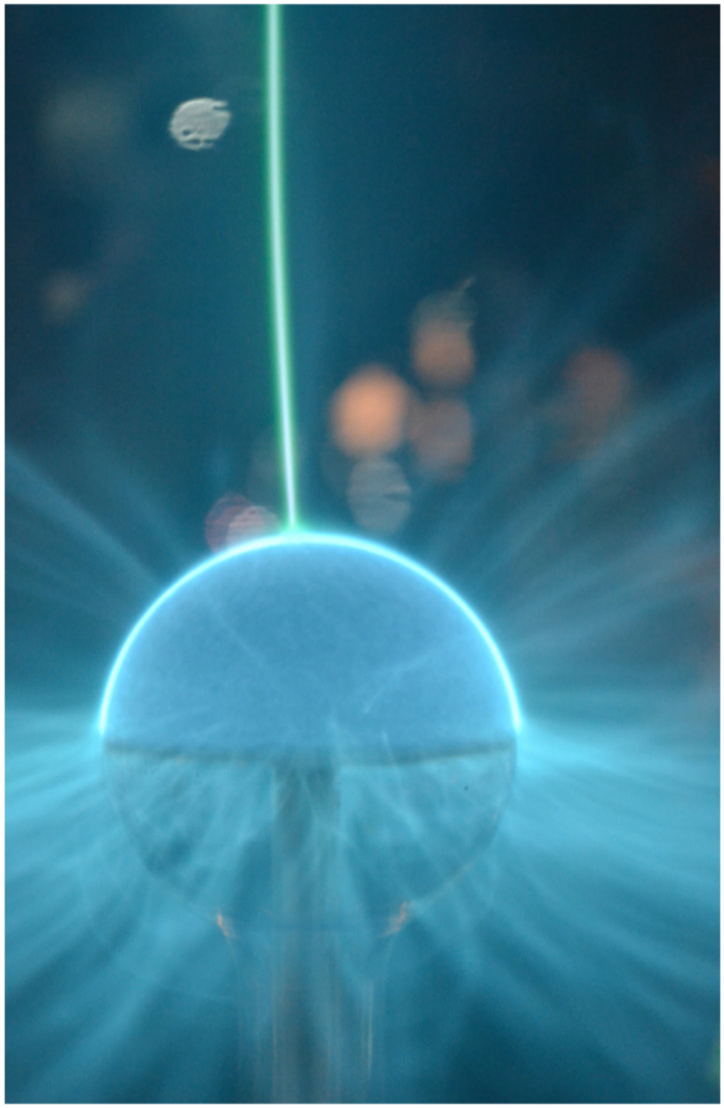

The Returns to Vehicle Electrification

AN ASSESSMENT OF THE ECONOMIC AND BUDGETARY IMPACTS OF ELECTRIC VEHICLE ADOPTION IN OREGON

Drive Oregon | February, 2015

Prepared by Elise Korejwa on behalf of Drive Oregon.

IMPLAN analysis was performed by the Northwest Economic Research Center, and we are deeply grateful for their assistance. The author takes full responsibility for this paper's content.

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Executive Summary

Oregon and other states have made commitments to dramatically increase the number of electric vehicles (EVs) on the road, primarily to reduce reliance on foreign oil and to reduce greenhouse gas emissions. However, the adoption of EVs also yields substantial economic benefits by saving drivers money over the life of the vehicle, drawing federal tax incentives to Oregon, and shifting spending from petroleum (which yields little local economic activity) to electricity and other spending.

Every time an Oregon driver purchases an EV rather than a gasoline or diesel-powered vehicle, that driver is pumping more money back into Oregon's economy, creating jobs and increasing state and local tax revenue. We estimate impacts for several common scenarios, concluding that each such vehicle decision can increase state and local tax revenue between $426 and $1,503 over a ten-year period, under today's conditions.

The roughly 5,000 EVs already on Oregon's roads today are estimated to contribute between $1.79 million and $10.15 million annually to the Oregon economy, and between $191,600 and $676,700 to state and local tax revenue. By 2030, EVs could contribute between $113 million and $225 million annually to the economy, and between $12 million and $14.7 million to tax revenue, depending on the rate of adoption.

In order to obtain the maximum benefit from EV adoption, we recommend that Oregon policy makers take additional steps to improve the attractiveness of EVs for Oregon consumers. A rebate program is generally considered the most effective and equitable way to incentivize EV purchases. The U.S. Department of Energy (DOE) estimates that tax credits are likely to be half as effective as a rebate in incentivizing PEV sales.

The U.S. DOE also estimates that decreasing the purchase price of a vehicle by as little as 10% would increase its market share by 50 – 80%, all other factors being equal.[1] This would in turn help Oregon meet several state goals including the 10-Year Energy Action Plan, the Statewide Transportation Strategy, and the Global Warming Strategy.

By the Numbers

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$1.8-$10 million

annual economic impact of EV ownership in Oregon today

$113-$226 million

annual economic impact of EVs in Oregon by 2030

$64.66 million

net present value of state and local taxes attributable to EV adoption from 2014 to 2030

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[1] United States Department of Energy. 2013. "PEV 'New Areas in Policy Analysis' (NAPA) Project Overview." Presentation: August 23, 2013. Seth Federspiel, Jake Ward, Austin Brown, Chris King, and Steve Capanna.

Contents

Introduction

Electric vehicles (EVs), which in this report refers to both plug-in hybrid vehicles (PHEVs) and all-electric vehicles, have the potential to dramatically reduce the consumption of fossil fuels and the consequent emission of greenhouse gases and toxic substances into our atmosphere. For this reason, states across the country are making commitments to increase the number of EVs and other zero-emission vehicles on the road.[2] Yet, the benefit of EVs goes beyond their environmental friendliness—the can also help to grow the local economies in which they are operated.

Some of the economic benefit of EVs comes from shifting expenditures from petroleum to other goods and services. Money spent on petroleum produces very few jobs for the local economy compared to other industries. A 2012 report from economist David Roland-Holst on behalf of the California Electric Transportation Coalition (CalETC) found that on average, every dollar saved at the gas pump and instead spent on other goods and services that households want creates 16 times more jobs. This economic stimulus was found to "lift all boats" and actually increase the incomes of low-income groups more than high-income groups. However, the extent to which this would be true in Oregon depends on how much of the gas money would be spent on locally-produced goods and services.

Consumers also benefit from EV adoption through reduced operating costs over the long term. Ultimately, how much a particular consumer saves by choosing an EV over a hybrid or conventional combustion engine depends on the vehicle they would have otherwise chosen. However, even if you assume that people are willing to pay a premium to go green or adopt a new, exciting technology, the fuel savings will often more than make up the difference. Some of these savings are then spent in the local economy, creating a multiplier effect on economic growth. EV adoption also had the potential to benefit the growing EV industry in Oregon, which already is responsible for some 1,500 jobs and $266 million in economic activity and which has been designated as a key industry for Oregon.[3]

Despite all this, there has yet to be a comprehensive study analyzing the economic and tax revenue impacts of EV adoption in Oregon. This study begins to fill this gap by determining the implications of existing data when applied to the Oregon economy. We also include an original analysis, which improves on other studies by using better information on which vehicles EV owners would otherwise purchase. Of course we can't lose sight of the fact that electric vehicles reduce state fuel tax revenue. So we juxtapose the various estimates of the additional state and local tax revenue with reasonable estimates of lost fuel tax revenue. However, Oregon is currently exploring innovative ways to fund transportation spending, so the loss of fuel tax revenue may only be a short-term issue.

[2] As of May, 2014, California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont had all set a target that 15% of their new-car sales will be zero-emission vehicles within ten years.
[3] Northwest Economic Research Center. 2013. *Oregon's Electric Vehicle Industry*.

Research Methods

This research effort took the methodological triangulation approach to research design—a widely used strategy involving the use of multiple research methods to improve the validity of the findings. The first component was performed by Drive Oregon in collaboration with the Northwest Economic Research Institute with publicly available data. The two others build on existing research performed elsewhere in order to determine what their findings mean for Oregon.

Two of the three research components involve the use of IMPLAN (IMpact analysis for PLANing) to produce estimates of the state economic and budgetary impact. IMPLAN is a widely-used and accepted economic impact modeling system that can be used to estimate the effect that a specific change in an economy has on production, payroll, employment, taxes, and GDP. It combines extensive databases with traditional input-output modeling and region-specific Social Accounting Matrices and economic multipliers. One shortcoming of IMPLAN is that is does not have region-specific information on tax rates and instead relies on national averages.

All estimates in this report are presented in constant, 2014, dollars.

Research Component 1: Analysis of EV Ownership Under Today's Conditions

This component of the study attempts to answer the question: "if a representative sample of 100 potential EV buyers went out tomorrow and purchased an EV instead of a reasonable alternative, what would the state-level impacts be on GDP and tax revenue?" This is different from studies that were conducted in the past in that we focus on the individual decisions made by consumers instead of on macro-level trends. We are also not making any predictions or assumptions about adoption rates or technological change. Instead, we focus on the set of choices faced by consumers today, and what the impact of that decision would be on an annual basis.

Before we could proceed, we first had to answer the all-important question: "which cars are potential EV customers deciding between?" The choice of EV was relatively straight forward since the Nissan Leaf is currently the highest selling plug-in vehicle. The comparison vehicles were more difficult to choose. While it's likely that many EV adopters are only interested in purchasing an EV, in order to assess the economic impact of EV purchases, we also needed to answer the counterfactual question: "which cars would EV buyers choose if EVs were not available?" A quick convenience survey of Facebook followers of the internet-based news organization *Green Car Reports* (n=55) revealed a wide variety of responses. The most common responses were the Toyota Prius and clean diesels like the Volkswagon Jetta TDI. There were also a number of luxury vehicles like Jaguars, BMWs, and Audis. We decided to combine this information with common sense logic about the purchasing decisions made by a price-discriminating customer. At one end of that spectrum is the possibility that someone would purchase a vehicle roughly equal in price to their choice of EV. At the other end is the possibility that someone would purchase a vehicle roughly equal to the price of their choice of EV minus the value of the federal tax credit. The final result was that we decided to compare Nissan Leaf to the Toyota Prius, the Volkwagon Jetta SportWagen, and the BMW 228i. These represent an all-electric vehicle, the most fuel-efficient hybrid, the most fuel-efficient diesel engine, and an average MPG luxury sedan, respectively.

Vehicle	Base MSRP	MPG (combined)
Nissan Leaf	$28,980	114[4] (MPGe)
BMW 228i	$32,100	28
VW Jetta SportWagen	$20,995	34
Toyota Prius	$24,200	50

To facilitate compatibility with IMPLAN, we measured the difference in purchasing decisions in terms of the effect on household income. The components of these calculations included vehicle miles traveled by income, fuel efficiency, current retail fuel prices, vehicle manufacturer's suggested retail prices (MSRPs), EV charger and installation costs, and federal tax credit amount by income. Since not everyone has enough tax liability to take full advantage of the federal tax credit, we used Internal Revenue Service data on the average tax liability by income to determine the average tax credit amount for each income category. To gain a representative sample of EV buyers by income, we used data from California on the income distribution of current EV owners and made adjustments to correct for the difference between Oregon and California's income distribution.[5] We then calculated the change in income for each household income category attributable to choosing an EV over one of the three alternatives (formulas included in the appendix). These numbers were finally entered into IMPLAN to determine the impact on GDP and tax revenue. One shortcoming of using IMPLAN is that it did not take into account the loss of gas tax revenue attributable to choosing an EV. As a result, these calculations had to be performed separately.

This analysis made the following simplifying assumptions:

1) All vehicle prices are for the base model for model year 2014.
2) We assume one owner, consistent with the methodology used by the Electric Power Research Institute
3) We assume a vehicle lifetime of 10 years, which is the length of most battery warrantees.
4) We assume present conditions hold since we are only looking at the economic impact of electric vehicles bought in today's conditions. This assumption extends to the EV technology, vehicle and charging station prices, gasoline and electricity prices, and the current policy environment.
5) The total cost of ownership calculations are comprised of vehicle MSRP, maintenance, insurance, and fuel consumption. This excludes repair and other associated costs.
6) We model all vehicle acquisitions as purchases, when an estimated 50% of all EVs are leased. This may make our estimates slightly conservative since EV leases are often subsidized by vehicle manufacturers.
7) We assume driving patterns remain the same regardless of which vehicle the person purchases.
8) We only model the economic impact of cost savings and switching expenditures away from petroleum fuel.

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[4] For the Nissan Leaf, the miles per gallon are shown as miles per gallon equivalent (MPGe). This is calculated by determining the electricity content on a single gallon of gas. In terms of electricity consumption, this comes out to be equal to 3.38 miles per kilowatt hour.

[5] Polynomial regression was used to apportion the data into new categories since the income buckets are different between the EV ownership data, the data on Oregon and California's income distribution, and the categories used by IMLAN.

This analysis relied on estimates from external sources for many of the key parameters. All data were converted in 2011 dollars for compatibility with IMPLAN and were then converted back in 2014 dollars for consistency across the report. The formulas detailing how the total cost difference was calculated are available in the appendix.

Parameter	Value	Details	Source
Incentive for Residential Charging Unit	25% of cost, up to $750	Oregon tax credit	Oregon Department of Energy, 2014
Charger and Installation Price	$1,200	Based on average price of available models	Rocky Mountain Institute, 2014
Oregon Residential Electricity Rate	10.19 cents per kilowatt hour		EIA, March 2014
Retail Gasoline Rate	$3.66 dollars per gallon[6]	Average for west coast minus California	EIA, January-July 2014
Retail Diesel Rate	$3.98 dollars per gallon	Average for west coast minus California	EIA, January-July 2014
Oregon Fuel Tax Rate	30 cents per gallon		Oregon Department of Transportation, 2014
Maintenance Cost Difference	$212.38 per year	Average difference between a small, combustion-engined car and an equivalent EV	IFA, 2012
Insurance Cost Difference	$200 per year	Average difference between an EV and gasoline-powered car	CoverHound, 2014

Research Component 2: Building on the University of California-Berkeley Study

This component builds on a study performed by David Roland-Holst of the University of California-Berkeley on behalf of the California Electric Transportation Commission (CalETC) titled "Plug-in Electric Vehicle Deployment in California: An Economic Assessment." Theirs is a prospective study that attempts to model the economic and technological changes that would occur in California between 2012 and 2030 under different EV deployment scenarios. The study focuses on the expenditure shifting that occurs when less money is spent on imported petroleum fuels, leading to larger economic multipliers for the local economy. The baseline scenario assumes that California implements current commitments to fuel economy standards but that the economy only grows at levels forecast by the Department of Finance. The first alternative scenario, dubbed "PEV15," assumes that by 2030, 15.4% of the new light-duty vehicle fleet will consists of plug-in electric vehicles (PEVs). For the second alternative scenario, dubbed "PEV45," PEV deployment is

[6] A decline in the price of oil that occurred after this analysis was conducted reduces the economic benefits attributable to EVs. However, there are reasons to believe that oil prices will go back up sometime in the near future.

accelerated to 45% by 2030. These scenarios were modeled using the Berkeley Energy and Resources (BEAR) model.

Among the results of this study are estimates of the percent difference in household income between the baseline scenario and the PEV15 and PEV45 scenarios (Table 2.6). An interesting result of this study is that all households, not just those that choose to purchase or lease an electric vehicle, experience a slight increase in household income. The income change estimates in Table 2.6 are the broad-base changes in income felt by all households. We combined these percentages with information from the American Community Survey on Oregon's income distribution, to produce estimates of the total increased income by income category.

Predicted Percent Income Increase by Income Group

Income Group	ZEV15	ZEV45
Total	0.20%	0.40%
Less than $10,000	0.20%	0.40%
$10,000 to $14,999	0.20%	0.40%
$15,000 to $19,999	0.20%	0.40%
$20,000 to $24,999	0.20%	0.40%
$25,000 to $29,999	0.20%	0.40%
$30,000 to $34,999	0.20%	0.40%
$35,000 to $39,999	0.20%	0.40%
$40,000 to $44,999	0.20%	0.20%
$45,000 to $49,999	0.20%	0.20%
$50,000 to $59,999	0.20%	0.20%
$60,000 to $74,999	0.20%	0.20%
$75,000 to $99,999	0.20%	0.20%
$100,000 to $124,999	0.20%	0.20%
$125,000 to $149,999	0.20%	0.20%
$150,000 to $199,999	0.20%	0.20%
$200,000 or more	0.10%	0.20%

The estimates of the increase in household income were entered into IMPLAN using 2014 as the "Event Year." This means that we are holding all else constant from 2014 to 2030 except a marginal change in income from electric vehicle adoption. This allows us to predict the impact on state revenue, employment, and GDP. In order to make comparisons with other studies, we needed to be able to calculate the effect per 100 EVs. To get the number of EVs in Oregon under these scenarios, we multiplied the adoption rate by the number of new light duty vehicle sales in 2014. Data on new vehicle sales were only available through October 2014, so we assumed that the rate of car purchases remain fairly constant over the year in order to forecast the year's total.[7] In the period from January through October 2014, 108,259 new light duty vehicles were registered in Oregon. Since this time period accounts for 83% of the year, this suggests that by the end of the calendar year, this number will grow to 130,416.

[7] Data from the Federal Reserve on the monthly seasonal factors for auto and light truck sales suggest that this is a reasonable assumption.

Research Component 3: Building on the University of Michigan Study

Several researchers at the University of Michigan Ross School of Business, on behalf of the Ford Motor Company, conducted a study outlining the economic and policy impacts of vehicle electrification. Like the CalETC study, this is a prospective study that makes assumptions about lower prices and increased EV sales resulting, at least in part, from improved EV technology. For their study, they selected a representative sample of states to analyze. Among these states, Maryland is the most similar to Oregon due to the lack of oil refineries and EV production in both states as well as the mutual absence of a subsidy for EV sales and the presence of a zero emission vehicle (ZEV) mandate.

As a result, we used the predictions that were produced for Maryland and adjusted them for the size of the Oregon economy. The Ford study predicts that from 2012 to 2020, electric vehicles would increase Maryland's GDP by just under 0.035%. Combining this information with state-by-state GDP data from the Bureau of Economic Analysis, we estimated that vehicle electrification will contribute $79.33 million annually to the Oregon economy by 2020. From 2004 to 2012, state and local tax revenue ranged between 5.27% and 6.08% of Oregon GDP. Using the average of 5.68%, we estimated that $79.33 million in GDP would result in additional state and local taxes.

Results

Using data from a University of Michigan study, it was estimated that vehicle electrification will contribute $79.33 million annually to the Oregon economy by 2020. Historical data indicates that state and local tax revenue average around 5.63% of state GDP. This implies that a $79.33 million boost to the economy would result in an annual revenue increase of $4.2 million. Using data from a similar study conducted at the University of California-Berkeley, it was estimated using IMPLAN that adoption of EVs will contribute between $113 million and $226 million annually to the Oregon economy by 2030, depending on the adoption rate. This corresponds with additional revenue of $12 million to $15 million in state and local taxes and 1,544 to 1,912 additional jobs. The benefit per EV is lower for the scenario with the higher adoption rate, suggesting that there are diminishing returns to EV adoption in terms of the macro-level economic effect, even though there are reasons to believe that there are increasing returns at in the individual, micro-level, as well as for the environment. However, the cumulative effect on GDP is always greater with larger penetration rates.

Table 1: Total annual impact in 2030, 2014 dollars

EV Adoption Rate	Employment	Labor Income	Low GDP estimate	High GDP estimate	Revenue
15% of new car sales	1,544.5	$62,960,474	$113,322,919	$182,338,780	$11,997,795
45% of new car sales	1,912.3	$77,987,435	$140,074,117	$225,769,644	$14,745,577

Table 2: Annual impact in 2030 per 100 EVs, 2014 dollars

EV Adoption Rate	Employment	Labor Income	Low GDP estimate	High GDP estimate	Revenue
15% of new car sales	7.89	$321,851	$579,301	$932,107	$61,332
45% of new car sales	4.88	$199,329	$358,017	$577,047	$37,688

EVs were also determined to have a positive economic impact under today's conditions. For every 100 EVs that are adopted in place of a common alternative, annual GDP was predicted to increase by between $579 thousand and $358 thousand. Today there are approximately 4,500 EVs on the road in Oregon according to records obtained from the Oregon Department of Motor Vehicles. The cumulative effect is an additional $1.79 million to $10.15 million contributed to the Oregon economy and 23 to 86 additional jobs. Using IMPLAN, we also estimated that each EV on the road today generates an annual $42-$150 more in state and local tax revenue than common alternatives.[8] Assuming that the vehicle is owned for 10 years, this results in $425 to $1,503 in additional revenue over the life of the vehicle. Currently, there is some loss in fuel tax revenue, however plans are underway to reform the transportation funding system to make up for reduced fuel consumption across the transportation sector.

[8] This does not include lost gas tax revenue. See Policy Recommendations for a full discussion of the gas tax issue.

Table 3: Present annual impact (total), 2014 dollars.

Scenario	Employment	Labor Income	Low GDP estimate	High GDP estimate	Revenue
Nissan Leaf EV instead of a Toyota Prius Hybrid	22.5	$985,700	$1,790,000	$2,866,000	$191,600
Nissan Leaf EV instead of a VW Jetta SportWagen	27	$1,130,000	$2,048,000	$3,278,000	$219,500
Nissan Leaf EV instead of a BMW 228i	88.5	$3,500,000	$6,331,000	$10,150,000	$676,700

Table 4: Present annual impact per 100 EVs, 2014 dollars.

Scenario	Employment	Labor Income	Low GDP estimate	High GDP estimate	Revenue
Choosing a Nissan Leaf EV instead of a Toyota Prius Hybrid	0.5	$21,904	$39,771	$63,696	$4,258
Choosing a Nissan Leaf EV instead of a VW Jetta SportWagen	0.6	$25,118	$45,512	$72,840	$4,878
Choosing a Nissan Leaf EV instead of a BMW 228i	1.9	$77,772	$140,700	$225,464	$15,037

Combining the results from all three studies, we can see how the economic and revenue impacts of EV adoption grow over time. Figures 1 and 2 show the total annual impact of EV adoption in Oregon from 2014 to 2030 as predicted by the three studies. The shaded region shows our attempt to "triangulate" the data, providing a sense of what outcomes are consistent with the three studies. There does seem to be some general agreement among the studies, when you bear in mind that these studies assume that EV adoption will grow as EV technology improves. Looking at the average trend through the shaded regions, we predict a compound annual growth rate of 4.34% for the impact on state GDP and 4.19% for the impact on state and local tax revenue. The net present value of EV adoption from 2014 to 2030 was predicted to be $897.32 million for the economy and $64.66 million in state and local tax revenue.[9]

[9] Consistent with the Electric Power Research Institute's 2013 report, we used a discount rate of 2% for the first 5 years and 5% for all years thereafter.

Figure 1: Annual Change in GDP from EV Adoption

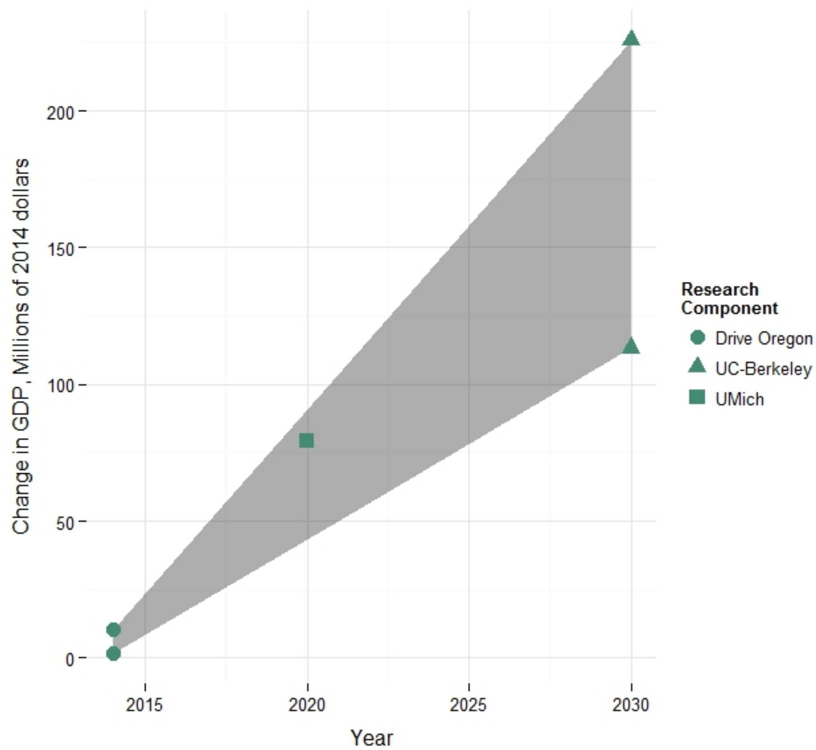
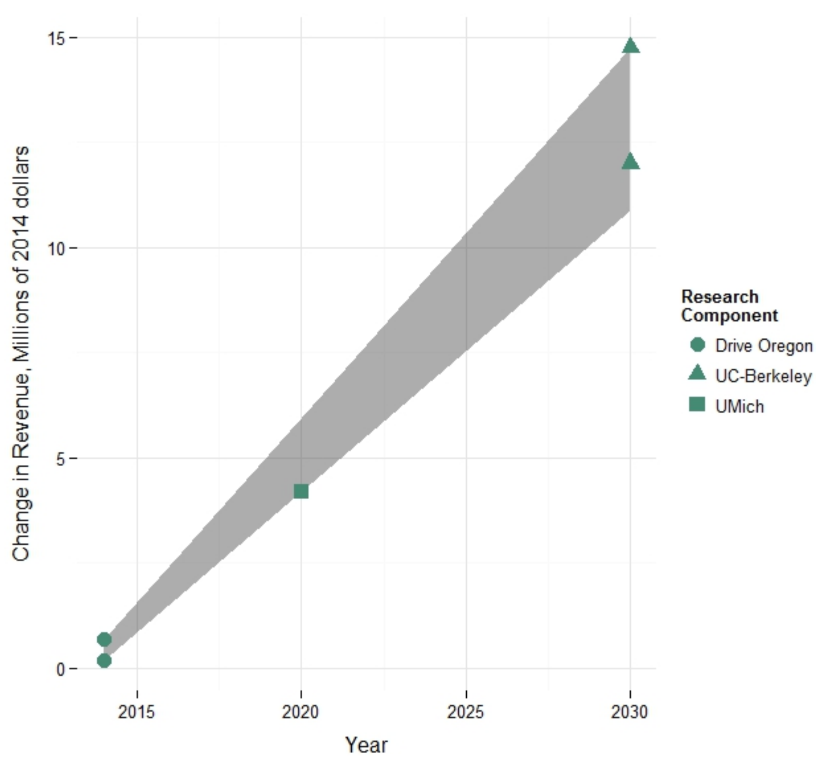


Figure 2: Annual Change in State and Local Tax Revenue from EV Adoption



Policy Recommendations

Today, EVs are estimated to contribute between $1.79 million and $10.15 million to the Oregon economy. By 2030, they could contribute between $113 million and $225 million, depending on the rate of adoption. In order to obtain the maximum benefit from EV adoption, we recommend that Oregon take additional steps to improve the attractiveness of EVs for Oregon consumers. By aiming for a 45% adoption rate by 2030, Oregon stands to gain between $26.75 million and $43.43 million in economic activity, 368 jobs, $15.02 million in wages, and $2.747 million in state and local taxes annually when compared to a 15% adoption rate.

Recommended Policy Approach

In order to help overcome initial barriers to electric vehicle adoption, many policies have been passed at the state and national level. These include investments in research and development, infrastructure improvements, and purchase incentives. A 2012 study by Zhenhong Lin at Oak Ridge National Laboratory found that in the short-term, vehicle subsidies have the greatest impact on the rate of EV adoption, while in the long-term, consumer confidence and infrastructure play a larger role. The State of Oregon has taken significant steps to promote the development of EV infrastructure and for this reason Oregon has caught the attention of the EV industry. However, it lags other states in incentivizing the EVs themselves.

Top Nissan LEAF EV markets nationally:

State	***Incentive(s) for vehicles***
California **(San Francisco #1, Los Angeles #2)**	Up to $2,500 rebate for all residents or up to $7,000 for low-income residents,[10] HOV lane exemption, free parking
Georgia (**Atlanta #3**)	$5,000 tax credit, HOV lane exemption
Washington (**Seattle #4**)	Sales tax exemption on vehicle purchase (value varies, but approximately $2,600 for a Nissan Leaf)
Oregon (**Portland #5**)	None

We recommend that Oregon explore the possibility of promoting EV adoption by subsidizing EV purchases. The U.S. DOE estimates that decreasing the purchase price of a vehicle by as little as 10% would increase its market share by 50 – 80%, all other factors being equal.[11] This would in turn help Oregon meet several state goals. For example, EV adoption is considered an important component of Oregon's goal to reduce greenhouse gas (GHG) emissions to 75% below 1990 levels by 2050. In addition, the EV industry has a strong presence in Oregon and is seen as an important growth industry for job creation in the state. This report demonstrates that EV ownership alone contributes to increased prosperity for Oregonians. Thus, accelerated EV adoption would help Oregon lawmakers meet their commitments to the climate, the state economy, and individual prosperity.

[10] Starting in 2015, there is an additional subsidy for low-income residents, who get $1,500 for returning a high-polluting clunker and a $3,000 voucher towards the purchase of a new vehicle, for a total of $7,000 towards the purchase of an EV or other zero-emission vehicle.
[11] United States Department of Energy. 2013. "PEV 'New Areas in Policy Analysis' (NAPA) Project Overview." Presentation: August 23, 2013. Seth Federspiel, Jake Ward, Austin Brown, Chris King, and Steve Capanna.

There are three main methods of incentivizing EV purchases: a tax credit such as offered by the federal government, a rebate to consumers such as offered by the State of California, and a rebate to EV dealers. A rebate program is generally considered the most effective and equitable way to incentivize EV purchases. According to the U.S. DOE "tax credits are much less valuable to consumers than a discount at the point of sale. The present value of a future tax decrease is less than that of an immediate discount. Consumers' tax liability may not be high enough to allow taking the full tax credit, or they may be unaware of the credit." By comparison with a tax credit, an estimated 80% of taxpayers do not have enough tax liability to fully take advantage of the incentive and the delay between vehicle purchase and receipt of the credit is believed to reduce its impact on buying decisions. The U.S. DOE estimates that tax credits are likely to be half as effective as a rebate in incentivizing PEV sales. They also found that significant subsidies are worth the investment to society, but they need long-term commitments to be effective.

STATE PLANS FURTHERED BY EV ADOPTION:

- Oregon's 10-Year Energy Action Plan has a core strategy of accelerating the market transition to a more efficient, cleaner transportation system. The plan calls for a 20-percent conversion of fleets to alternative fuel vehicles over the next ten years.
- The Pacific Coast Action Plan on Climate and Energy calls for leadership in transitioning the West Coast to clean modes of transportation and aims for 10 percent of new vehicle purchases in fleets to be zero emission vehicles by 2016.
- The 8-State Zero-Emission Vehicle Programs Memorandum of Understanding agreed to a collective target of having at least 3.3 million zero-emission vehicles on the road by 2025 and to pursue incentives for ZEVs when appropriate.
- The Statewide Transportation Strategy (called for by SB 1058) puts forth a pathway to reach Oregon's 2050 greenhouse gas reduction goals (established in 2007 by HB 3543) and includes 53% EV and hybrid fleet composition by 2050, contributing to fuel cost savings, cleaner air, and higher local economic development.
- Transportation and Land Use Roadmap to 2020, sets goals of having a 10% reduction in the carbon intensity of transportation by 2020 and for 90% of the miles traveled to be by electric and other low-or non-carbon vehicles by 2050.

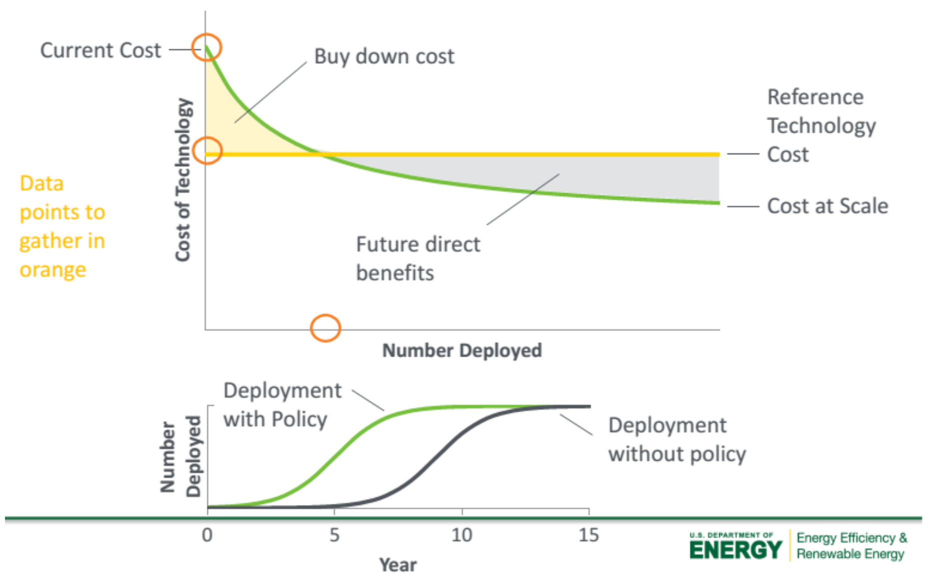
ADDRESSING THE FUEL TAX ISSUE:

Scenario	Increase in State and Local Revenue	Decrease in Fuel Tax Collections
Leaf vs Prius Hybrid	$4,258	$6,506
Leaf vs Jetta TDI	$4,878	$9,567
Leaf vs BMW 228i	$15,037	$11,617

As shown in the table above, any gain in state and local tax revenue would be canceled out by the lost fuel tax revenue. Though these monies would go into different funds, we feel it is important to couple future policies reducing petroleum consumption with a new mechanism for funding the State Highway Fund.

Economic Rational for Government Intervention

In 1989, economist W. Brian Arthur presented the idea that under increasing returns, an inferior technology may become locked-in due to path-dependency. In other words, if an inferior technology initially offers a higher return, adoption of a superior technology may not occur. Applied to the transportation sector, this problem is sometimes referred to as “carbon lock-in” which “arises through a combination of systematic forces that perpetuate fossil fuel-based infrastructures in spite of their known environmental externalities and the apparent existence of cost-neutral, or even cost-effective, remedies” (Unruh, 2000, p. 817). Though at one time the concept of technological lock-in was controversial or believed to be inaccurate, its presence is well-acknowledged in the academic literature (Unruh 2000, 2002; Dolfsma & Leydesdorff, 2009; Berkout, 2002; Carrillo-Hermosilla, 2006; Kalkuhl, Edenhofer, & Lessman, 2012; and Schmidt & Marschinski, 2009). Technological lock-in can result in a market equilibrium that is sub-optimal, and as a result can be considered a reason for government intervention (Dolfsma and Leydesdorff, 2009 and Kalkuhl, Edenhofer, and Lessman 2012).



The causes of lock-in include increasing returns to scale, long investment cycles, and network externalities (Unruh, 2000, 2002 and Schmidt & Marschinski, 2009). In the case of electric vehicles, the major source of lock-in is learning economies of scale. The development of a new technology goes through two stages: R&D, when invention occurs, and learning-by-doing, which can lead to cost reductions, greater proficiency in technology operation, and institutional transformations to support technology deployment (Sagar and Van der Zwaan, 2006). Technologies that have only gone through the first stage of development have greater potential than is readily apparent. This leads to a Catch-22 of sorts, in which the technology needs to be adopted in order to mature, but the incentives for adoption are lower than in the matured state. As a result, there is a tendency to underinvest in technologies in the learning phase of development, resulting in economic inefficiency. This dynamic is illustrated in the “learning curves” produced by the U.S. Department of Energy (U.S. DOE). The first graph shows how the cost of a new technology decreases over time and the second graph shows how policies to promote a new technology can accelerate technology deployment.

The historical events that led to the establishment of the internal combustion engine (ICE) as the dominant technology for vehicle propulsion is neatly described by Unruh (2000):

> At the beginning of the 20th century, competition existed among steam-, electric- and gas-powered ICE vehicles as potential mechanized substitutes for the horse and carriage (Mowery and Rosenberg, 1998). There

> is no single reason for the establishment of the ICE as the dominant design. Indeed, in 1885, it was considered the least promising option, being the most noxious, noisy, complicated and dangerous alternative. However, the very cheap cost of gasoline, which at the time was a hazardous by-product from the production of kerosene, clearly played a role (Ayers and Ezekoye, 1991). Several chance events, like the closing of horse troughs used to supply steam vehicles and a 1895 victory in a horse-less carriage race that led Olds to shift to the ICE, also provide a relative lead over alternatives (Arthur, 1988). Once established, the ICE-powered car, and its associated Fordist system of mass production, entered a period of increasing returns to scale, driving prices down, improving performance and locking-in the ICE as the dominant propulsion design (p. 821).

There was a renewed interest in electric vehicles after the oil crisis of the 1970s. At this time, many politicians became concerned by the transportation system's dependence on unstable Middle East politics. Consequently, in 1976, the US Senate authorized the Energy Research and Development Association to spend $160 million developing hybrid and electric vehicles. However, the program was largely a failure, owing primarily to the immaturity of battery technology (Cowen and Hultén, 1996).

Today, the outlook for electric vehicles is much brighter. For example, between 2011 and 2012 sales of electric vehicles more than doubled (2013 Global EV Outlook). Environmental legislation, volatility in the price of oil, questions of peak oil and sustainability, and improvement in battery technology have created a regulatory, investment, and technological climate favorable to the development of an electric vehicle innovation system. Yet, in 2012 the total EV stock only accounted for 0.02% of total passenger cars (2013 Global EV Outlook). To some extent, the technological system is still immature, resulting in a traditional market failure. However, electric vehicles are already able to go the distances travelled for most daily use (Pearre et al., 2011). In addition, they are already cost neutral with vehicles propelled by ICEs when considering the total cost of ownership (Electric Power Research Institute, 2013). The Boston Consulting Group report on "Batteries for Electric Vehicles" concluded that with current incentives and oil prices in the United States, EV purchasers will reach lower total ownership costs within 3 to 5 years of operation. A 2011 status report by the U.S. Department of Energy (U.S. DOE) identifies two factors that explain consumer's reluctance to purchase electric vehicles. The first is that consumers tend to be risk-adverse and prefer well-proven technology. This is especially the case with automobiles, which are a major financial purchase. The second is that consumers tend to undervalue future fuel savings, consequently over-estimating the total cost of ownership relative to traditional vehicles.

Conclusion

Bringing together the three different studies examined in this report, we estimate that the net present value of EV adoption from 2014 to 2030 is $897.32 million for the economy and $64.66 million in state and local tax revenue.[12] However, whether we reach these levels depends on the adoption rate. We argue that Oregon should speed the rate of adoption by improving the attractiveness of EVs for Oregon consumers. The U.S. DOE estimates that decreasing the purchase price of a vehicle by as little as 10% would increase its market share by 50 – 80%, all other factors being equal.[13] Using this information, we recommend an incentive amount of $3,000, which is just slightly more than 10% of the base MSRP for the popular Nissan Leaf. If we were to fund the incentive with just the predicted revenue from EV adoption, Oregon could incentivize the purchase of 21,000 EVs. This is over four and a half times as many EVs as are registered in Oregon today. This would create a critical mass of EVs on the road, which could spur private investment in EV infrastructure, such as charging stations, thereby creating a "virtuous cycle" or positive feedback loop leading to further EV adoption.

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[12] Consistent with the Electric Power Research Institute's 2013 report, we used a discount rate of 2% for the first 5 years and 5% for all years thereafter.

[13] United States Department of Energy. 2013. "PEV 'New Areas in Policy Analysis' (NAPA) Project Overview." Presentation: August 23, 2013. Seth Federspiel, Jake Ward, Austin Brown, Chris King, and Steve Capanna.

Appendix

I) DATA AND FORMULAS

Research Component 1

1) Formulas

$$Net\ Change\ in\ Income = Avg.\ Annual\ Vehicle\ Cost\ Difference + Average\ Annual\ Gas\ Cost - Average\ Annual\ Electricity\ Cost + Difference\ in\ Insurance\ Costs + Difference\ in\ Maintenance\ Costs$$

$$Average\ Annual\ Vehicle\ Cost\ Difference = Number\ of\ EVs * \frac{1}{10}(Tax\ Credit\ Amount + (Comparison\ MSRP - Leaf\ MSRP) - Charger\ Costs$$

$$Average\ Annual\ Gasoline\ Cost = Numbers\ of\ EVs * Vehicle\ Miles\ Traveled * \frac{1}{Miles\ per\ Gallon} * Dollars\ per\ Gallon$$

$$Average\ Annual\ Electricity\ Cost = Numbers\ of\ EVs * Vehicle\ Miles\ Traveled * \frac{1}{Miles\ per\ Killowatt\ Hour} * Dollars\ per\ Kilowatt\ Hour$$

2) Numbers Inputted Into IMPLAN

		Net Annual Change in Income		
Income Group	**#EVs purchased**	**Leaf vs Prius**	**Leaf vs. Jetta SportWagen**	**Leaf vs. BMW 228i**
Total	100.00	62280.96	73546.14	210581.77
Less than $10,000	0.32	367.08	399.39	835.00
$10,000 to $14,999	0.35	349.30	370.12	845.22
$15,000 to $24,999	1.31	218.78	214.57	1961.44
$25,000 to $34,999	2.53	383.18	432.51	3824.52
$35,000 to $49,999	6.71	2358.04	3852.34	13301.30
$50,000 to $74,999	7.33	4276.32	5889.67	16209.21
$75,000 to $99,999	15.83	10106.60	11799.55	33464.80
$100,000 to $149,999	28.53	18071.52	21305.10	60407.37
$150,000 or more	37.08	23365.81	27568.00	78383.27

Research Component 2

1) Formulas

$$Total\ Income\ Increase = Midpoint\ of\ Income\ Range * Number\ of\ Households * Predicted\ Percent\ Income\ Increase$$

2) Numbers Inputted Into IMPLAN

	Total increased income	
Income Group	**ZEV15**	**ZEV45**
Total	186287416.75	243970164.99
Less than $10,000	1191210.00	2382420.00
$10,000 to $14,999	2177387.90	4354775.80
$15,000 to $19,999	3033643.32	6067286.64
$20,000 to $24,999	3992671.27	7985342.54
$25,000 to $29,999	4775783.17	9551566.33
$30,000 to $34,999	5324913.08	10649826.15
$35,000 to $39,999	5986495.18	11972990.36
$40,000 to $44,999	6685256.35	6685256.35
$45,000 to $49,999	6349733.16	6349733.16
$50,000 to $59,999	14014972.59	14014972.59
$60,000 to $74,999	21149618.34	21149618.34
$75,000 to $99,999	31919817.60	31919817.60
$100,000 to $124,999	14996903.91	14996903.91
$125,000 to $149,999	16705364.25	16705364.25
$150,000 to $199,999	18735796.47	18735796.47
$200,000 or more	13640400.00	27280800.00

II) DATA SOURCES

Charging Station and Installation Costs
Rocky Mountain Institute. "Pulling Back the Veil on EV Charging Station Costs." April 29, 2014

Electric Vehicle Ownership by Income
The Center for Sustainable Energy, the Clean Vehicle Rebate Project, and the California Air Resources Board, "EV Owner Demographics & Diffusion Survey" 2013-2014.

Electric Vehicle Ownership in Oregon
Oregon Department of Motor Vehicles. August, 2014

Fuel Efficiency
U.S. Department of Energy, www.fueleconomy.gov, 2014.

Gasoline, Diesel, and Electricity Retail Prices
Energy Information Administration, 2014.

Household Income Distribution in Oregon
U.S. Census Bureau American Community Survey. 3-year estimates. 2012.

Insurance Cost Differences
CoverHound Insurance. *Counting the Costs of Electric Vehicles.* Report. 2014.

Maintenance Cost Differences
Institute for Automotive Research (IFA) at the Nürtingen-Geislingen University. *Electric mobility: Electric cars have significantly lower upkeep*. Report. 2012.

Manufacturer's Suggested Retail Price
U.S. Department of Energy, www.fueleconomy.gov, 2014.

Oregon Fuel Tax Rate
Oregon Department of Transportation, 2014.

New Retail Light Vehicle Registrations
Oregon Automobile Dealers Association. "Oregon Auto Outlook." October, 2014.

Tax Liability by Income
Internal Revenue Service, Statistics of Income Division, Table 3.3, Tax Year 2011.

Vehicle Miles Traveled by Income
U.S. Department of Transportation, Federal Highway Administration, 2009 National Household Travel Survey. URL: http://nhts.ornl.gov.

Sources Used for Research Components

California Electric Transportation Commission & Roland-Holst, D. Plug-In Electric Vehicle Deployment in California: An Economic Assessment. (Technical Report), 2012.

Cornfeld, J.; Kim, J.; Kraut, J.,; & Voit, B. Charging Ahead with Electric Vehicles. (Technical Report). University of Michigan and Ford Motor Company: 2014.

III) REFERENCES

Arthur, W. B. 1989. Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal*, 116-131.

The Boston Consulting Group, "Batteries for Electric Vehicles: Challenges, Opportunities, and the Outlook to 2020", January, 2010

Berkhout, Frans. 2002. "Technological Regimes, Path Dependency and the Environment." *Global Environmental Change* 12(1): 1–4.

Carrillo-Hermosilla, Javier. 2006. “A Policy Approach to the Environmental Impacts of Technological Lock-In.” *Ecological Economics* 58(4): 717–42. http://www.sciencedirect.com/science/article/pii/S0921800905003940 (January 9, 2014).

Clean Energy Ministerial, Electric Vehicles Initiative, and the International Energy Agency. 2013. *Global EV Outlook: Understanding the Electric Vehicle Landscape to 2020.* (Technical Report).

Cowan, Robin, and Staffan Hultén. 1996. “Escaping Lock-in: The Case of the Electric Vehicle.” *Technological Forecasting and Social Change* 53(1): 61–79.

Dolfsma, Wilfred, and Loet Leydesdorff. 2009. “Lock-in and Break-out from Technological Trajectories: Modeling and Policy Implications.” *Technological Forecasting and Social Change* 76(7): 932–41.

Electric Power Research Institute. 2013. *Total Cost of Ownership Model for Current Plug-in Electric Vehicles*. (Technical Report).

Kalkuhl, Matthias, Ottmar Edenhofer, and Kai Lessmann. 2012. “Learning or Lock-in: Optimal Technology Policies to Support Mitigation.” *Resource and Energy Economics* 34(1): 1–23.

Northwest Economic Research Center.2013. *Oregon’s Electric Vehicle Industry*. (Technical Report).

Pearre, N. S., Kempton, W., Guensler, R. L., & Elango, V. V. 2011. Electric vehicles: How much range is required for a day’s driving?. *Transportation Research Part C: Emerging Technologies*, 19(6), 1171-1184.

Sagar, Ambuj D., and Bob van der Zwaan. 2006. “Technological Innovation in the Energy Sector: R&D, Deployment, and Learning-by-Doing.” *Energy Policy* 34(17): 2601–8.

Schmidt, Robert C., and Robert Marschinski. 2009. “A Model of Technological Breakthrough in the Renewable Energy Sector.” *Ecological Economics* 69(2): 435–44.

Unruh, Gregory C. 2000. “Understanding Carbon Lock-In.” *Energy Policy* 28(12): 817–30.

Unruh, Gregory C. 2002. “Escaping Carbon Lock-In.” *Energy Policy* 30(4): 317–25.

United States Department of Energy. 2011. One Million Electric Vehicles by 2015. (Status Report).

United States Department of Energy. 2013. “PEV ‘New Areas in Policy Analysis’ (NAPA) Project Overview.” Presentation: August 23, 2013. Seth Federspiel, Jake Ward, Austin Brown, Chris King, and Steve Capanna.