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Impact of Introducing an Electric Vehicle Tax Credit on the North Carolina State Economy

PREPARED FOR:
Securing America's Future Energy and
The Electrification Coalition

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EXECUTIVE SUMMARY

This study, commissioned by Securing America's Future Energy (SAFE), in partnership with the Electrification Coalition, and prepared under the direction of Keybridge's Robert F. Wescott, Ph.D., examines the economic effects of a possible electric vehicle (EV) tax credit on the North Carolina state economy. The study assumes a scenario whereby North Carolina adopts a tax credit to support the purchase of electric vehicles — specifically, a $2,500 credit for both battery electric vehicles (BEVs) and plug-in hybrids (PHEVs) with an electric battery capacity of at least 10 kilowatt hours (kWh). The assumed tax credit would be designed to boost the electric vehicle penetration in the state's new vehicle sales mix.

The study evaluates two scenarios: (1) a "baseline" scenario in which North Carolina continues to have no EV tax credit and (2) a "policy" scenario in which an EV tax credit is assumed to be in effect from 2016 through 2020. It quantifies the impact on state GDP of implementing the tax credit by comparing the two scenarios. The study starts with an accounting of the household-level response to the imposition of a tax credit 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 North Carolina's economy developed by REMI, Inc., a leading supplier of regional economic models.

The study finds that a $2,500 tax credit for BEVs and large-battery PHEVs would boost North Carolina's real GDP (or aggregate state income) each year between 2016 and 2031.

- The cumulative 5-year gain in North Carolina's GDP (or total state income) would be $37 million, and the cumulative 16-year gain would be $52 million, assuming that the tax credit causes some consumers to shift to EVs instead of conventional internal combustion engine (ICE) vehicles.
- The study assumes that the EV tax credits are fully paid for (i.e., deficit-neutral). The overall gain in North Carolina GDP occurs despite an assumed cutback of state government spending by the same amount as the aggregate tax credits and net lost state gasoline tax collections, leaving North Carolina's budget position unchanged.
- The study finds that with the tax credit, North Carolina drivers would save $50 million in gasoline bills over the next five years (which is only partially offset by $20 million in higher electricity bills), and $233 million in gasoline savings through 2031 (which is only partially offset by $91 million in higher electricity bills). These fuel savings occur despite the current low gasoline price environment.
- Further, the study finds that if gasoline prices revert to their average level of the past five years, the boost to North Carolina's GDP would be even larger: $41 million over five years and $68 million over the 16-year study period.

- The study also finds that an EV tax credit would serve as a type of economic insurance policy for North Carolina consumers. If the tax credit were implemented and there were more EVs on North Carolina roads, and if gasoline prices then spiked by $1.50 a gallon in 2020 due to an oil shock, North Carolina car owners would save an additional $12 million per year for fuel beyond the numbers cited above.

Two key factors would account for the increase in North Carolina GDP. First, with significantly more EVs on the road with the tax credit, state drivers would pay less for transportation fuel over the coming years, because EVs are cheaper to operate and maintain than conventional vehicles. This would cause more spending on other North Carolina-produced goods and services — including electricity. Second, the tax credit would cause more North Carolina households to buy EVs and therefore receive the federal government's $7,500 EV income tax credit, which would represent a form of additional net income to North Carolina families.

I. INTRODUCTION

In an effort to increase electric vehicle sales, the North Carolina state government has implemented several programs to incentivize electric vehicle use, including high occupancy vehicle (HOV) lane exemptions for electric vehicles and a retail sales tax exemption for alternative fuels.[1] In addition, several local communities have initiatives to promote EV use, such as the "Triangle Clean Cities" program in Raleigh, Durham, and Chapel Hill. However, despite these programs, North Carolina's EV penetration rate — at 0.3 percent in of all new light-duty vehicles in 2015 — is roughly half of the national average.

In order to further encourage EV ownership, some North Carolina interest groups have proposed a tax credit program: a $2,500 income tax credit for the purchase of new battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) with an electric battery capacity of at least 10 kilowatt-hours. Proponents of the tax credit cite the household benefits associated with increased EV ownership, while opponents argue that the cost to the state budget might outweigh these benefits. This study, commissioned by Securing America's Future Energy (SAFE) in partnership with the Electrification Coalition, quantifies the economic impact of a possible state tax credit for EVs on North Carolina's economy. It considers what the likely impact would be on North Carolina's economy if, in response to the new tax credit, some people currently purchasing conventional vehicles instead purchase electric vehicles.

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 North Carolina'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 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

In recent years, car manufacturers have introduced several new 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 gasoline price fluctuations, and improve U.S. energy diversification.[2] 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

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[1] North Carolina Laws and Incentives. U.S. Department of Energy Alternative Fuels Data Center. Accessible at: http://www.afdc.energy.gov/laws/9353; http://www.afdc.energy.gov/laws/5664.

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

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, conventional internal combustion engine vehicles). This may be due to a variety of factors, including entrenched consumer habits, an extensive conventional infrastructure (e.g., 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 U.S. federal government has established an income tax credit of up to $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 a rebate. 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. Over the long term, this frees up a larger share of household budgets to be spent on other goods and services, including goods and services that are more likely to be produced within the state of North Carolina. In North Carolina, some policymakers are proposing to capture these benefits by establishing a state tax credit for electric vehicles. While critics of the proposed tax credit emphasize its likely cost to the state budget, proponents assert that the benefits of reduced gasoline consumption would create positive ripple effects throughout North Carolina's economy.

III. METHODOLOGY

3.1 TECHNICAL APPROACH

This study evaluates two core scenarios: (1) a "baseline" scenario in which North Carolina continues to have no EV incentive and (2) a "policy" scenario in which the state offers an EV tax credit from 2016 to 2020. The tax credit's likely impact on state GDP is quantified by comparing results from the policy scenario to the results from the baseline scenario. The study considers a 16-year time horizon, which spans the five years during which the state tax credit is assumed to be in place, and is also intended to coincide with the average lifetime of new vehicles (i.e., vehicles purchased in the fifth and final year of the tax credit are assumed to be taken off the road in the last year of the modeling time horizon).

The study begins with a "bottom up" approach, starting with an accounting of the household-level response to the introduction of the tax credit 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 North Carolina's economy developed by REMI, Inc., which is based upon a U.S. Bureau of Economic Analysis input-output database that captures the specific structure of the North Carolina 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 introducing a state-level EV tax credit under several different scenarios. First, the study includes two gasoline price scenarios: a "current low price" scenario and a "five-year average" gasoline price assumption, which assumes that gasoline prices revert back to their average level of the past five years. Second, it adopts the EPRI study's approach to assessing the relative costs of EV ownership by reporting two sets of results: one set assumes that, in the absence of a North Carolina EV incentive, most would-be EV-purchasers instead purchase a conventional ICE vehicle, while the other set assumes that they purchase a hybrid ICE vehicle.

3.1.1 Micro-Level North Carolina Consumer Model

Introducing a state tax credit for EVs in North Carolina will cause a number of consumers who would have purchased an ICE vehicle to purchase a BEV or PHEV instead. This behavioral change in response to the change in the incentive structure regarding EVs will decrease the share of consumers' budgets spent on gasoline, leaving more disposable income to be spent on other goods and services throughout the state. It will also increase the number of North Carolina households receiving the federal EV tax credit, which can be applied to the cost of a new EV purchase, or toward purchases of additional "other" goods and services.

In order to quantify these changes, this study develops a consumer cost model that represents the average North Carolina consumer. The consumer model quantifies the impact on the average North Carolina consumer's household budget of owning and operating an electric vehicle, instead of a conventional or hybrid ICE 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 results of the consumer model are multiplied by the number of North Carolina residents who are expected to be affected by the introduction of the tax credit. In order to determine the number of residents affected — in other words, North Carolina's "demand response" to the state incentive — the study compares EV penetration rates in North Carolina to the penetration rate in a regionally neighboring state (Georgia) that previously implemented an EV tax credit.

North Carolina Demand Response

North Carolina's current EV penetration rate is roughly half of the national average. In 2015, 0.3 percent of all new vehicles in North Carolina were BEVs or PHEVs, totaling about 1,200 sales. In comparison, 0.6% of all U.S. new vehicles sales were EVs in 2015. Specifically, in North Carolina, BEV and qualifying PHEV (i.e., PHEVs with an electric battery capacity of at least 10 kWh) sales totaled 734 in 2015.[3] The study's baseline scenario assumes that this rate of annual EV sales continues for the duration of the modeling period. Conversely, the policy scenario assumes that a $2,500 state tax credit would result in 4,724 qualifying EVs sold in North Carolina per year, an increase of more than 500 percent over the baseline scenario. (Including small-battery PHEVs, annual EV sales would total 5,179 in the policy scenario). This jump in expected EV purchases quantifies the demand response of North Carolina consumers to the introduction of the state tax credit, and is based on experience from a nearby state which has previously implemented an EV tax credit: Georgia. Georgia was selected as a comparison state for North Carolina given the two states' regional co-location, similar climates, and the fact that both have at least one major urban area, which provides a demand center for EVs. However, because the Georgia legislature removed the EV tax credit in mid-2015, Georgia's EV penetration rate in 2014, rather than 2015, is used in estimating North Carolina's demand response. Specifically, this study assumes that if North Carolina were to introduce a tax credit for EVs, its penetration rate would be generally in line with that in Georgia — scaled for the size of the proposed incentive (see Appendix B for a more detailed description of the demand response calculation).

3.1.2 Macro-Level North Carolina State Model

The results of the consumer cost model, scaled up to account for demand response of North Carolina consumers to the new tax credit, were used as the first of two key input assumptions to 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 North Carolina consumer model — to calculate the impact of the policy on North Carolina's economic output. The model assumes that household budgets are fixed. That is, increases or decreases in specific spending categories (e.g., vehicle purchases or gasoline) are offset by reciprocal increases or decreases in other spending categories. An exception to this assumption is the treatment of the federal and state tax credits. Because these incentives are, in effect, additional after-tax income for consumers, they result in spending increases (primarily on motor vehicles) that are not offset by a decrease in other spending. For this reason, the introduction of the North Carolina tax credit results in a net increase in consumer spending.

(2) **Government Spending:** The second major input to the REMI model is the change in North Carolina state government spending as a result of the state tax credit. The study explicitly assumes that the net budget position of state of North Carolina is unchanged because of the EV incentive. Therefore, the study assumes that the introduction of the EV credit causes the state of North Carolina to cut its purchases of other goods and services by the cost of the aggregate tax credits. In addition, with more EVs there would be some net loss of state gasoline tax revenue, and the study assumes that state spending would be reduced by this amount as well—again to keep the state budget position unchanged. The study assumes

[3] In addition, roughly 450 PHEVs with electric battery capacities under 10 kWh were sold in North Carolina in 2015. These vehicles are exempt from the proposed EV tax credit, but small-battery PHEV sales are included in North Carolina's 0.3 percent EV penetration rate.

that with an EV tax credit, roughly two-thirds of new EV purchases in North Carolina would be BEVs (see "Core Technical Assumptions" section for support for this assumption), and that these vehicles would pay North Carolina's $130 annual fee on BEVs, which largely (but not completely) offsets the decline in gasoline tax revenues from these vehicles. However, roughly one-third of new EVs that would be purchased under an EV tax credit would be PHEVs, which not subject to the $130 annual fee, and there would be some further reduction in state gasoline tax collections because of these vehicles. Altogether, the study assumes a $13 million reduction in state spending over a 16-year time horizon to offset this assumed loss of gasoline tax revenues.

Based upon these key input assumptions, the macro model is used to estimate the impact of North Carolina's proposed EV tax credit on state economic output from 2016 through 2031.

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.

Most of the study's assumptions regarding vehicle characteristics and the costs of vehicle ownership and operation 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 for BEVs and PHEVs, as well as a comparison group of 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 vehicle and fuel prices, including more up to date assumptions regarding gasoline prices and North Carolina-specific electricity prices. A review of the study's core assumptions is included below and a more detailed discussion is presented in Appendix B.

Vehicle Model: As simplifying assumptions, this study takes the price and characteristics of the Nissan LEAF as representative of BEVs sold in North Carolina and the Chevrolet Volt as representative of large-battery PHEVs (i.e., a battery capacity of 10 kWh or greater). The study does not assume a particular model for conventional or hybrid ICE vehicles, but rather relies on EPRI's average vehicle characteristics for comparator conventional and hybrid vehicles.

EV Demand Composition: In the baseline scenario, it is assumed that the composition of North Carolina BEV and large-battery PHEV sales over time is consistent with their composition in 2015 (based on Polk vehicle sales data). However, in the policy scenario, the distribution of EV sales shifts as North Carolina consumers respond to the new tax credit. Because small-battery PHEVs are excluded from the proposed state tax credit, it is assumed that sales of PHEVs are unchanged in the policy scenario — meaning that small-battery PHEVs' share of total EV purchases declines once the tax credit is introduced. With the tax credit in place, BEVs and large-battery PHEVs are assumed to comprise all new EV sales in North Carolina. Further, the study assumes that the balance between BEVs and qualifying PHEVs remains unchanged from the 2015 sales distribution. In other words, of all new EVs sold in North Carolina (excluding small-battery PHEVs), the study assumes that 68.8 percent will be BEVs while the remaining 31.2 percent will be large-battery PHEVs.

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 2015 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, by extension, the relative affordability of operating EV versus ICE vehicles).

Gasoline Prices: Gasoline price assumptions are based on regional historical prices reported in the Energy Information Administration's (EIA) March 2016 Short-Term Energy Outlook (STEO), and regional price forecasts reported in the EIA's 2015 Annual Energy Outlook (AEO). This approach grounds the model in recent gasoline price trends while allowing prices to move over time in line with the EIA's latest forecasts. The study assumes a gasoline price in North Carolina of $1.86 per gallon in 2016, $2.18 in 2021, $2.56 in 2026, and $3.04 in 2031.

Acknowledging the uncertainty and volatility inherent in predicting gasoline prices, the study also conducts sensitivity analysis around the gasoline price assumption. A "five-year historical average" gasoline price scenario uses the 2011–2015 average gasoline price as the 2016 price, and then allows the price of gasoline to increase at the pace projected in the AEO. Under the "five-year historical average" gasoline price scenario, prices are $3.25 a gallon in 2016 and peak at $5.23 per gallon in 2031.

Electricity Prices: Electricity price assumptions are based on state-specific historical prices reported by the EIA and regional price forecasts reported in the EIA's March 2016 Short-Term Energy Outlook (STEO) and 2015 Annual Energy Outlook (AEO). The North Carolina electricity price for 2014 was used as the jumping-off point, and this price increases gradually over time based on regional forecast growth rates provided 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. North Carolina's electricity price is assumed to remain below the national average throughout the forecast period.

Tax Credit "Capture": The size of the federal EV tax credit is based on vehicles' battery capacity; BEVs and large-battery PHEVs receive a larger federal tax credit than small-battery PHEVs.[4] As a simplifying assumption, this study assumes that BEVs and all large-battery PHEVs receive the maximum $7,500 credit amount.[5]

The study assumes that North Carolina consumers who purchase an EV capture 100% of the amounts of both the federal and state tax credits for which the vehicle is eligible. 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]

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[4] Plug-In Electric Vehicle Credit. Internal Revenue Service. Accessible at: http://www.irs.gov/Businesses/Plug-In-Electric-Vehicle-Credit-IRC-30-and-IRC-30D.

[5] Federal Tax Credits for All-Electric and Plug-In Electric Hybrid Vehicles. U.S. Deparment of Energy. Accessible at: http://www.fueleconomy.gov/feg/taxphevb.shtml.

[6] The EV Project (August 2013). "Who are the Participants in the EV Project?" Accessible at: http://www.theevproject.com/cms-assets/documents/128842-80098.devproj.pdf.

In cases when an EV is leased instead of purchased, it is assumed that leasing companies pass on the full amount of any tax credit in order to provide a more competitive lease rate.[7]

Consumer Behavior: Given the cost differential between the average EV and the average conventional vehicle, it is assumed that all EV purchasers make up some of the cost difference by putting the full amount of the federal tax credit received toward the EV purchase. However, the same assumption is not applied to consumer behavior vis-à-vis the North Carolina tax credit. Instead, the study assumes that one group of EV purchasers treats the state tax credit as a necessary incentive to purchase an EV (i.e., the "treatment group"), and that this group applies the full amount of the credit toward the cost of the EV. The study assumes that a second group of EV purchasers would have purchased the EV even without the state incentive (i.e., the "control group"), and that this group spends a portion of the state tax credit on non-vehicle goods and services, and saves the remainder. The "control group" in North Carolina is approximately 16% of total qualifying EV purchasers.

IV. RESULTS

The study finds that a $2,500 EV tax credit would increase North Carolina's real GDP each year between 2016 and 2031. Specifically, it finds that the cumulative 5-year GDP boost to the state economy is $37 million, and the cumulative 16-year gain is $52 million, assuming that some consumers respond to the tax credit by purchasing electric vehicles instead of conventional internal combustion engine vehicles. This overall increase in North Carolina GDP occurs despite a general reduction in state government spending by an amount equivalent to: 1) the aggregate EV tax credits and 2) the net loss of state gasoline tax revenue. That is, the EV program is designed to be deficit neutral for the state. The net gains to the North Carolina economy also hold under both gasoline price scenarios and regardless of whether consumers choose to purchase an EV instead of a conventional ICE vehicle or an EV instead of a hybrid ICE vehicle.

Two key factors account for this increase in real state GDP. First, with significantly more EVs on the road after the introduction of the state tax credit, North Carolina drivers would pay less for transportation fuel over the coming years due to the fact that EVs cost less to operate and maintain than conventional vehicles. Second, the state tax credit would cause a substantial increase in the number of EVs sold in North Carolina, which would boost cash inflows to state households from the federal income tax credit.

The sections below elaborate on the modeling results. Section 4.1 describes the results of the consumer model, aggregated to the state level (i.e., the impact of a new state tax credit on consumer and government spending). Section 4.2 describes the results of the macro model (i.e., the impact on state GDP). Appendix A provides complete results tables that report results for both conventional and the hybrid alternate vehicle scenarios.

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[7] Jordan Golson (August 2014). "Why It's Cheaper to Lease a New Electric Car than to Buy One Used" *Wired.* Accessible at: http://www.wired.com/2014/08/why-its-cheaper-to-lease-a-new-electric-car-than-to-buy-one-used/.

4.1 CONSUMER MODEL RESULTS: IMPACTS ON SPENDING

4.1.1 Changes in Consumer Spending

Shifts in North Carolina consumer spending in response to the state tax credit and the costs of operating an EV versus a conventional vehicle affect several major spending categories:

- **Motor Vehicles:** Spending on motor vehicles increases by roughly $41 million each year from 2016 to 2020, resulting in a cumulative $206 million increase in motor vehicle spending. This shift accounts for the "new" EV purchasers who would have purchased a conventional ICE vehicle in the absence of the state incentive, but chose to pay a higher sticker price for a BEV or PHEV instead.

- **Motor Fuel:** With the EV tax credit, spending on electricity increases by a total of $91 million over the modeling period, while gasoline spending falls by $233 million. These spending shifts reflect lower fuel costs for EVs than for conventional vehicles. With the introduction of North Carolina's EV tax credit, consumers would spend less on motor fuel and more on other goods and services, given the study's fixed household budget assumption (see Figure 1 for the effects of reduced spending on gasoline and increased spending on electricity on "other" spending). Importantly, these North Carolina fuel savings occur even in the current low gasoline price environment. According to the study's "five-year historical average" gasoline price scenario, total spending on gasoline declines by a large $401 million by 2031.

The Impact of an Oil Price Shock

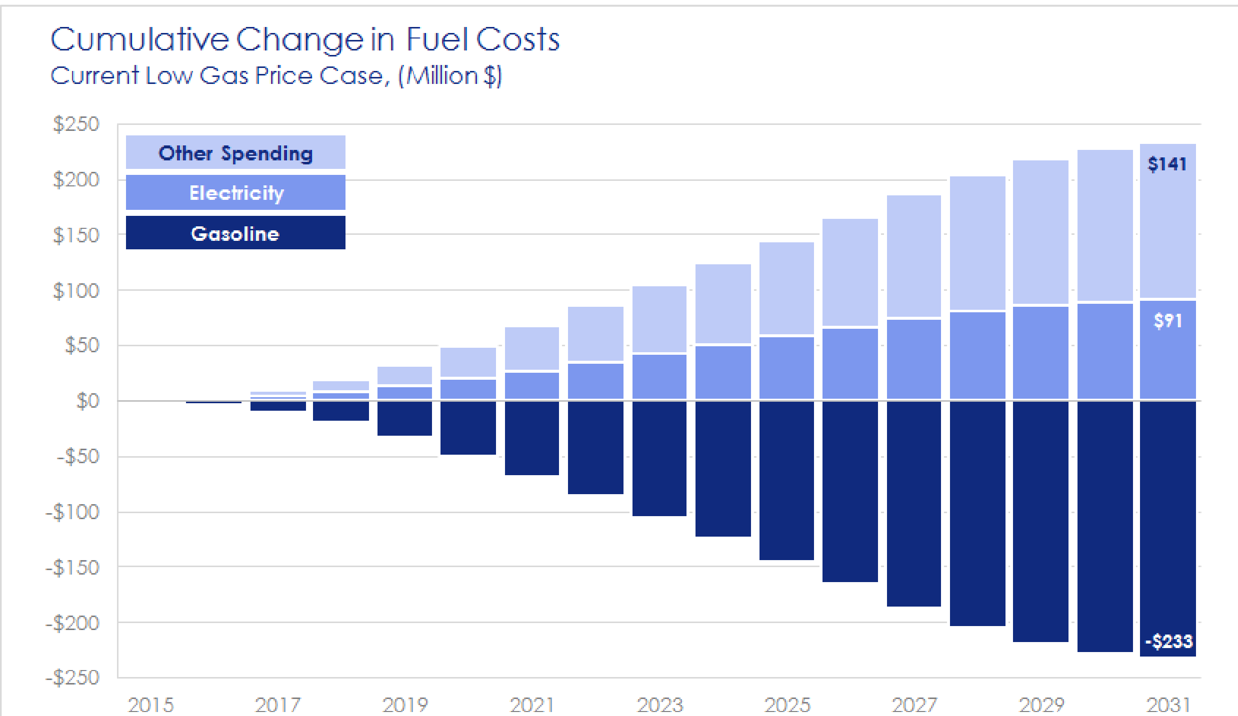
In addition to the low and high gasoline price scenarios, the study also examines the impact of an oil price shock on gasoline spending. In the event that unforeseen economic or political events prompt a severe and sustained oil supply shock — simulated in this study as a sudden $1.50 spike in gas prices in 2020 and 2021 — North Carolina consumers would save an additional $12 million per year on fuel. This $12 million is in addition to the roughly $17 million in annual gasoline savings as a result of the state tax credit under more typical gas prices. In essence, introducing the incentive would add nearly 20,000 EVs to North Carolina roads by 2020, thereby serving as a type of future economic insurance policy against oil price spikes for state consumers.

- **Vehicle Maintenance & Operation:** With an EV tax credit, spending on motor vehicle maintenance decreases by $83 million over the modeling period, freeing up $83 million for spending on other goods and services. This results stems from lower average maintenance costs for EVs compared to conventional vehicles. However, based on the EPRI assumption that BEV owners must rent replacement vehicles on days that require a greater driving range than the BEV is able to provide, the tax credit would increase replacement costs to

BEV owners by $67 million over 16 years, reducing general consumer spending by this amount.[8]

- **Other Consumer Spending:** Finally, because the consumer model assumes that North Carolina household budgets are fixed, shifts in motor-vehicle related spending necessarily affect a household's ability to spend on other items. Introducing a state EV tax credit would have the effect of increasing other household spending by North Carolina consumers by $157 million over the modeling period, predominantly (although not exclusively) through savings stemming from less gasoline consumption. (See Figure 2 for the net change in consumer spending predicted by the consumer cost model).

Figure 1. Shifts in North Carolina Motor Fuel Spending



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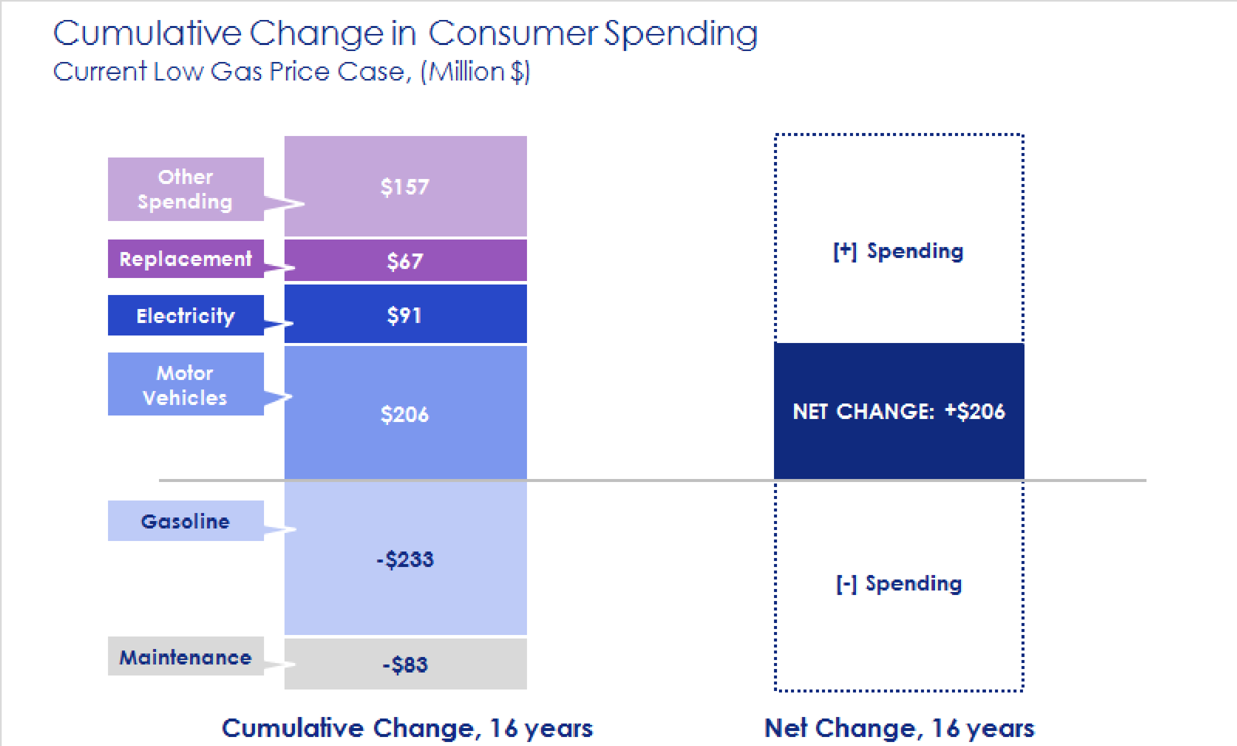
[8] According to the EPRI studies, PHEV drivers do not pay any vehicle replacement costs, given that PHEVs possess the ability to drive using gasoline when their electric charges run out.

Figure 2. Shifts in Household-Level Consumer Spending



4.1.2 Changes in Government Spending

The introduction of the EV tax credit would represent a new cost for the North Carolina state government. Given this study's budget neutrality assumption regarding the tax credit's effect on state spending, the study assumes that government spending is reduced by the amount of the aggregate EV tax credits. Accordingly, the study finds that government purchases would fall by $12 million in each year from 2016 to 2020, totaling $59 million over the 5-year policy period. Further, the study also assumes that the state government cuts spending by the amount of gas tax revenue lost when the EV tax credit is introduced (while accounting for new revenue from the state's $130 annual BEV fee), totaling $13 million over 16 years. Combined, these spending cuts total $72 million over the study's 16-year time horizon.

Table 1. Impact on Consumer & Government Spending, Current Low Gas Price Case (Million $)

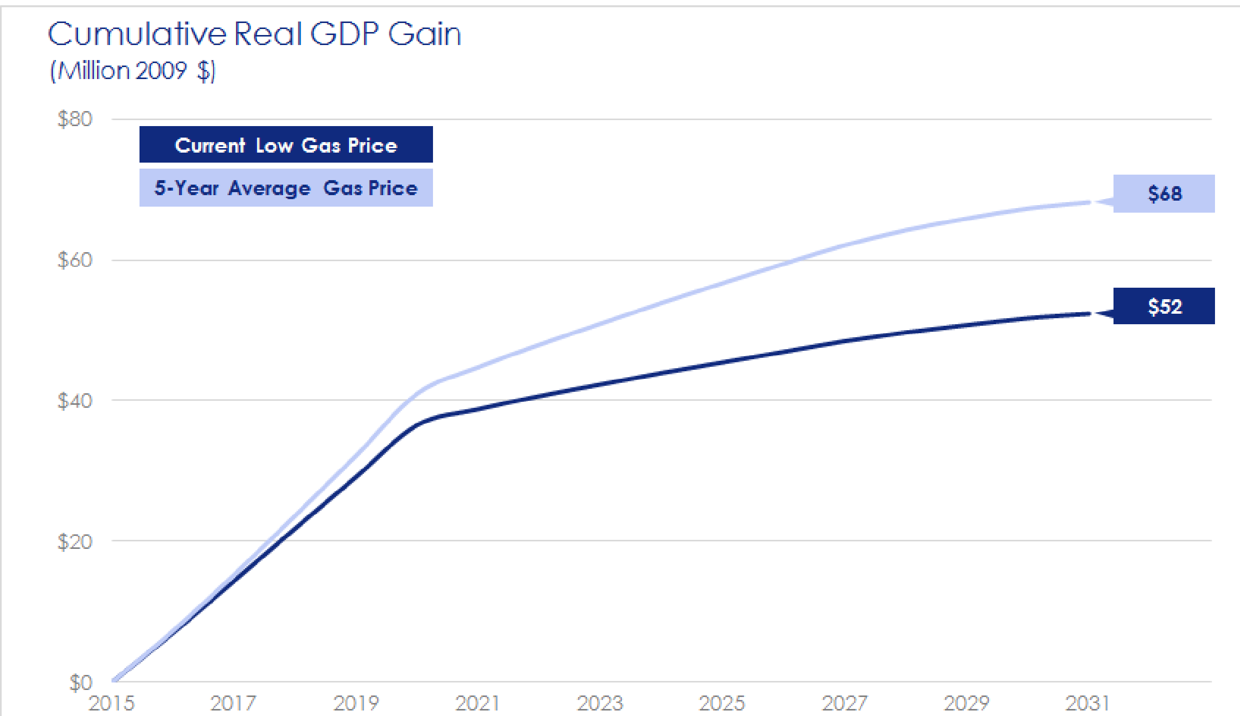
Impact on Spending	1 Year	5 Years	16 Years
Household-Level			
Motor Vehicle Spending	$39	$206	$206
Electricity Spending	$1	$20	$91
Gasoline Spending	-$3	-$50	-$233
Maintenance Spending	$0	-$13	-$83
Replacement Spending	$1	$14	$67
Other Consumer Spending	$3	$28	$157
State-Level			
Government Spending	-$12	-$62	-$72

4.2 MACRO MODEL RESULTS: IMPACT ON THE STATE ECONOMY

Overall, the study finds that the North Carolina EV tax credit program would increase the state's real GDP each year between 2016 and 2031. Note that real GDP is equal to aggregate state income as well as total state economic output (inflation-adjusted). The cumulative 5-year GDP gain is $37 million, and the cumulative 16-year gain totals $52 million.

The North Carolina EV tax credit would also increase aggregate consumer spending. In fact, the effect on aggregate consumer spending is larger than its impact on state GDP. If North Carolina were to introduce the tax credit in 2016, aggregate consumer spending would increase by $198 million over the 5-year policy period and by $216 million over the full 16-year modeling period. The reason the impact is larger for consumer spending than for state GDP is that motor vehicles and related goods are often produced outside of the state of North Carolina. North Carolina is not a hub of vehicle manufacturing, and goods and services produced outside of the state do not count toward North Carolina's GDP.

Figure 3. Impact on North Carolina Real GDP



The two most important drivers of changes in aggregate consumer spending are (1) transportation fuel savings, and (2) additional after-tax income from the federal and state tax credits.

- First, new EV purchasers will spend significantly less on motor fuel as a result of the state tax credit, which frees up more of their disposable income to be spent on other goods and services. Given that much of the motor fuel-related savings is spent on goods and services produced within the state of North Carolina, while petroleum is predominately imported from outside North Carolina, the shift in spending has a positive effect on state GDP.

- Second, with the state incentive in effect, new EV purchasers gain additional income from the federal tax credit. This additional income has ripple effects throughout the state economy.

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

Impact on State Economy	1 Year	5 Years	16 Years
Aggregate Consumer Spending (2009 $)	$40	$198	$216
Real GDP (2009 $)	$7	$37	$52

The study's core finding — that North Carolina's proposed EV tax credit results in a GDP gain in each of the 16 years — remains intact under both gasoline price scenarios and regardless of whether North Carolina consumers purchase EVs instead of conventional or hybrid ICE vehicles. In the "five-year historical average" gasoline price scenario, GDP increases by a cumulative $41 million in the first five years and by $68 million over the 16-year horizon.

While consistently positive, the economic impact of the state tax credit is modest relative to the size of North Carolina's economy (roughly $500 billion). This finding is expected, given that EVs are a new technology and play a limited role in the overall state economy, with or without a state tax credit.

V. CONCLUSION

Introducing a $2,500 tax credit for BEVs and PHEVs with an electric battery capacity of at least 10 kWh would boost North Carolina's GDP by $52 million over the period from 2016 to 2031. This gain in GDP would be somewhat larger if gasoline prices were to revert back to their average level from the past five years. However, state GDP would increase each year over the next 16 years for either gasoline price assumption.

There are two key channels through which the state tax credit would benefit the economy. First, with the presence of the tax credit there would be substantially more EVs on North Carolina roads, and North Carolina households would spend substantially less each year for their transportation fuel. This is because electric vehicles cost less to operate and maintain per mile driven than conventional gasoline vehicles, even with gasoline prices at their current low levels. Second, the state tax credit would incentivize more North Carolina households to purchase EVs, which would mean significantly greater inflows of the federal EV tax credit to state residents.

APPENDIX A: DETAILED MODELING RESULTS

Current Low Gasoline Price Case (Million $)

EV vs. Conventional ICE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
	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	$38.8	$39.9	$41.1	$42.3	$43.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	$1.3	$2.6	$4.0	$5.4	$7.0	$7.3	$7.4	$7.6	$7.7	$7.9	$8.1	$8.2	$6.7	$5.1	$3.5	$1.8
Gasoline	-$3.0	-$6.4	-$9.8	-$13.4	-$17.2	-$17.7	-$18.3	-$18.9	-$19.5	-$20.1	-$20.8	-$21.5	-$17.8	-$13.8	-$9.5	-$4.9
Maintenance	$0.0	-$1.2	-$2.5	-$3.9	-$5.3	-$6.8	-$7.0	-$7.3	-$7.5	-$7.7	-$7.9	-$8.2	-$6.7	-$5.2	-$3.6	-$1.8
Replacement	$0.9	$1.8	$2.8	$3.9	$5.0	$5.2	$5.3	$5.5	$5.7	$5.8	$6.0	$6.2	$5.1	$3.9	$2.7	$1.4
Other Consumer Spending	$3.3	$4.4	$5.6	$6.7	$8.0	$12.2	$12.6	$13.1	$13.6	$14.1	$14.7	$15.3	$12.7	$9.9	$6.9	$3.6
Government Spending	-$12.0	-$12.2	-$12.4	-$12.7	-$12.9	-$1.1	-$1.1	-$1.1	-$1.1	-$1.1	-$1.1	-$1.1	-$0.8	-$0.6	-$0.4	-$0.2
Macro Results																
Real GDP (2009 $)	$7.0	$7.4	$7.5	$7.3	$7.4	$2.3	$1.9	$1.6	$1.6	$1.5	$1.5	$1.5	$1.2	$1.0	$1.0	$0.6
Aggregate Consumer Spending (2009 $)	$39.7	$39.8	$39.7	$39.5	$39.4	$2.5	$2.3	$2.2	$2.1	$1.8	$1.8	$1.7	$1.4	$1.1	$0.9	$0.6
Total Employment (Individuals)	89	85	77	67	59	-1	-6	-9	-8	-10	-10	-10	-7	-5	0	1

EV vs. Hybrid ICE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
	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	$14.6	$15.0	$15.4	$15.9	$16.4	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	$1.3	$2.6	$4.0	$5.4	$7.0	$7.3	$7.4	$7.6	$7.7	$7.9	$8.1	$8.2	$6.7	$5.1	$3.5	$1.8
Gasoline	-$2.0	-$4.2	-$6.4	-$8.8	-$11.3	-$11.6	-$12.0	-$12.4	-$12.8	-$13.2	-$13.6	-$14.1	-$11.6	-$9.0	-$6.2	-$3.2
Maintenance	$0.0	-$0.3	-$0.6	-$0.9	-$1.2	-$1.6	-$1.6	-$1.7	-$1.7	-$1.8	-$1.8	-$1.9	-$1.5	-$1.2	-$0.8	-$0.4
Replacement	$0.9	$1.8	$2.8	$3.9	$5.0	$5.2	$5.3	$5.5	$5.7	$5.8	$6.0	$6.2	$5.1	$3.9	$2.7	$1.4
Other Consumer Spending	$26.4	$26.2	$25.9	$25.6	$25.2	$0.8	$0.9	$1.0	$1.1	$1.2	$1.4	$1.6	$1.4	$1.2	$0.9	$0.5
Government Spending	-$11.8	-$11.8	-$11.9	-$11.9	-$11.9	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1	$0.0	$0.0	$0.0
Macro Results																
Real GDP (2009 $)	$10.9	$12.0	$12.8	$13.3	$13.7	$4.9	$4.2	$3.9	$3.7	$3.7	$3.7	$3.7	$3.2	$2.5	$1.8	$1.1
Aggregate Consumer Spending (2009 $)	$38.0	$38.4	$38.5	$38.6	$38.6	$4.2	$4.0	$3.8	$3.7	$3.7	$3.6	$3.6	$3.2	$2.5	$2.0	$1.5
Total Employment (Individuals)	154	161	162	160	156	37	28	23	21	20	19	20	17	13	10	7

Five-Year Average Gasoline Price Case (Million $)

EV vs. Conventional ICE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
	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	$38.8	$39.9	$41.1	$42.3	$43.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	$1.3	$2.6	$4.0	$5.4	$7.0	$7.3	$7.4	$7.6	$7.7	$7.9	$8.1	$8.2	$6.7	$5.1	$3.5	$1.8
Gasoline	-$5.3	-$11.1	-$16.9	-$23.0	-$29.6	-$30.6	-$31.5	-$32.5	-$33.6	-$34.7	-$35.8	-$37.0	-$30.6	-$23.7	-$16.4	-$8.5
Maintenance	$0.0	-$1.2	-$2.5	-$3.9	-$5.3	-$6.8	-$7.0	-$7.3	-$7.5	-$7.7	-$7.9	-$8.2	-$6.7	-$5.2	-$3.6	-$1.8
Replacement	$0.9	$1.8	$2.8	$3.9	$5.0	$5.2	$5.3	$5.5	$5.7	$5.8	$6.0	$6.2	$5.1	$3.9	$2.7	$1.4
Other Consumer Spending	$5.5	$9.1	$12.7	$16.4	$20.4	$25.0	$25.8	$26.7	$27.7	$28.7	$29.7	$30.8	$25.5	$19.9	$13.8	$7.2
Government Spending	-$12.0	-$12.2	-$12.4	-$12.7	-$12.9	-$1.1	-$1.1	-$1.1	-$1.1	-$1.1	-$1.1	-$1.1	-$0.8	-$0.6	-$0.4	-$0.2
Macro Results																
Real GDP (2009 $)	$7.3	$8.0	$8.4	$8.5	$8.8	$3.7	$3.2	$3.0	$3.0	$2.8	$2.8	$2.6	$2.1	$1.7	$1.4	$0.9
Aggregate Consumer Spending (2009 $)	$40.1	$40.7	$41.0	$41.1	$41.4	$4.6	$4.1	$3.9	$3.8	$3.6	$3.4	$3.1	$2.5	$1.9	$1.5	$1.0
Total Employment (Individuals)	92	93	89	82	77	17	11	7	8	6	5	4	3	3	5	3

EV vs. Hybrid ICE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
	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	$14.6	$15.0	$15.4	$15.9	$16.4	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Electricity	$1.3	$2.6	$4.0	$5.4	$7.0	$7.3	$7.4	$7.6	$7.7	$7.9	$8.1	$8.2	$6.7	$5.1	$3.5	$1.8
Gasoline	-$3.5	-$7.2	-$11.1	-$15.1	-$19.4	-$20.0	-$20.6	-$21.3	-$22.0	-$22.7	-$23.5	-$24.3	-$20.1	-$15.6	-$10.7	-$5.6
Maintenance	$0.0	-$0.3	-$0.6	-$0.9	-$1.2	-$1.6	-$1.6	-$1.7	-$1.7	-$1.8	-$1.8	-$1.9	-$1.5	-$1.2	-$0.8	-$0.4
Replacement	$0.9	$1.8	$2.8	$3.9	$5.0	$5.2	$5.3	$5.5	$5.7	$5.8	$6.0	$6.2	$5.1	$3.9	$2.7	$1.4
Other Consumer Spending	$27.9	$29.3	$30.6	$31.9	$33.4	$9.2	$9.5	$9.9	$10.3	$10.8	$11.2	$11.7	$9.8	$7.7	$5.4	$2.8
Government Spending	-$11.8	-$11.8	-$11.9	-$11.9	-$11.9	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1	-$0.1	$0.0	$0.0	$0.0
Macro Results																
Real GDP (2009 $)	$11.1	$12.4	$13.4	$14.1	$14.6	$5.8	$5.2	$4.8	$4.6	$4.5	$4.5	$4.5	$3.8	$2.9	$2.1	$1.2
Aggregate Consumer Spending (2009 $)	$38.2	$39.0	$39.4	$39.7	$39.9	$5.5	$5.2	$5.0	$4.9	$4.8	$4.7	$4.6	$3.9	$3.1	$2.5	$1.7
Total Employment (Individuals)	156	166	170	170	168	48	39	34	31	30	29	29	24	19	14	8

APPENDIX B: TECHNICAL ASSUMPTIONS

Vehicle-Specific Assumptions			
INPUT	VALUE	SOURCE	NOTES
Battery Electric Vehicle (Nissan LEAF)			
Purchase Price	$36,542	Nissan MSRP	Average of 3 LEAF 2016 Model MSRP
Vehicle Sales Tax	6.9%	Tax Foundation	Average combined state and local sales tax
Miles Per Gallon	N/A	EPRI (2014)	
kWh per Mile	0.30	DOE	Fueleconomy.gov reported for 2016 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 BEV owners when they have transportation needs beyond the range of a BEV and must procure a "replacement" vehicle.
Annual Battery Costs	$0	EPRI (2014)	All BEVs 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 no battery replacement costs.
Plug-in Electric Vehicle, >10 kWh Battery Capacity (Chevrolet Volt)			
Purchase Price	$36,448	Chevrolet MSRP	
Vehicle Sales Tax	6.9%	Tax Foundation	Average combined state and local sales tax
Miles Per Gallon	42	DOE	Fueleconomy.gov reported for 2017 Volt
kWh per Mile	0.31	DOE	Fueleconomy.gov reported for 2017 Volt
Share of Miles Using Gasoline	26%	Chevrolet	DOE, pulled from Partnership for Clean Transportation, Inc. calculations
Annual Maintenance Cost	$240	EPRI (2014)	
Annual Battery Costs	$0	EPRI (2014)	See Note above.
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 STEO, 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 2015 Transporation Energy Data Book estimates annual VMT for light-duty vehicles at 12,720. This number has been rounded down, acknowledging that EVs may be driven slightly less on average than comparative conventional vehicles.
Life of Vehicle (yrs)	12	Keybridge calc	= Lifetime Miles / Miles per Year; Rounded up to nearest whole year
Baseline EV Sales	1,189	Polk Database	2015 sales
Federal Tax Credit, BEV & PHEV (battery capacity >10 kWh)	$7,500	DOE	The study uses the Cheverolet Volt as the representative large-battery PHEV
State Tax Credit, BEV & PHEV (battery capacity >10 kWh)	$2,500	--	Excludes PHEVs with an electric battery capacity under 10 kWh
EV Sales After Policy Shock	5,179	Keybridge calc	See description below for more detail
Demand Response (EV Sales)	+3,990	Keybridge calc	See description below for more detail
Propensity to Consume	70.0%	Keybridge calc	See description below for more detail
Length of EV Program	5	--	
BEV Annual Fee	$130	NC DOT	BEVs only
Motor Fuel Tax (per gallon)	$0.35	NC DOT	The actual per-gallon tax will vary slightly from this amount, depending on the year as well as future policy changes. The actual tax is projected to decline to $0.34 in mid-2016 and decrease slightly in future 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 rebate. The proportion of income spent depends on several factors, including income, wealth, and financial liquidity.[9] This study's assumption regarding the marginal propensity to consume of North Carolina households affects the size of the policy shock's GDP impact. However, the MPC assumption only affects a subset of North Carolina EV owners.[10]

- The "treatment group" of North Carolina EV purchasers includes those consumers who are assumed to require the state incentive in order to purchase an EV. The MPC assumption does not apply to them, given that they are assumed to apply the full value of the state tax credit to the vehicle purchase.

- The "control group" of North Carolina EV purchasers includes consumers who would have purchased an EV without the state incentive. Because North Carolina does not currently offer an EV tax credit, the size of the control group is based directly on actual 2015 vehicle sales data (qualifying EVs only). The MPC assumption does apply to this group, given that they treat the state incentive as "extra" money and do not apply it to the vehicle purchase.

This study adopts a three-step income-based approach in order to calculate the MPC of the "control group" of North Carolina EV 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 U.S. 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 percent.

(3) Finally, it is important to note that some EV 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 EV purchasers will tend to decline somewhat over the next five years as these vehicles are increasingly viewed as more mainstream purchases. For these reasons, this study rounds up the calculated 65 percent MPC assumption to 70 percent.

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[9] In general, recent literature puts the U.S. MPC in the range of 40-90 percent. See Parker (2011).

[10] The division of North Carolina EV-purchasers is based on Polk vehicle sales data. The share of consumers in the "control group" is based on 2015 EV sales in North Carolina, while the share of consumers in the "treatment group" is based on data from a comparator state, Georgia (see "Demand Response" discussion on page B-4).

Demand Response – Detailed Methodology

Due to the limited economic literature on the relationship between electric vehicle incentives and sales, this study estimates North Carolina consumers' response to the proposed tax credit using historical vehicle sales data from a regionally neighboring state (Georgia) which previously had an EV tax incentive in place. Georgia was selected as a comparison state due its regional proximity to North Carolina, and general cultural, climate, and economic similarities.

Specifically, if North Carolina were to institute a state tax credit for EVs, the study assumes that state demand for EVs will be equivalent to the penetration rate in Georgia, scaled down to reflect the smaller size of the proposed North Carolina incentive relative to Georgia' past incentive.

- **Georgia:** Offered a $5,000 tax credit for BEVs from 1998 to July 2015. Because Georgia legislators removed the tax credit in mid-2015, the state's EV penetration rate from 2014 (i.e., the most recent full year in which the incentive was in place) is used for this analysis. The EV penetration rate in Georgia was 2.3 percent of all new light-duty vehicles sold in 2014.
- **North Carolina Demand Response:** The proposed North Carolina tax credit is $2,500 for BEVs and large-battery PHEVs (i.e., electric battery capacity of at least 10 kWh). The current combined EV penetration rate in the state is 0.3 percent of all new light-duty vehicle sales (includes small-battery PHEVs). North Carolina's demand response is calculated using Georgia's 2014 EV penetration rate (2.3 percent), which is then scaled to reflect the smaller size of the proposed North Carolina tax credit relative to the Georgia incentive. Specifically, the demand response to a new state tax credit is assumed to push the EV penetration rate up to 1.1 percent of all new light-duty vehicles sold in 2016 through 2020, when the policy is assumed to expire.

Based upon these assumptions, total EV sales (including small-battery PHEVs) in North Carolina would equal 5,179 each year of the policy period, a roughly 340% increase in EV sales from 2015 levels. This study assumes that small-battery PHEV sales will remain at 2015 levels throughout the modeling period, as these vehicles are excluded from the state tax credit. In other words, with the state tax credit in effect, the increase in North Carolina EV sales is entirely due to BEV and large-battery PHEVs. The breakdown between sales of BEVs and large-battery PHEVs is assumed to remain consistent with their relative sales shares in 2015: 68.8 percent of all new EVs sold (excluding small-battery PHEVs) during the policy period are assumed to be BEVs, while the other 31.2 percent are assumed to be PHEVs with a battery capacity of at least 10 kWh.[11]

[11] Polk Vehicle Database.

APPENDIX C: REMI MODEL DESCRIPTION

To perform this analysis, Keybridge relied upon an economic model of North Carolina 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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