregate Consumer Spending (2009 $)	-$14.3	-$29.2	-$30.0	-$30.6	-$31.1	-$6.7	-$6.4	-$6.1	-$6.1	-$6.5	-$6.5	-$6.4	-$5.8	-$4.3	-$3.5	-$2.2
Real GDP (2009 $)	-$5.1	-$10.6	-$11.4	-$11.9	-$12.2	-$4.3	-$3.8	-$3.4	-$3.1	-$3.3	-$3.5	-$3.4	-$3.1	-$2.3	-$2.0	-$1.1

Low Gasoline Price Case (Million $)

BEV vs. Conventional ICE	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Model Inputs																
Motor Vehicle Spending	-$9.8	-$20.1	-$20.7	-$21.3	-$22.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	-$0.4	-$1.5	-$2.2	-$3.0	-$3.7	-$3.8	-$3.8	-$3.8	-$3.8	-$3.9	-$3.9	-$4.0	-$3.2	-$2.5	-$1.7	-$0.9
Gasoline	$0.7	$3.7	$5.5	$7.5	$9.7	$10.2	$10.6	$11.1	$11.7	$12.1	$12.6	$13.1	$10.8	$8.4	$5.8	$3.0
Maintenance	$0.0	$0.8	$1.5	$2.4	$3.3	$4.2	$4.4	$4.5	$4.6	$4.8	$4.9	$5.0	$4.2	$3.2	$2.2	$1.1
Replacement	-$0.3	-$1.4	-$2.2	-$3.0	-$3.9	-$4.0	-$4.1	-$4.3	-$4.4	-$4.5	-$4.7	-$4.8	-$4.0	-$3.1	-$2.1	-$1.1
Government Spending	$3.8	$7.6	$7.6	$7.6	$7.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Other Consumer Spending	-$1.7	-$4.2	-$4.7	-$5.3	-$6.1	-$6.6	-$7.1	-$7.5	-$8.0	-$8.5	-$8.9	-$9.3	-$7.8	-$6.1	-$4.2	-$2.2
Macro Results																
Real GDP (2009 $)	-$1.8	-$3.8	-$4.1	-$4.4	-$4.7	-$3.1	-$3.1	-$3.0	-$2.9	-$3.1	-$3.3	-$3.3	-$2.9	-$2.1	-$1.5	-$0.8
Aggregate Consumer Spending (2009 $)	-$11.3	-$23.1	-$23.6	-$24.0	-$24.8	-$6.1	-$6.3	-$6.2	-$6.3	-$6.6	-$6.8	-$6.8	-$6.0	-$4.3	-$3.1	-$1.7

BEV vs. Hybrid ICE	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Model Inputs																
Motor Vehicle Spending	-$3.3	-$6.8	-$7.0	-$7.2	-$7.4	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	-$0.4	-$1.5	-$2.2	-$3.0	-$3.7	-$3.8	-$3.8	-$3.8	-$3.8	-$3.9	-$3.9	-$4.0	-$3.2	-$2.5	-$1.7	-$0.9
Gasoline	$0.5	$2.5	$3.7	$5.1	$6.5	$6.9	$7.2	$7.5	$7.9	$8.2	$8.5	$8.8	$7.3	$5.6	$3.9	$2.0
Maintenance	$0.0	$0.2	$0.5	$0.8	$1.1	$1.4	$1.4	$1.5	$1.5	$1.6	$1.6	$1.7	$1.4	$1.1	$0.7	$0.4
Replacement	-$0.3	-$1.4	-$2.2	-$3.0	-$3.9	-$4.0	-$4.1	-$4.3	-$4.4	-$4.5	-$4.7	-$4.8	-$4.0	-$3.1	-$2.1	-$1.1
Government Spending	$3.8	$7.6	$7.6	$7.6	$7.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Other Consumer Spending	-$7.9	-$15.8	-$15.6	-$15.4	-$15.3	-$0.5	-$0.7	-$0.9	-$1.2	-$1.4	-$1.6	-$1.7	-$1.5	-$1.2	-$0.9	-$0.5
Macro Results																
Aggregate Consumer Spending (2009 $)	-$13.8	-$28.3	-$28.4	-$28.7	-$28.9	-$4.3	-$4.1	-$3.9	-$3.9	-$4.1	-$3.9	-$4.2	-$3.9	-$2.8	-$2.1	-$1.3
Real GDP (2009 $)	-$4.9	-$10.1	-$10.6	-$10.9	-$10.9	-$3.0	-$2.5	-$2.0	-$2.0	-$1.9	-$2.1	-$2.3	-$2.1	-$1.4	-$0.9	-$0.4

High Gasoline Price Case (Million $)

EV vs. Conventional ICE	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Model Inputs																
Motor Vehicle Spending	-$9.8	-$20.1	-$20.7	-$21.3	-$22.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	-$0.4	-$1.5	-$2.2	-$3.0	-$3.7	-$3.8	-$3.8	-$3.8	-$3.8	-$3.9	-$3.9	-$4.0	-$3.2	-$2.5	-$1.7	-$0.9
Gasoline	$1.7	$7.4	$11.0	$14.9	$18.9	$19.4	$19.8	$20.3	$20.8	$21.3	$21.8	$22.3	$18.2	$13.9	$9.5	$4.8
Maintenance	$0.0	$0.8	$1.5	$2.4	$3.3	$4.2	$4.4	$4.5	$4.6	$4.8	$4.9	$5.0	$4.2	$3.2	$2.2	$1.1
Replacement	-$0.3	-$1.4	-$2.2	-$3.0	-$3.9	-$4.0	-$4.1	-$4.3	-$4.4	-$4.5	-$4.7	-$4.8	-$4.0	-$3.1	-$2.1	-$1.1
Government Spending	$3.8	$7.6	$7.6	$7.6	$7.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Other Consumer Spending	-$2.6	-$7.9	-$10.2	-$12.7	-$15.3	-$15.8	-$16.3	-$16.7	-$17.2	-$17.7	-$18.1	-$18.5	-$15.2	-$11.6	-$7.9	-$4.0
Macro Results																
Real GDP (2009 $)	-$2.2	-$5.6	-$6.7	-$7.5	-$8.6	-$7.0	-$6.8	-$6.7	-$6.4	-$6.4	-$6.5	-$6.3	-$5.3	-$3.8	-$2.7	-$1.4
Aggregate Consumer Spending (2009 $)	-$12.0	-$26.2	-$28.2	-$29.7	-$31.8	-$13.2	-$12.9	-$12.8	-$12.7	-$12.8	-$12.7	-$12.8	-$10.8	-$7.8	-$5.7	-$3.3

EV vs. Hybrid ICE	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Model Inputs																
Motor Vehicle Spending	-$3.3	-$6.8	-$7.0	-$7.2	-$7.4	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	-$0.4	-$1.5	-$2.2	-$3.0	-$3.7	-$3.8	-$3.8	-$3.8	-$3.8	-$3.9	-$3.9	-$4.0	-$3.2	-$2.5	-$1.7	-$0.9
Gasoline	$1.1	$5.0	$7.4	$10.0	$12.7	$13.1	$13.4	$13.7	$14.1	$14.4	$14.7	$15.0	$12.3	$9.4	$6.4	$3.3
Maintenance	$0.0	$0.2	$0.5	$0.8	$1.1	$1.4	$1.4	$1.5	$1.5	$1.6	$1.6	$1.7	$1.4	$1.1	$0.7	$0.4
Replacement	-$0.3	-$1.4	-$2.2	-$3.0	-$3.9	-$4.0	-$4.1	-$4.3	-$4.4	-$4.5	-$4.7	-$4.8	-$4.0	-$3.1	-$2.1	-$1.1
Government Spending	$3.8	$7.6	$7.6	$7.6	$7.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Other Consumer Spending	-$8.5	-$18.3	-$19.3	-$20.4	-$21.5	-$6.7	-$6.9	-$7.1	-$7.4	-$7.6	-$7.8	-$7.9	-$6.5	-$4.9	-$3.3	-$1.7
Macro Results																
Aggregate Consumer Spending (2009 $)	-$14.5	-$30.2	-$31.5	-$32.3	-$33.4	-$8.9	-$8.7	-$8.6	-$8.2	-$8.3	-$8.4	-$8.3	-$7.2	-$5.4	-$4.2	-$2.5
Real GDP (2009 $)	-$5.2	-$11.3	-$12.3	-$12.9	-$13.5	-$5.5	-$5.0	-$4.7	-$4.3	-$4.4	-$4.5	-$4.4	-$3.7	-$2.9	-$2.1	-$1.2

APPENDIX B: TECHNICAL ASSUMPTIONS

Vehicle-Specific Assumptions			
INPUT	**VALUE**	**SOURCE**	**NOTES**
Battery Electric Vehicle (Nissan Leaf)			
Purchase Price	$35,948	Nissan MSRP	Average of 3 Leaf Model MSRP (includes WA combined sales tax)
Vehicle Sales Tax	9.18%	Tax Foundation	Average combined local and state sales tax plus Washington motor vehicle use tax
Miles Per Gallon	N/A	EPRI (2014)	
kWh per Mile	0.30	DOE	Fueleconomy.gov reported for 2015 Leaf
Share of Miles Using Gasoline	0%	EPRI (2014)	
Annual Maintenance Cost	$88	EPRI (2014)	
Annual Replacement Cost	$325	EPRI (2014)	The costs incurred by EV owners when they have transportation needs beyond the range of an EV and must procure a "replacement" vehicle.
Annual Battery Costs	$0	EPRI (2014)	All EV's experience some battery decline after 8-12 years. However, the EPRI study concludes that there is not yet enough evidence to support a specific cost assumption, and so assumes $0 battery replacement costs. (Note: depending upon the state, vehicle manufacturers have committed to a 100-150,000 mile battery pack warranty)
Conventional ICE Vehicle			
Purchase Price	$26,800	EPRI (2014)	Includes 7.2% sales tax, a weighted average of state sales tax
Miles Per Gallon	29	EPRI (2014)	Reflects a "blended" conventional model
kWh per Mile	N/A	EPRI (2014)	
Share of Miles Using Gasoline	100%	EPRI (2014)	
Annual Maintenance Cost	$440	EPRI (2014)	
Hybrid ICE Vehicle			
Purchase Price	$32,866	EPRI (2014)	Includes 7.2% sales tax, a weighted average of state sales tax
Miles Per Gallon	43	EPRI (2014)	Reflects a "blended" hybrid model
kWh per Mile	N/A	EPRI (2014)	
Share of Miles Using Gasoline	100%	EPRI (2014)	
Annual Maintenance Cost	$205	EPRI (2014)	

General Assumptions			
INPUT	**VALUE**	**SOURCE**	**NOTES**
Gasoline Price (per gallon)	--	EIA STEO, AEO	No single value; varies by year
Electricity Price (per kWh)	--	EIA MER & AEO	No single value; varies by year
Inflation Rate	3.0%	EPRI (2013, 2014)	
Interest Rate	2.0%	EPRI (2013, 2014)	
Discount Rate (1-5 yr)	2.0%	EPRI (2013, 2014)	
Discount Rate (>5 yr)	5.0%	EPRI (2013, 2014)	
Vehicle Miles	150,000	EPRI (2013, 2014)	EPRI cites NHTSA (2006) Vehicle Survivability and Travel Mileage Schedules
Vehicle Miles Per Year	12,500	ORNL	ORNL 2014 Transporation Energy Data Book estimates annual VMT for light-duty vehicles at 12,928. This number has been rounded down, acknowledging that EV's may be driven slightly less on average than comparative conventional vehicles.
Life of Vehicle (yrs)	12	KBR calc	= Lifetime Miles / Miles per Year; Rounded up to nearest whole year
Baseline EV Sales	3,396	Polk Database	2014 sales (Jan-Oct actual sales*12/10)
Federal Tax Credit on EV	$7,500	DOE	Alternative Fuels Data Center
State Sales Tax Exemption on EV	$2,239	WA	Washington State Legislature (calculated based on Leaf purchase price)
Annual State EV Fee	$100	WA	Washington State Legislature
EV Sales After Policy Shock	1,262	Keybridge calc	See description below for more detail
Demand Response (EV Sales)	-2,134	Keybridge calc	See description below for more detail
Marginal Propensity to Consume	70.0%	Keybridge calc	See description below for more detail
Duration of EV Program	5 years	--	

Marginal Propensity to Consume (MPC) – Detailed Methodology

According to economic theory, households tend to save a portion of temporary income, such as a tax credit or exemption. The proportion of income spent depends on several factors, including income, wealth, and financial liquidity.[8] This study's assumption regarding the marginal propensity to consume of Washington households affects the size of the policy shock's GDP impact. However, the MPC assumption only affects a small subset of Washington BEV-owners.[9]

- The "treatment group" of Washington BEV purchasers includes those consumers who are assumed to require the full state incentive in order to purchase a BEV. The MPC assumption does not apply to them, given that they are assumed to apply the full value of the state tax exemption to the vehicle purchase.
- The "control group" of Washington BEV purchasers includes consumers who are assumed to purchase a BEV even without the state incentive. The MPC assumption applies to this group, given that they are thought to view the state tax credit as "extra" money.

This study adopts a three-step income-based approach in order to calculate MPC of Washington BEV purchasers:

(1) The U.S. 2013 Census Bureau's Consumer Expenditure Survey (CEX) reports average propensity to consume by income quintile. These data were used to calculate the MPC for each quintile: *change in consumption between quintiles / change in after-tax income between quintiles*

(2) 2013 survey data from The EV Project, funded by the Department of Energy, indicate that the majority of EV owners tend to have income in the top fourth and fifth quintiles. These data were applied to the CEX-based MPCs by quintile to develop a weighted average MPC: 65%.

(3) Finally, it is important to note that some BEV owners lease rather than purchase their vehicles, and consumers who lease vehicles are assumed to have somewhat lower income than consumers who purchase vehicles. It is also assumed that household income levels of BEV purchasers will tend to decline somewhat over the next 5 years as these vehicles are increasingly viewed as more mainstream purchases. For these reasons, this study rounds up the calculated 65% MPC assumption to 70%.

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[8] In general, recent literature puts the U.S. MPC in the range of 40-90%. See Parker (2014).

[9] The division of Washington EV-purchasers is based on Polk vehicle sales data. The share of consumers in the "control group" is based on BEV sales shares in neighboring states (see "Demand Response" discussion on page B-4).

Demand Response – Detailed Methodology

Due to the limited literature on the relationship between electric vehicle tax incentives and sales, this study estimates Washington consumers' response to the expiration of the tax exemption using historical vehicle sales data from neighboring Oregon, which currently has no electric vehicle tax benefit, and from other states with no EV tax-based incentives in place.

Specifically, BEV sales in Washington are assumed to drop from 1.2 percent of total vehicle sales to just 0.5 percent of sales, which entails a 63% decline in EV sales from 2014 levels. This demand response was based upon an average of the following:

- Oregon's 2014 BEV-penetration rate of 0.8%, weighted 0.5
- The 2014 national average BEV-penetration rate for all other states that do not currently have an EV tax benefit in place – 0.1%, weighted 0.5.

Oregon was selected as a key comparison state, given its regional proximity to Washington and general demographic, climate, and cultural similarities. In addition, both states share similar EV-charging infrastructure, the scale of which is somewhat unique relative to the rest of the country. However, several state-specific factors have created a particularly conducive environment in Oregon for EV ownership, and the state has an elevated BEV penetration rate despite its lack of a tax incentive; it is unclear the extent to which Washington consumers would behave similarly. Furthermore, it is preferred to use a sample set of more than one state for comparative purposes; integrating consumer demand behavior for BEVs in other states without an EV tax benefit helps to balance any potential bias in using Oregon as the only comparator state.

APPENDIX C: REMI MODEL DESCRIPTION

To perform this analysis, Keybridge relied upon an economic model of Washington produced by Regional Economic Modeling Inc. (REMI). The REMI PI+ model is a structural economic forecasting and policy analysis model. It integrates input-output, computable general equilibrium, econometric and economic geography methodologies. The model is dynamic, with forecasts and simulations generated on an annual basis and behavioral responses to compensation, price, and other economic factors. The model consists of thousands of simultaneous equations with a structure that is relatively straightforward. The exact number of equations used varies depending on the extent of industry, demographic, demand, and other detail in the specific model being used. The overall structure of the model can be summarized in five major blocks: (1) Output and Demand, (2) Labor and Capital Demand, (3) Population and Labor Supply, (4) Compensation, Prices, and Costs, and (5) Market Shares.

The Output and Demand block consists of output, demand, consumption, investment, government spending, exports, and imports, as well as feedback from output change due to the change in the productivity of intermediate inputs. The Labor and Capital Demand block includes labor intensity and productivity as well as demand for labor and capital. Labor force participation rate and migration equations are in the Population and Labor Supply block. The Compensation, Prices, and Costs block includes composite prices, determinants of production costs, the consumption price deflator, housing prices, and the compensation equations. The proportion of local, inter-regional, and export markets captured by each region is included in the Market Shares block.

Models can be built as single region, multi-region, or multi-region national models. A region is defined broadly as a sub-national area, and could consist of a state, province, county, or city, or any combination of sub-national areas. Single-region models consist of an individual region, called the home region. The rest of the nation is also represented in the model. However, since the home region is only a small part of the total nation, the changes in the region do not have an endogenous effect on the variables in the rest of the nation.

Block 1. Output and Demand

This block includes output, demand, consumption, investment, government spending, import, commodity access, and export concepts. Output for each industry in the home region is determined by industry demand in all regions in the nation, the home region's share of each market, and international exports from the region.

For each industry, demand is determined by the amount of output, consumption, investment, and capital demand on that industry. Consumption depends on real disposable income per capita, relative prices, differential income elasticities, and population. Input productivity depends on access to inputs because a larger choice set of inputs means it is more likely that the input with the specific characteristics required for the job will be found. In the capital stock adjustment process, investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population.

Block 2. Labor and Capital Demand

The Labor and Capital Demand block includes the determination of labor productivity, labor intensity, and the optimal capital stocks. Industry-specific labor productivity depends on the availability of workers with differentiated skills for the occupations used in each industry. The occupational labor supply and commuting costs determine firms' access to a specialized labor force.

Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. Demand for capital is driven by the optimal capital stock equation for both non-residential capital and equipment. Optimal capital stock for each industry depends on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

Block 3. Population and Labor Supply

The Population and Labor Supply block includes detailed demographic information about the region. Population data is given for age, gender, and race, with birth and survival rates for each group. The size and labor force participation rate of each group determines the labor supply.

These participation rates respond to changes in employment relative to the potential labor force and to changes in the real after-tax compensation rate. Migration includes retirement, military, international, and economic migration. Economic migration is determined by the relative real after-tax compensation rate, relative employment opportunity, and consumer access to variety.

Block 4. Compensation, Prices and Costs

This block includes delivered prices, production costs, equipment cost, the consumption deflator, consumer prices, the price of housing, and the compensation equation. Economic geography concepts account for the productivity and price effects of access to specialized labor, goods, and services.

These prices measure the price of the industry output, taking into account the access to production locations. This access is important due to the specialization of production that takes place within each industry, and because transportation and transaction costs of distance are significant. Composite prices for each industry are then calculated based on the production costs of supplying regions, the effective distance to these regions, and the index of access to the variety of outputs in the industry relative to the access by other uses of the product.

The cost of production for each industry is determined by the cost of labor, capital, fuel, and intermediate inputs. Labor costs reflect a productivity adjustment to account for access to specialized labor, as well as underlying compensation rates. Capital costs include costs of nonresidential structures and equipment, while fuel costs incorporate electricity, natural gas, and residual fuels.

The consumption deflator converts industry prices to prices for consumption commodities. For potential migrants, the consumer price is additionally calculated to include housing prices.

Housing prices change from their initial level depending on changes in income and population density.

Compensation changes are due to changes in labor demand and supply conditions and changes in the national compensation rate. Changes in employment opportunities relative to the labor force and occupational demand change determine compensation rates by industry.

Block 5. Market Shares

The market shares equations measure the proportion of local and export markets that are captured by each industry. These depend on relative production costs, the estimated price elasticity of demand, and the effective distance between the home region and each of the other regions. The change in share of a specific area in any region depends on changes in its delivered price and the quantity it produces compared with the same factors for competitors in that market. The share of local and external markets then drives the exports from and imports to the home economy.

APPENDIX D: REFERENCES

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