Plug-in Electric Vehicle Deployment in California:

An Economic Assessment

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Research Papers on Energy, Resources, and Economic Sustainability

This report is part of a series of research studies into alternative energy and resource pathways for the global economy. In addition to disseminating original research findings, these studies are intended to contribute to policy dialog and public awareness about environment-economy linkages and sustainable growth.

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Executive Summary

ES 1. Introduction

Plug-in electric vehicles (PEVs) are an essential component of California's path towards meeting its economic and environmental goals. This report presents an economic assessment of statewide deployment of light-duty PEVs. To elucidate the linkages between PEV deployment, economic growth, and job creation, we used a state-of-the-art economic forecasting model to evaluate different scenarios for PEV deployment. Our most salient findings are summarized in table ES1.1.

Table ES1.1: Main Findings

- **Light-duty vehicle electrification can be a potent catalyst for economic growth, contributing up to 100,000 additional jobs by 2030.**
- **On average, a dollar saved at the gas pump and spent on the other goods and services that households want creates 16 times more jobs.**
- **Unlike the fossil fuel supply chain, the majority of new demand financed by PEV fuel cost savings goes to in-state services, a source of diverse, bedrock jobs that are less likely to be outsourced.**
- **Individual Californians gain from economic growth associated with fuel cost savings due to vehicle electrification, whether they buy a new car or not. As a result of light-duty vehicle electrification, the average real wages and employment increase across the economy and incomes grow faster for low-income groups than for high-income groups.**

PEV adoption stimulates economic growth by promoting transport efficiency, reducing the cost of transportation fuel, reducing carbon fuel use, and saving money for households and enterprises. These savings return as different expenditures that are, on average, more job-intensive and less import-dependent than the petroleum fuel supply chain. Consequently, the new expenditures have stronger "multiplier" effects on state product and create many more jobs than they displace.

For all these reasons, scenarios that promote adoption and diffusion of PEV technologies will enable California to enjoy significant reductions in energy dependence and global warming pollution, while stimulating its economy and statewide employment with the resulting fuel savings.

ES 2. Economic Assessment

Table ES2.1: PEV Deployment Scenarios

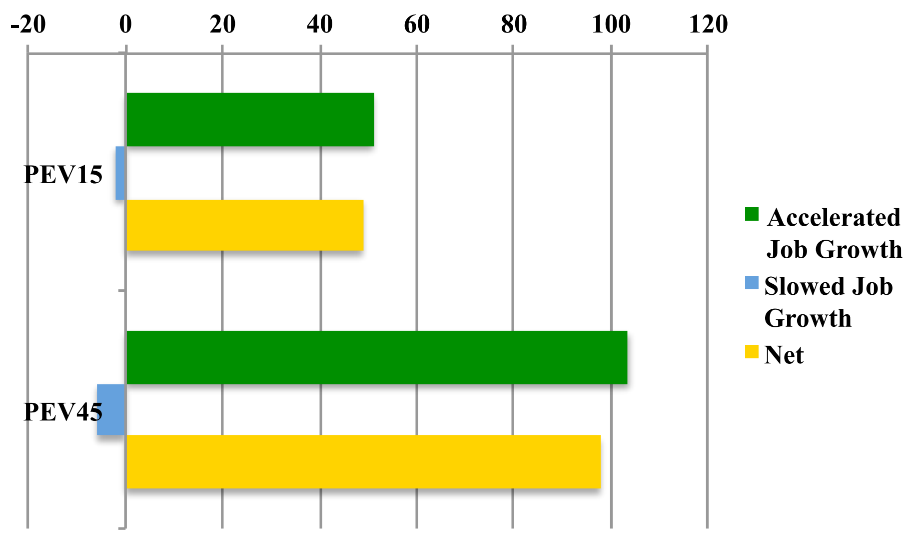
Scenario	Name	Description
1	Baseline	Assume California implements current commitments to state and post-1990 federal fuel economy standards, but continues growth at levels forecast by the Department of Finance. This is the baseline scenario.
2	PEV15	Including the Baseline scenarios, but assuming 15.4% PEV deployment in the new light-duty vehicle fleet by 2030, this would be consistent with the ZEV regulations being met by PEVs. Tax credits for PEV vehicles are phased out by 2020, and LCFS credits are awarded for pollution reduction (see section 3).
3	PEV45	Same as PEV15, except PEV deployment is accelerated to 45% of the new light-duty vehicle fleet by 2030.

To appraise the economic impacts of PEV deployment on the California economy, we used a state-of-the-art forecasting tool, the Berkeley Energy and Resources (BEAR) model. After calibrating it to detailed data on the state economy, vehicle fleet, and related information, we evaluated a set of three policy scenarios, summarized in Table ES2.1.

Long-term aggregate economic effects of the three vehicle deployment alternatives are presented in Figure ES2.1 and Table ES2.2. These projections indicate that new vehicle technologies, particularly those that reduce our reliance on fossil fuels, stimulate economic growth and job creation. Overall, these results are consistent with a large body of related research on energy efficiency and economic growth.[1] While total employment still grows in all sectors by 2030, some (fossil fuel related) sectors grow more slowly (blue), most others experience accelerated growth (green).

[1] See e.g. Roland-Holst: 2010, 2011a, CARB:2010, EAAC:2009.

Figure ES2.1: PEV Employment Impacts



Source: Authors' estimates.
Note: Results are changes from Baseline values in 2030. Jobs in 1,000s of FTE workers.

Generally speaking, the most robust finding of this study, as illustrated above, is that statewide economic growth and employment rise with the degree and scope of PEV adoption. What matters is that PEV technologies have positive net value to those who adopt them. When vehicle owners realize these savings, be they households or enterprises, they will reappear as demand for goods and services outside the petroleum fuel supply chain, and the result will be higher state economic growth and employment.[2]

Table ES2.2: Statewide Macroeconomic Impacts

	PEV15	PEV45
Real GSP	4.954	8.177
Net Job Growth	48,816	97,761

Source: Authors' estimates.
Notes: Real Gross State Product (GSP, dollar billions) and Employment (FTE) are expressed as changes from Baseline values in 2030.

[2] These findings are wholly consistent with a recent meta-review of some 48 past state and regional policy assessments (Laitner and McKinney 2008) which notes that significant energy efficiency improvements of all kinds can yield net positive employment and GDP benefit to the economy (see,).

We summarize salient features of the growth impacts below:

- **PEV15** – Increasing the market share of new PEVs to 15.4% by 2025 would confer new economic growth via long-term energy fuel savings, adding about $5 billion to Gross State Product (GSP) and about 50,000 more jobs by 2030. Shifting the fleet's average energy fuel content more strongly toward electricity also reduces potential emissions.
- **PEV45** –More aggressive PEV deployment, that places California on track to meet Executive Order S-3-05 greenhouse gas reduction goal (80% below 1990 levels by 2050), achieving a milestone of 45% of new vehicle market share by 2030, would more strongly stimulate state growth. Real GSP is estimated be over $2 billion higher, about 100,000 additional jobs. Clearly, the shift from traditional transportation fuels to electricity is a potent catalyst for growth across the economy.

More detailed analysis of economywide impacts (section 2 below) show that low, middle, and high income households all gain from the PEV deployment. Moreover, households gain whether they buy a new car or not, as PEVs reduce upward pressure on fuel prices and stimulate job creation across the economy.

ES 3. Conclusions

Using a long-term economic forecasting model that details patterns of vehicle ownership and use across the state, we evaluated scenarios for accelerated deployment of PEVs. In all cases, PEV deployment translated into significant new demand for more job-intensive goods and services, ranging over a broad spectrum of in-state activities and jobs.

This evidence shows that accelerated PEV deployment can be a catalyst for economic growth. Because, on average, household demand is 16 times more job-intensive than the fossil fuel supply chain, every dollar saved at the gas pump and spent on the other goods and services consumers traditionally buy adds stimulus to state incomes, employment, and real wages.

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Plug-in Electric Vehicle Deployment in California: An Economic Assessment

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1 Introduction

California's commitment to alternative-fuel vehicles, in particular plug-in electric vehicles (PEVs) have set a course for determined improvements in our energy security and environment over the next generation. This report presents an economic assessment focusing on accelerated statewide deployment of PEVs.

This research does not advocate particular policies, our primary objective is to promote evidenced-based dialogue that can make public policies more effective and transparent. California's initiative in this area makes it an essential testing ground and precedent for other states, nationally, and internationally.

As much as any economy in modern times, California owes its prosperity to transportation. The state is a gateway for half the nation's trade flows and home to agriculture and industries that supply extensive national markets. Moreover, California represents the most extensive laboratory for regional development based on ex-urban residential systems and interlinked townships. For all these reasons, motorized transport has been, is, and will be indispensable to California living. The state is also committed to reducing vehicle miles travelled, diversifying the transportation fuels market and shifting to a sustainable clean fuels future that both protects the State's economy and its environment. Plug-in electric vehicles can play a decisive role in

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this process. The environmental justification for adoption of PEV technologies is relatively transparent, but because they represent substantial change to established patterns of behavior and economic relations, policies promoting them are not without controversy. This study provides new evidence to support more informed public and private dialog on the economic implications of wider PEV adoption. Generally speaking, we find that such measures, by increasing economic efficiency, confer significant long-term gains on the California economy.

Table 1.1: Main Findings

- **Light-duty vehicle electrification can be a potent catalyst for economic growth, contributing up to 100,000 additional jobs by 2030.**
- **On average, a dollar saved at the gas pump and spent on the other goods and services households want creates 16 times more jobs.**
- **Unlike the fossil fuel supply chain, the majority of new demand financed by PEV efficiency savings goes to in-state services, a source of diverse, bedrock jobs that are less likely to be outsourced.**
- **Individual Californians gain from fuel efficiency policy whether they buy a new car or not. Average real wages and employment increase across the economy and incomes grow faster for low-income groups than for high-income groups.**

To elucidate the linkages between PEVs, economic growth, and job creation, we used a state-of-the-art economic forecasting model to evaluate different scenarios for PEV deployment. This model closely tracks the evolution of California's vehicle fleet over time, projected macroeconomic aggregates, energy use, and emissions patterns between now and 2030. Before discussing the individual scenarios, we summarize the most salient findings in Table 1.1.

Plug-in electric vehicles stimulate economic growth by saving money for households and enterprises, promoting more efficient vehicle technology and reducing the carbon fuel intensity of transportation. These savings return as different expenditures that are, on average, less import dependent and more job intensive than the fossil fuel supply chain. Consequently, the new expenditures have stronger "multiplier" effects on state product and create many more jobs than they displace.

Except for in sectors directly linked to the fossil fuel supply chain, transport fuel efficiency stimulates job creation across all economic activities where consumers and enterprises spend money. This leads to employment growth far beyond "green" sectors and "green-collar" occupational categories.

For all these reasons, accelerated PEV deployment will enable California to diversity its transportation fuels sector, reduce global warming and other pollutants while stimulating its economy and statewide employment with the resulting fuel savings.

2 Economic Assessment

To appraise the economic impacts of PEV deployment on the California economy, we use a macroeconomic forecasting model. Over the last five years, economists at UC Berkeley have conducted independent research to inform public and private dialogue surrounding California climate policy. Among these efforts has been the development and implementation of a statewide economic model, the Berkeley Energy and Resources (BEAR) model, the most detailed and comprehensive forecasting tool of its kind. The BEAR model has been used in numerous instances to promote public awareness and improve visibility for policy makers and private stakeholders.[4]

The BEAR model has been peer reviewed and fully documented elsewhere (Roland-Holst: 2010), and its general structure is summarize in Annex 1 below. Rigorous policy research tools like the BEAR model can shed important light on the detailed economic incidence of accelerated PEV deployment. By revealing detailed interactions between direct and indirect effects across a broad spectrum of stakeholders, this kind of empirical evidence improves our understanding of the many indirect benefits of PEV market penetration.

[4] See e.g. Roland-Holst (2006ab, 2007a).

This study finds the action of accelerating the deployment of PEVs in the light-duty vehicle fleet actually saves money and increases employment overall because the indirect effects are so important. These overall benefits only become apparent when the economy-wide spillovers and innovation potential of the scenarios are taken into account. For example, we see below that fuel savings allow consumers and enterprises to redirect their spending, largely on in-state goods and services, and this stimulates California growth and employment. An economy-wide perspective like that of the BEAR model is needed to balance the adjustment and growth perspectives.

2.1 PEV Deployment Scenarios

Table 2.1 summarizes three alternative scenarios assessed in this study. After detailed examination of baseline growth characteristics, these are thought to best represent the potential growth in the PEV market, looking ahead for two decades.[5]

Table 2.1: PEV Deployment Scenarios

Scenario	Name	Description
1	Baseline	Assume California implements current commitments to state and post-1990 federal fuel economy standards, but continues growth at levels forecast by the Department of Finance. This is the baseline scenario.
2	PEV15	Including the Baseline scenarios, but assuming 15.4% PEV deployment in the new light vehicle fleet by 2025, which is assumed to hold constant to 2030. Tax credits for PEV vehicles are phased out by 2020, and LCFS credits are awarded for pollution reduction (see section 3).
3	PEV45	Same as PEV15, except PEV deployment is accelerated to 45% of the new light vehicle fleet by 2030.

The first scenario is a baseline that assumes California implements its commitment under the National Program GHG emission and fuel economy standards, which are used as a reference to evaluate existing policy commitments to fuel efficiency. The baseline includes the first round of the National Program standards reaching the equivalent of 250 grams of CO_2 per mile (or 35.5 mpg-equivalent) by model year (MY) 2016 and the second round increasing to 163 grams of CO_2 per mile (or 54.5 mpg-equivalent) by MY 2025.

[5] See Lutsey: 2010, for a survey of the broader spectrum of policies.

The PEV15 scenario was designed based upon CARB's recent decision to accelerate deployment of zero-emission vehicles as a reference point, where diffusion of these technologies is expected to reach 15.4% of new vehicle sales by 2025. For the 2012-2030 interval of our forecasts, we hold the 2025 deployment level constant over 2026-2030.

Scenario 3 represents accelerated deployment of PEVs, consistent with the California's goal of reducing economy-wide emissions (80% below 1990 levels) by 2025. This scenario includes more aggressive PEV deployment, with 45% of the state's new light-duty vehicle fleet by 2030 having some capability to be powered by grid electricity. We assume that this milestone is achieved in the PEV45 scenario, with these vehicles displacing other technologies in a linear fashion over the 2018-2030 time interval.

Because so many elements of the future are uncertain, economic forecasting must rely on assumptions to simplify our understanding of scenario comparisons. Without summarizing all the formal structure of economic theory, a few assumptions specific to the current policy context should be emphasized.

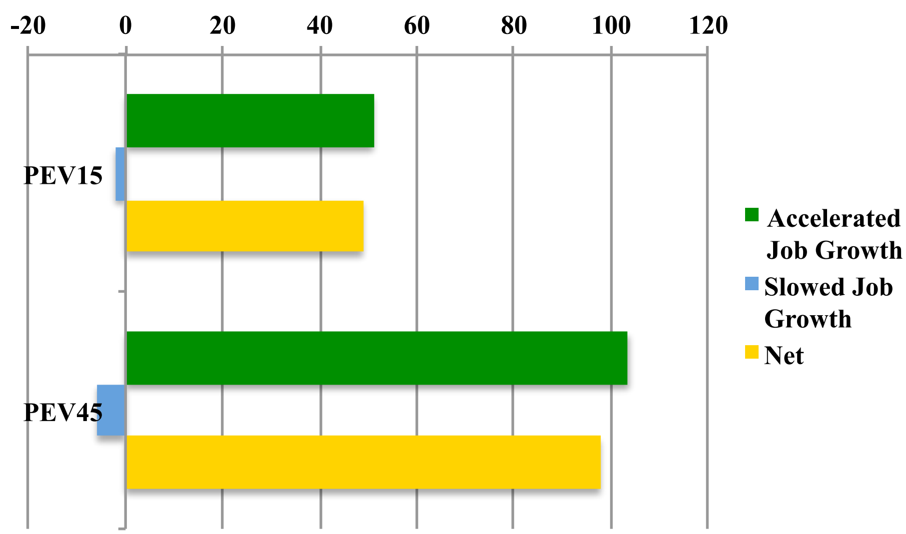
1. This assessment does not forecast vehicle adoption behavior explicitly, but models the impact of different deployment rates.
2. For PEV owners, we use National Academy of Science (NAS:2011) estimates of the so-called Indirect Cost Multiplier (ICM) for new vehicle technologies. This issue is discussed in more detail in section 3 below.
3. For economic benefits of fuel cost savings in for vehicles, we do not discount the spillover effects of these savings in the future. This was done because we want to assess the impact of these savings on the state economy when they are realized, in constant (2010) dollars.
4. We assume that existing State and Federal incentive programs for PEVs are retired linearly by 2020. When modeling the tax credits applicable to these vehicles, the BEAR model takes full account of fiscal costs and forgone consumption arising from this.
5. The analysis assumes that on-road efficiency is about 80% of the laboratory, or CAFE, value (see, e.g. De Cicco: 2005).

6. We assume, in accordance with U.S. Energy Information Administration's (EIA) Annual Energy Outlook forecasts, adjusted for California, that a gasoline price averaging about $4.00 per gallon prevails across the Baseline scenario (see Figure 3.5 below). There are many reasons to suspect that long-term real prices could be much higher than this.
7. For other fuels, we follow EIA forecasts and adjust with state estimates of historic California price differentials (discussed in Section 3 below).
8. PEV vehicle owners are awarded LCFS credits for pollution mitigation during the course of their vehicle use. Section 3 discusses this in greater detail.

2.2 Plug-in Electric Vehicle Deployment and Macroeconomic Growth

Because of the ubiquity of personal vehicle use in California, it is hardly surprising that significant technological change in this activity will have sizeable and lasting macroeconomic impacts. The results in Figure 2.1 and Table 2.2 show estimated long-term, statewide impacts both alternative vehicle deployment scenarios. In terms of real income (GSP in constant 2010 dollars) and employment, these projections indicate that more efficient PEV technologies can be a catalyst for economic growth and job creation.[6] Overall, these results are consistent with a large body of related research on energy efficiency and economic growth.[7]

Figure 2.1: PEV Employment Impacts



Source: Authors' estimates.
Note: Results are changes from Baseline values in 2030. Jobs in 1,000s of FTE workers.

Generally speaking, the most robust finding of this study, as illustrated above, is that statewide economic growth and employment rise with the degree and scope of PEV adoption. What matters is that PEV technologies have positive net value to those who adopt them. When vehicle owners realize these savings, be they households or enterprises, they will reappear as demand

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[6] While total employment still grows in all sectors by 2030, some (fossil fuel related) sectors grow more slowly (blue), most others experience accelerated growth (green).
[7] See e.g. Roland-Holst: 2010, CARB:2010, EAAC:2009.

for goods and services outside the petroleum fuel supply chain, and the result will be higher state economic growth and employment.[8]

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We summarize salient features of the growth impacts below:

- **PEV15** – Increasing the market share of new PEVs to 15.4% by 2025 would confer new economic growth via long-term energy fuel savings, adding about $5 billion to Gross State Product (GSP) and about 50,000 more jobs by 2030. Shifting the fleet's average energy fuel content more strongly toward electricity also reduces potential emissions.
- **PEV45** – More aggressive PEV deployment, that sets California on track to meet it's goal of 80% below 1990 levels by 2050, achieving a milestone of 45% of new vehicle market share by 2030, would more strongly stimulate state growth. Real GSP is estimated be over $2 billion higher, about 100,000 additional jobs.

More detailed analysis of economywide impacts (section 2.4 below) shows that low, middle, and high income households all gain from the PEV deployment. Moreover, households gain whether they buy a new car or not, as PEVs reduce upward pressure on fuel prices and stimulate job creation across the economy.

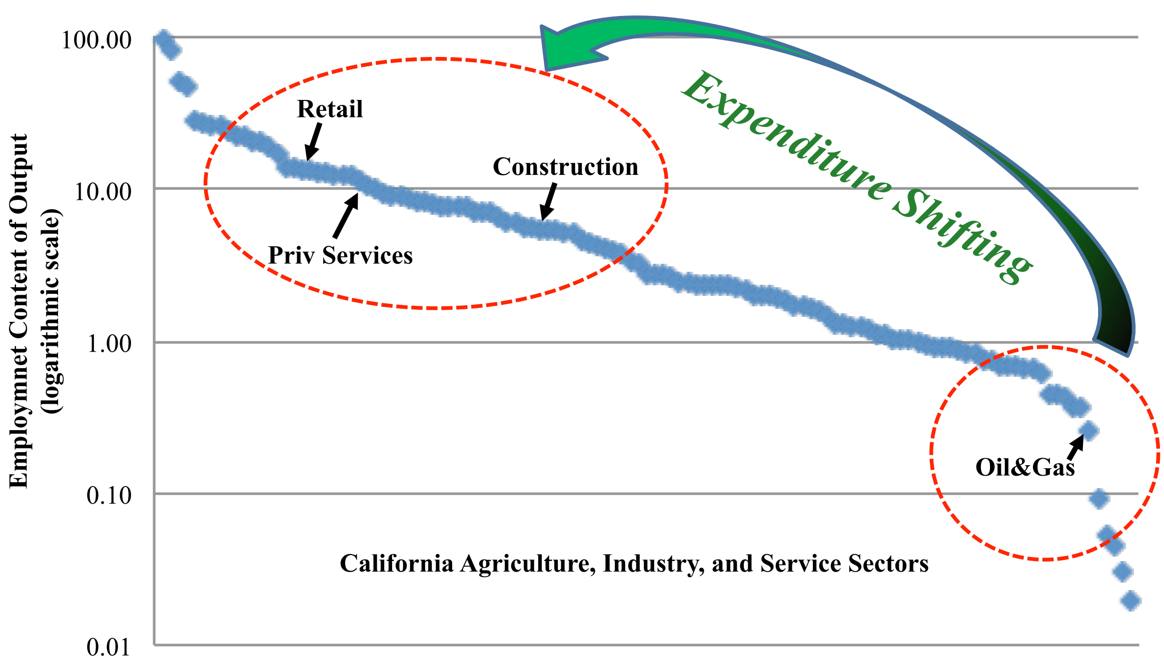
2.3 Why Fuel Saving Promotes Economic Growth

As we saw in the foregoing macroeconomic results, PEV efficiency, particularly when combined with shifting from liquid fossil to electricity fuel, offers significant aggregate

[8] These findings are wholly consistent with a recent meta-review of some 48 past state and regional policy assessments (Laitner and McKinney 2008) which notes that significant energy efficiency improvements of all kinds can yield net positive employment and GDP benefit to the economy (see,).

economic stimulus. The PEV growth dividend arises from a relatively simply mechanism called expenditure shifting. Household and enterprise fuel savings are spent on new vehicle technology and other consumer goods and services. Because the latter two categories of spending create many more jobs per dollar of demand than the fossil fuel supply chain, the result of this shift is substantial employment growth. New jobs in turn lead to more spending, with its own induced income and employment stimulus, extending the virtuous growth cycle that economists call the multiplier process.

Figure 2.2: Employment Intensity by Sector
(labor/output ratios for 124 California sectors)



Source: California Employment Development Department dataset.

The implications of expenditure shifting are illustrated schematically in Figure 2.2 goods and services require different amounts of labor to produce and deliver them, and this figure shows the ratio of FTE work hours to output across the California economy. Production is divided into 124 different economic activity sectors, ordered from left to right from highest to lowest job content (blue diamonds). Note that labor intensity across the economy varies so much that a logarithmic scale is needed to encompass it.

When households and enterprises reduce fuel expenditures, these savings are removed from the fossil fuel energy supply chain, among the least employment intensive in the economy (lower right circle). Since about 70% of California household demand and a significant portion of enterprise spending on non-energy inputs goes to services (upper right circle), the resulting expenditure shifting will result in substantial net job creation. Simply put, a dollar saved on traditional energy is a dollar earned by 10-100 times as many new workers.

Table 2.3: Index of Job Intensity by Sector

Sector	Job Index
Agriculture	20
Construction	42
Oil & Gas	1
Vehicle Manufacturing	5
Vehicle Sales & Service	19
Wholesale & Retail Trade	29
Other Service	34

Source: California Employment Development Department dataset.

To give a more focused picture of the forces behind expenditure shifting, we present in Table 2.3 a measure of jobs per million dollars of revenue, indexed to units of job intensity in the California petroleum sector. For example, the same dollar demand for Vehicle Sales and Service generates 19 times as many jobs as the Oil & Gas sector. On average, a dollar that goes to increasing California household spending is 16 times as job-intensive as that same dollar going to the fossil fuel supply chain.

Other aspects of this job creation process are also noteworthy. Firstly, it is apparent that energy fuel sector wages can be high, but they are not higher than service sector wages by anything like the employment multiples evident from these comparisons. Moreover, jobs created from this expenditure diversion are distributed across a broad spectrum of sectors and occupational categories, not restricted to green technology or import-dependent energy fuels and services. On the contrary, most of the jobs created by PEV deployment are in service sectors with high levels of in-state inputs and value added. Jobs like this have stronger and longer multiplier linkages inside the state economy, and they are at very low risk of being outsourced.

When reflecting on these results, a few caveats should be borne in mind. We believe these findings to be robust subject to reasonable uncertainty regarding external events, and the BEAR model earned such a reputation in the past. Still, it is always worth emphasizing that an economic forecasting model is not a crystal ball. Our model does not capture individual decision-making, but simulates the behavior of representative agents subject to generic changes in the economic environment. The real world is full of heterogeneity and complex events beyond the ken of modelers, particularly over a time horizon as long as 15 years.

More research is needed to elucidate this important equity issue, but meanwhile we see interesting dynamics in these adjustments. Across the diverse state economy, households have vehicles of differing ages and efficiency levels, but the aggregate fuel cost savings confer employment growth and fuel price benefits across the economy. The basic message of these results is simple, however, lower fuel expenditure saves household money, increases employment and real wages and incomes, whether individual households buy a new vehicle or not, but most so if they do.

2.4 Composition of Job Growth

While the overall state economy gains from the scenarios considered here, the composition of impacts is more complex. Beneath the smooth veneer of macroeconomic aggregates, pervasive structural changes can take place. In particular, aggregate benefits can mask tradeoffs between different stakeholder groups across the economy. In particular, transition to PEVs obviously challenges enterprises in the fossil fuel supply chain, as is plainly evident in Table 2.4.

These figures break down the aggregate employment results of Table 2.2 on a sector-by-sector basis. Employment impacts within sectors are measured as net job creation, while the last three rows present statewide sector aggregates that reveal patterns of aggregate job creation and reduction. What is perhaps most noteworthy is that only one in twenty sectors experiences employment growth below baseline trends, most prominently the fossil fuel sector (Oil & Gas). Because of the expenditure shifting process described in the last subsection, job creation in both scenarios outweighs job reduction by a factor of more than 10. These results strongly support the notion that, over two decades, deployment of PEVs in the light-duty vehicle market will benefit many more people than might miss opportunities in traditional energy intensive activities. The Oil & Gas sector does not lose jobs per se, but instead experiences slower job growth overall over a twenty-year timeframe under these scenarios.

Table 2.4: Employment Effects by Sector
(change from 2030 Baseline values in thousands of FTE jobs)

Sector	PEV15	PEV45
Agriculture	0	0
Other Primary	0	0
Oil and Gas	-2	-6
Electric Gen and Dist	1	3
Natural Gas Dist.	0	0
Other Utilities	0	0
Processed Food	0	0
Construction –- Residential	1	2
Construction –- NonRes	2	5
Light Industry	3	6
Heavy Industry	1	3
Machinery	0	0
Technology	2	4
Electronic Appliances	0	0
Automobiles and Parts	1	2
Trucks and Parts	0	0
Other Vehicles	0	1
Wholesale, Retail Trade	15	30
Transport Services	2	4
Other Services	23	45
Total Net Jobs	49	98
New Employment	51	104
Reduced Job Growth	-2	-6

Source: Authors' estimates.

An especially important feature of these results is the diversity of job creation. As explained in the discussion of expenditure diversion, PEV fuel cost savings creates jobs across the economy, not just in sectors making new vehicle technologies or substitute energy fuels. These jobs are in all categories of that enjoy greater demand because households and enterprises have more money to spend. Based on long established demand patterns, we know these will be mainly service and consumer sector jobs, in-state and not as vulnerable to outsourcing.

2.5 Household Level Impacts

The BEAR model maintains economic information on California households by income. These are divided into seven tax brackets as in Table 2.5, which details number and population by household group. For any state policy encouraging vehicle electrification, the equity implications of economic impacts will be an essential consideration.

Table 2.5: California Household by Income Tax Bracket

		Households	Population	Percent
1	**< $12k**	**1.220**	**3.575**	**10**
2	**$12-28k**	**2.360**	**6.915**	**19**
3	**$28-40k**	**1.650**	**4.835**	**13**
4	**$40-60k**	**2.110**	**6.182**	**17**
5	**$60-80k**	**1.650**	**4.835**	**13**
6	**$80-200k**	**2.140**	**9.2**	**25**
7	**$200k+**	**0.710**	**1.113**	**3**
	Total	**12.510**	**36.654**	**100**

Source: California Department of Finance. Numbers in thousands.

Table 2.6: Real Income Impacts by Household Income Group

	Household	ZEV15	ZEV45
1	**< $12k**	**0.2%**	**0.4%**
2	**$12-28k**	**0.2%**	**0.4%**
3	**$28-40k**	**0.2%**	**0.4%**
4	**$40-60k**	**0.2%**	**0.2%**
5	**$60-80k**	**0.2%**	**0.2%**
6	**$80-200k**	**0.2%**	**0.2%**
7	**$200k+**	**0.1%**	**0.2%**
	Average	**0.2%**	**0.4%**

Source: Authors' estimates. Percentage changes from 2030 Baseline, average real household income.

For the two alternative deployment scenarios, Table 2.6 shows real income effects. Two aspects of these estimates are worthy of emphasis. Firstly, all income groups benefit from these deployment scenarios, regardless of who buys new vehicle types or their income levels. This is because the spillover effects of improved vehicle efficiency are widespread, creating jobs across nearly every sector of the economy and raising average real wages.

Moreover, even though most market research suggests that higher-income groups will have higher PEV adoption rates, at least initially, the largest relative income benefits accrue to lower income groups (2, 3, and 4). This again is a result of spillover effects that transmit higher-income consumption effects to lower-income income/employment benefits.

3 Plug-in Electric Vehicle Adoption: Costs and Benefits

Although this study emphasized the economy-wide benefits of PEV deployment, including extensive indirect benefits from household expenditure shifting and structural adjustment, the fuel cost savings effects generally begin at the microeconomic level. Individual economic agents are assumed to make technology adoption and use decisions based on perception of costs and benefits that will accrue to them personally, their household, or their enterprise. These direct effects are a primary driver of market-oriented technology diffusion as well as the main target of policies that seek to influence adoption behavior, including standards, incentives, and fees.

Vehicle technology costs and benefits are primary drivers of the economic impacts of PEV deployment, and thus are the subject of intensive research and discussion. Our comprehensive review of the research literature reveals a range in estimates of both user costs and benefits, with attendant controversy that is predictable both in scope and orientation. To more effectively support public discussion of its own policies, EPA, NTHSA, and CARB have been working individually and in concert to improve this evidence. Their results, summarized by Lutsey (2010), also reflect extensive consultations with vehicle and energy sector participants. Generally speaking, these estimates suggest that under existing price expectations, government adoption incentives, and historically defensible technology assumptions, PEVs are very sound individual investments, yielding positive returns over vehicle lifetimes that aggregate to higher real incomes for the state economy.

BEAR is a model of the overall economy, but it does not detail vehicle costs and benefits at the individual level, especially with respect to emerging technologies and vehicle diversity. To calibrate this component of our estimation procedure, we created a detailed spreadsheet model of incremental vehicle cost (IVC). This entailed collection and synthesis of the most up-to-date information on available present and future vehicle technologies, a wide range of analysis and assumptions regarding ownership and use behavior, and assumptions about forward market conditions. The entire IVC spreadsheet is fully documented elsewhere, but we summarize its main characteristics and findings below.

3.1 Vehicle Technologies

Would be car buyers have by an ever-expanding array of model choices, both in Internal Combustion Engine (ICE) and PEV technologies, with each passing year. Because this analysis is macroeconomic, it is impractical to track all these alternatives individually. Still, vehicle heterogeneity is a primary determinant of the outcomes being considered, and we need to specify at least enough vehicle diversity to capture this. To that end, we consider representative ICE category each for cars and light trucks, reflecting average performance characteristics over the period considered (2012-2030). The fuel economy is modeled to improve significantly over time with new, ICE passenger cars achieving close to 45 miles per gallon (real world) and new, ICE passenger light trucks achieving 32 miles per gallon by model year 2025, consistent with the joint rulemaking between the U.S. Environmental Protection Agency and the U.S. National Highway Traffic Safety Administration.[9] This representative vehicle type is assumed to consume a blend of gasoline and diesel reflecting the shares of both fuel types in the light vehicle market. In addition to this, for both cars and light trucks we consider three PEV categories, PHEV20, PHEV40, and BEV100.[10] While there are more and more sub varieties appearing on the market, we believe these three capture the essential heterogeneity of the PEV fleet.

1. [9] U.S. EPA and U.S. DOT, November 2011, "Draft Regulatory Impact Analysis: Proposed Rulemaking for 2017 and 2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards" www.**epa**.gov/oms/climate/documents/**420d11004**.pdf

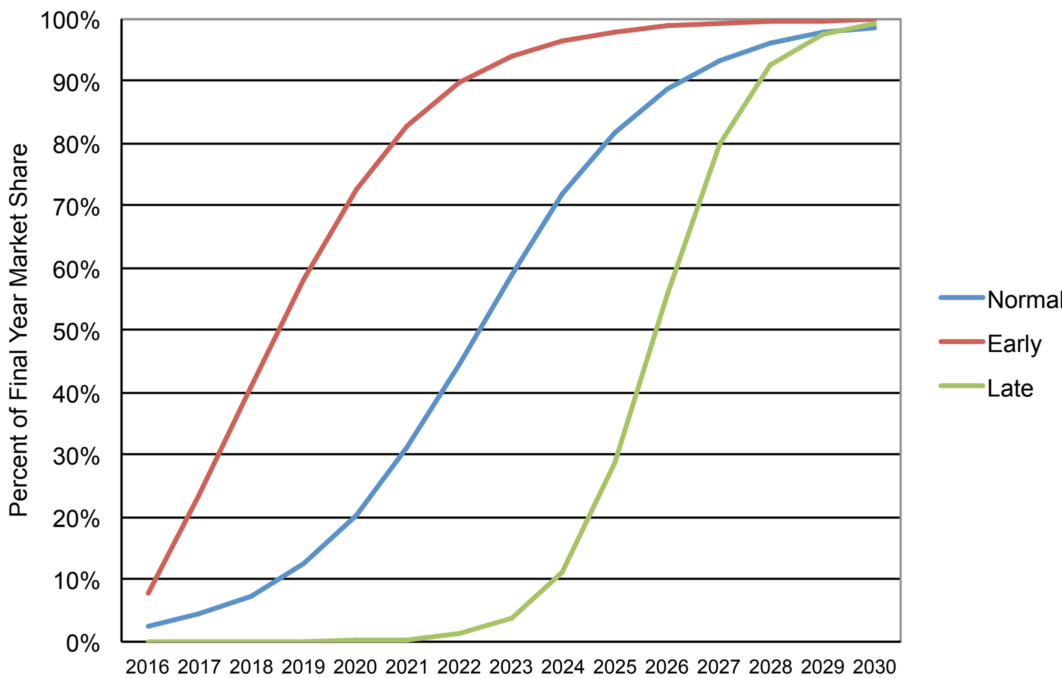
[10] In these acronyms, letters refer to the engine technology (PHEV = plug-in hybrid electric vehicle, BEV = Battery powered electric vehicle) and numbers represent the percentage of total driving distance on electric-only power.

3.2 Adoption and Use Behavior

3.2.1 Demand Growth

As was emphasized in the scenario section above, we do not model vehicle demand or adoption at the individual owner level. This is a very interesting area of behavioral research, but our goal in the present study is to estimate the impacts of policy scenarios that assume a given pattern of adoption, specified in terms of target sales or market shares in the terminal year 2030. In addition to this, we have calibrated our baseline PEV demand shares to match CARB estimates for 2015. Between this year and the 2030 target, we interpolate demand using a logistic function, the standard profile for technology adoption studies.

Figure 3.1: Schematic Technology Adoption Patterns



As Figure 3.1 indicates, adoption patterns can be accelerated (Early), as with fashionable consumer goods, or more gradual (Late), where significant learning might be required for adoption. For PEV deployment to reach the scenario market share targets, we assume a median case (Normal) that is typical of most successful automotive technology.

3.2.2 Fleet Composition

We considered six generic PEV vehicle types, cars and light trucks in three electric power categories, assuming long term market shares given in the following table:

Table 3.1: Assumed Shares of New PEV Sales

PEV Passenger Cars (by tech type)	
PHEV20	33%
PHEV40	33%
BEV100	33%
PEV Light Trucks (by tech type)	
PHEV20	50%
PHEV40	30%
BEV100	20%

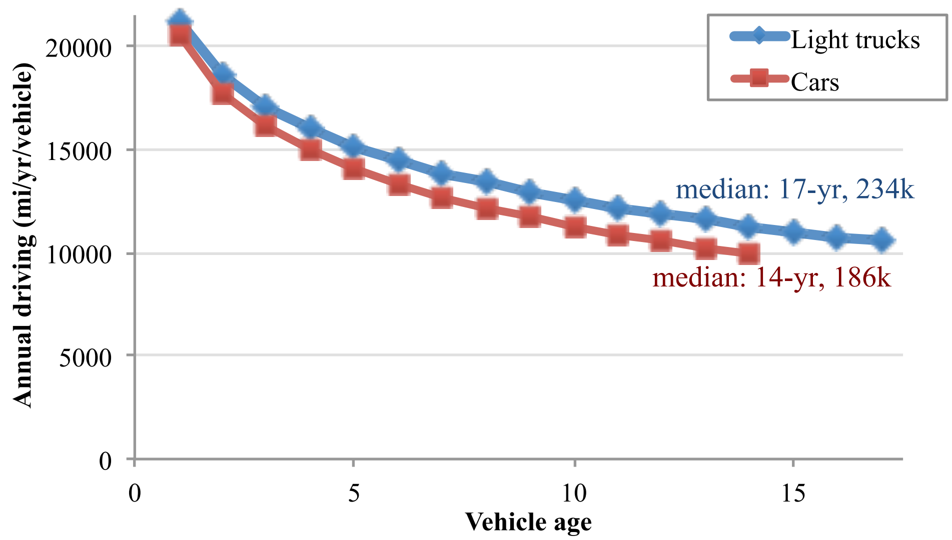
Having little reliable empirical evidence on the forward composition of this market, we chose fairly generic shares to capture diversity of the fleet. Depending on fuel price and innovation trends, more efficient vehicles could be expected gain larger market share.

3.2.3 Vehicle Miles Traveled

Costs of vehicle operation, particularly fuel costs and savings from PEVs, depend significantly on vehicle use levels, of which Vehicle Miles Traveled (VMT) is the primary indicator. Actual VMT vary with a myriad of vehicle and user characteristics, but for practical purposes we rely on averages from CARB (Figure 3.2) implemented for each model year and over the life of all vehicles sold in each model year.

Generally speaking, VMT will also vary with model of car or light truck, but we rely on averages for the current estimates. Some evidence suggested that the early PEVs were being driven fewer VMT than average for ICE models, but we assume this will change as the PEV fleet increases its market share and battery technology improves.

Figure 3.2: Light Vehicle Miles Traveled

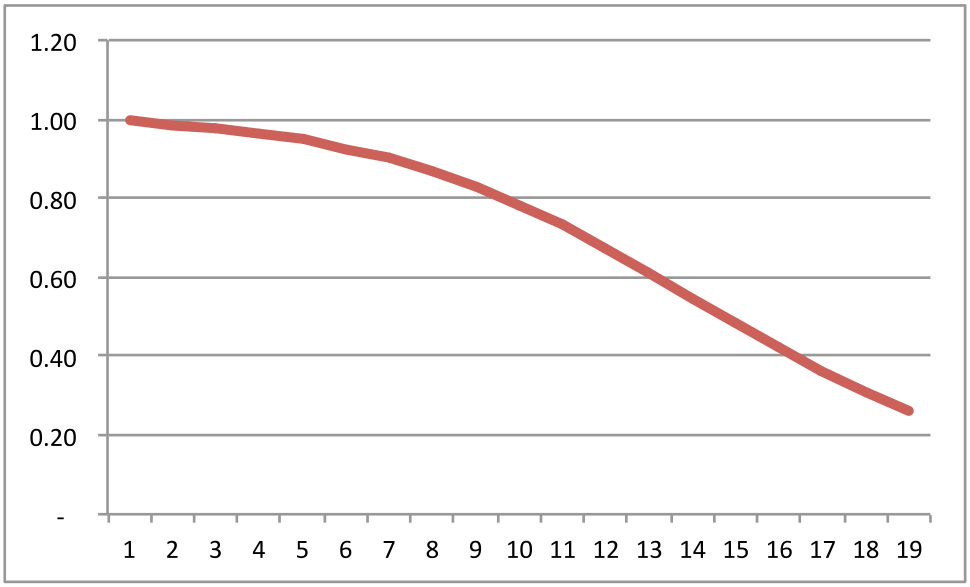


Source: CARB (2008).

3.2.4 Survival

Vehicle life expectancy varies with technology and driving conditions. To model this component of fleet turnover, we assumed survival rates for each model year followed trends published by the National Highway Transportation and Safety Authority and summarized in the figure below.

Figure 3.4: Light Vehicle Average Survival Rates



Source: NHTSA (2006)

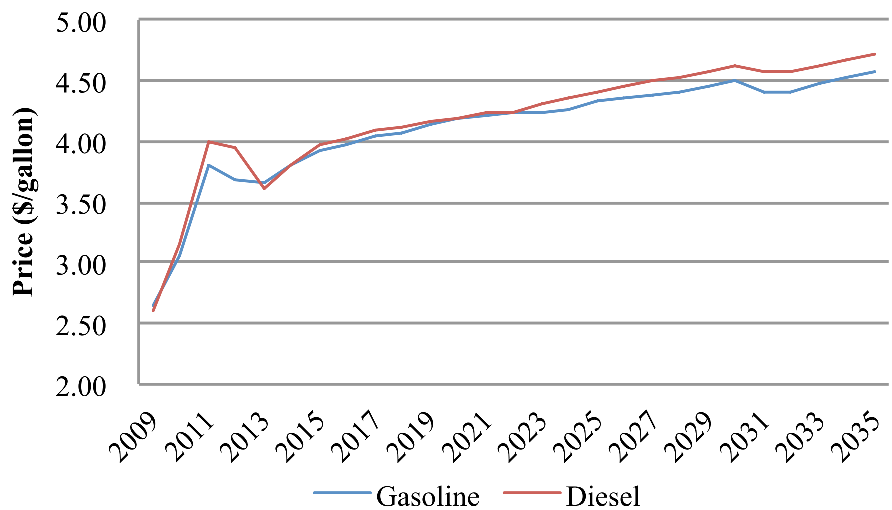
3.2.5 Financing

The overwhelming majority of new light vehicle sales include financing (90% according to the National Automobile Dealers Association, NADA:2008). In the context of PEV adoption, these options are quite important because it gives buyers the option to pay for their vehicle in significant part with fuel savings enjoyed after purchase. To capture this, we assumed a relatively simple finance model, allowing buyers of PEVs to pay the full cost of their vehicles in equal installments over five years, inclusive of a 5% APR premium. This interest rate is relatively conservative by the standards of recent years.

3.3 Energy Costs

The two primary energy sources relevant to our analysis are liquid transportation fuels and electric power. In the transport category, the primary fuels are gasoline and diesel. We assume global energy markets are independent of our policy scenarios, and that they drive national fuel prices according to trends set forth in the EIA's Annual Energy Outlook (early release, 2012). California fuel prices are further assumed to follow their historical pattern of being higher than national average prices, and the resulting baseline California prices are presented in Figure 3.5 below.

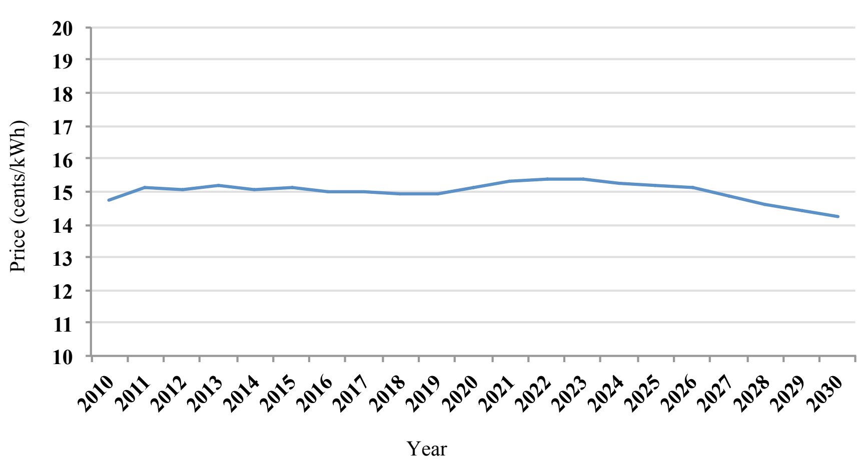
Figure 3.5: Forecast California Gasoline and Diesel Prices



Source: EIA (2012)

For electric power price trends over the period considered, we rely on a combination of EIA data forecasting Pacific region and California electricity prices. The resulting baseline trend is illustrated in Figure 3.6.

Figure 3.6: Baseline California Retail Electricity Prices



Source: EIA

3.4 Vehicle Costs

Our assumptions regarding vehicles explicitly recognize innovation processes and changing vehicle standards over the time period considered. To this end, we assume that ICE vehicles attain higher average mpg in accordance with EPA and NHTSA's National Program harmonizing greenhouse gas and fuel economy standards, and that conformity with these confers incremental costs for ICE vehicles. We utilize EPA and NHTSA's incremental cost estimates of $2,811 for MY2025 passenger cars and $3,052 for MY2025 passenger trucks versus today's new vehicles. For PEV vehicles, we built our IVC estimates from the bottom up, using the most up-to-date electric vehicle technology data available.[11]

Batteries are a primary cost component in all PEVs, and here we have assumed steady but moderate progress or "learning" in this technology. Estimation of battery costs was based on the projections by McKinsey and Company (2012). The usable state of charge window was adjusted from a fixed value of 70% to values of 60% for the PHEV10, 70% for the PHEV40, and 90% for the BEV100 to reflect the different usage characteristics of each vehicle type. Battery costs were scaled by 1.5 for the PHEV10 and 1.3 for the PHEV40 to reflect the increased costs to meet power requirements with smaller batteries (EPRI estimates). An indirect cost multiplier (ICM) of 1.5 was used to mark-up the direct costs to retail. ICMs generally account for indirect costs such as research and development, overhead, dealer markup, warranty, and dealer profit as documented by EPA (2009), NAS (2011), and CARB (2012). Component costs for PEVs were based on the U.S. Environmental Protection Agency and National Transportation Highway Safety Association regulatory impact analysis. We believe the ICMs and component mark ups utilized in the report are conservative. The result, as indicated in Figure 3.7, is a cost/efficiency improvement of about 80% over the next two decades.[12]

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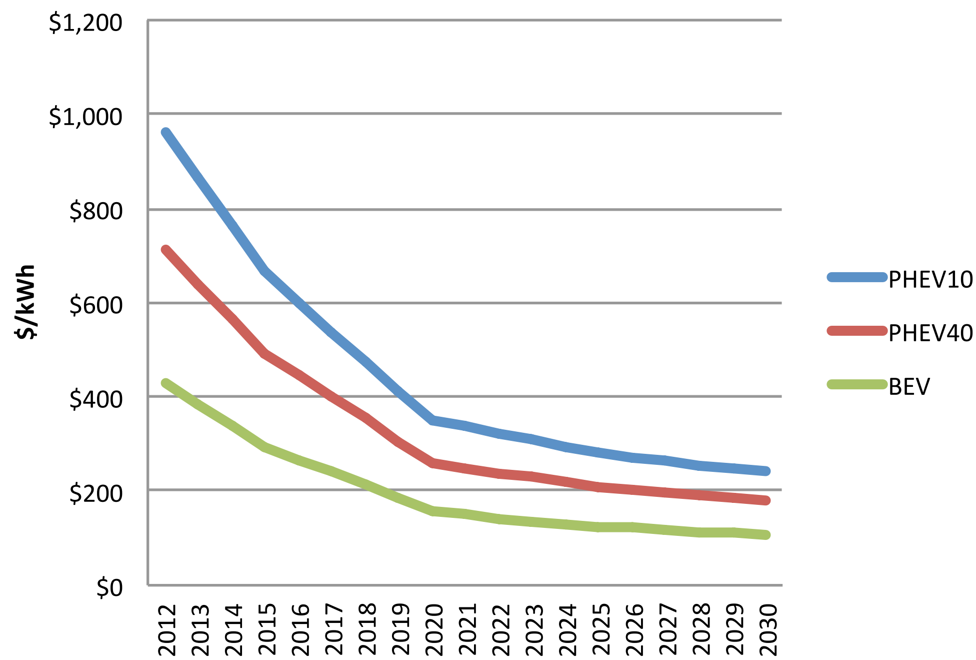
[11] National Program Phase 2 (MY2016-MY2025), EPA/NHTSA (2011) Proposed Rules, December 1, 2011, http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf, page 44. National Program Phase 1(MY2012-2016), http://www.gpo.gov/fdsys/pkg/FR-2010-05-07/pdf/2010-8159.pdf, p26.

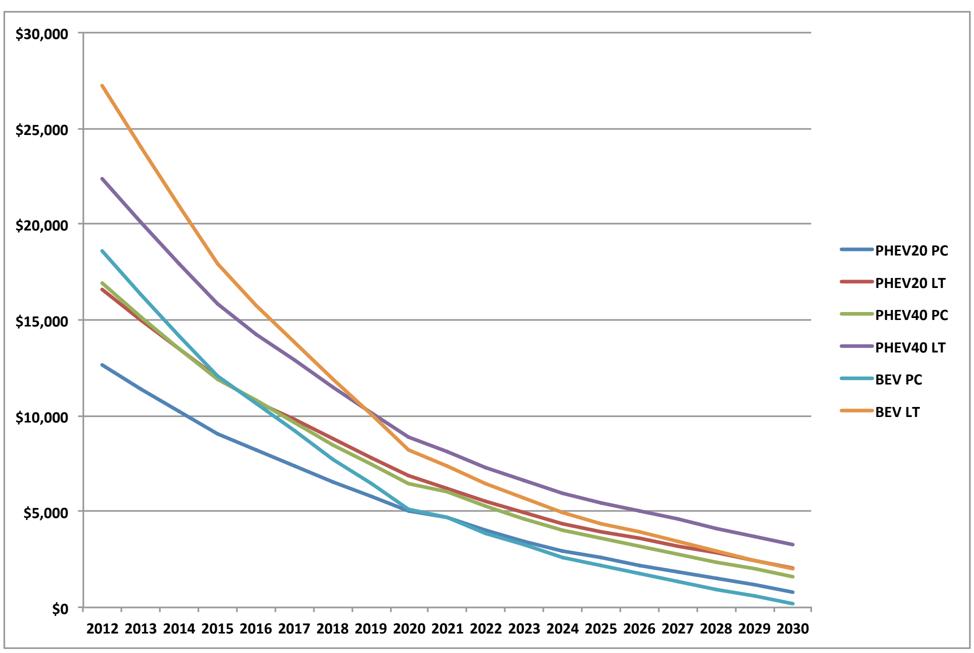
[12] The complete calculations are fully documented elsewhere, and can be made available up request.

Figure 3.7: Battery Cost/Efficiency, by Vehicle Type



Source: McKinsey: 2012.

Figure 3.8: Incremental Vehicle Costs, by Vehicle Type



Sources: McKinsey, EPA, CARB, EPRI

After a review of the vehicle engineering literature and consultation with experts in this field, we have estimated incremental vehicle cost for PEVs using these battery cost profiles and a 30% mark-up on other power and drivetrain components. The resulting IVC trends for our analysis are summarized in Figure 3.8 for the six PEV vehicle types in out analysis (PC=passenger car, LT=light truck).

3.5 Policy Components

3.5.1 Incentives

Because of both state and Federal commitments to vehicle electrification, a variety of financial incentives exist for individual who adopt PEV vehicles. We have incorporated current incentive schemes on a uniform average basis into our IVC model, and assume these are not renewed beyond 2020. In the BEAR model, the cost of fiscal incentives, in terms of foregone income/expenditure elsewhere in the economy, is fully accounted. The macroeconomic impact results in Section 2 are thus net of these transfer effects.

3.5.2 LCFS Credits

PEV owners are contributing to global greenhouse mitigation by reducing carbon fuel consumption. Under California's Low Carbon Fuel Standard (LCFS) regulations, providers of electricity as a fuel are required to return value derived from the sale of LCFS credits to PEV drivers. We have incorporated these credits into the net IVC calculations using CARB formulas for vehicle efficiency and emissions factors. CARB estimates that LCFS credit value to be between$15 and $50 per metric tonne of CO2 displaced, so we used the average ($32.50) for our calculations.

3.6 Aggregate Trends

Taking all the market, technology, and behavioral information discussed above, our IVC model calculated net economic returns to PEV deployment in both the PEV15 and PEV45 scenarios. The overall aggregate trends for IVC components are given in Figures 3.8 and 3.9 below, showing a strong positive dividend for those who adopt these vehicles, as well as support for the industries developing, selling, and maintaining them. By 2030, PEV vehicles are saving

California households over $1.5 billion per year, with cumulative savings since 2012 of over $6 billion. Under the 45% deployment scenario (PEV45) annual savings by 2030 are over $3.5 billion and cumulative household savings exceed $13 billion. With positive net savings (green trend) in nearly every year considered, electric vehicles represent a long-term stimulus package for the state economy.

A few notes on these figures are in order. Firstly, they represent aggregate private costs and benefits of PEV vehicles. For individual buyers, financing defers costs over five years, while their incentive payments accrue upon purchase. LCFS credits accrue over the useful life of their vehicles. From an aggregate perspective, positive private net benefits are strongly supported in later years by legacy adoption (fuel savings), but individual owners will face net costs upon purchase and have to overcome these in later years of ownership.

Figure 3.8: Aggregate Incremental Costs and Benefits of Electric Vehicle Deployment – PEV15 (millions of 2012 dollars)

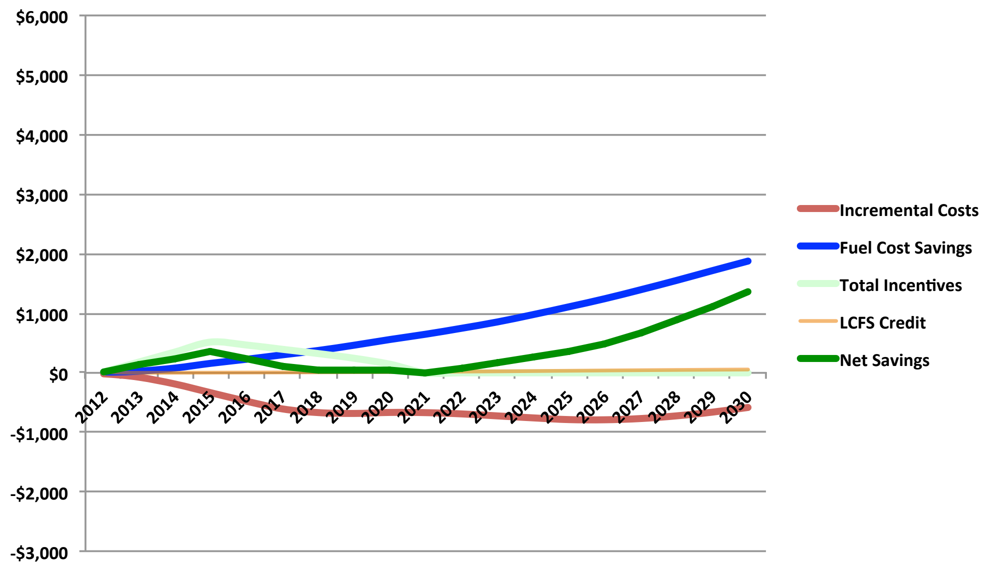
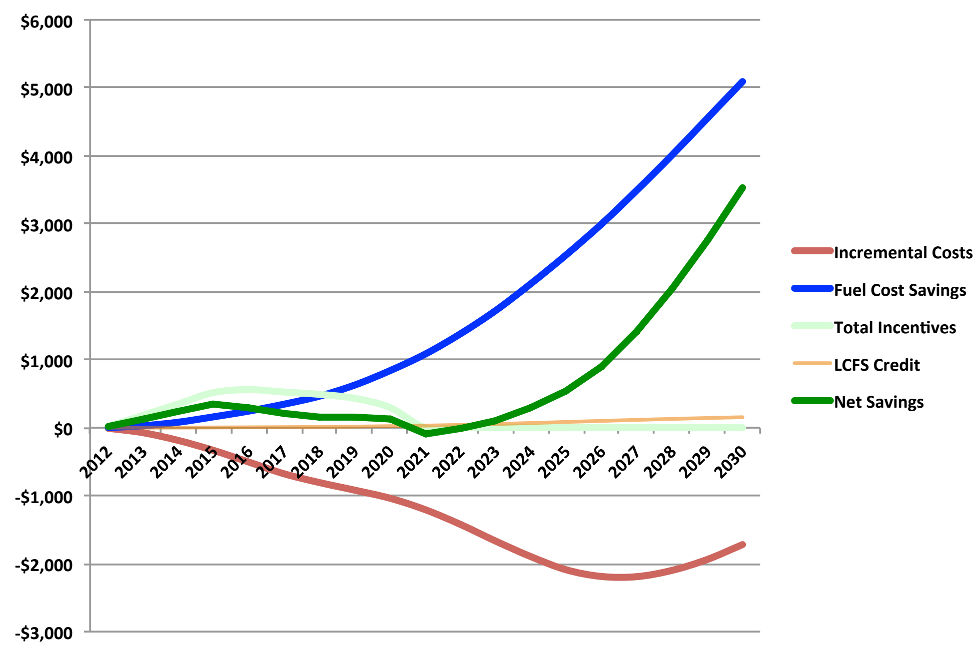


Figure 3.9: Aggregate Incremental Costs and Benefits of Electric Vehicle Deployment – PEV45 (millions of 2012 dollars)



Finally, we do not include public benefits here, such as the macroeconomic stimulus impacts presented in Section 2 above. In addition to individual financial benefits from fuel cost savings, large-scale adoption creates general equilibrium, or spillover benefits across the state economy. These take two primary forms, the expenditure shifting benefits already discussed, and cost-of-living benefits from reduced conventional energy demand. The second benefits results from the fact that, taken together, individual efficiency choices reduce aggregate energy demand and exert downward pressure on energy prices. For a small economy, these might not affect national or global energy markets, but because California comprises 11% of US GDP and is itself the nineth largest economy in the world, substantial changes in California energy fuel demand certainly will affect both national and global prices (although we do not consider the latter in this analysis).

Also, this analysis does not predict detailed adoption patterns, e.g. which income groups will adopt which vehicles, and thus assume that new vehicles are dispersed uniformly across the population. This means that we are probably underestimating the efficiency gains for high-income groups and overestimating them for others. In any case, it is clear from the patterns of employment creation that lower income groups reap indirect benefits of aggregate energy efficiency.

Finally, even though perceived economic costs and benefits are influential, however, they are by no means the only, or even in many cases the decisive, factors in vehicle adoption choice. A large and growing body of evidence makes it clear that consumers choose durable goods generally, and vehicles in particular, based on a range of subjective factors including individual and social identity style, and performance characteristics. Because they represent a dramatically different emergent technology, PEVs evoke quite complex responses, only some of which are of direct relevance to net cost of adoption. Innovative research by Turrentine and collaborators (e.g. McCarthy et al: 2010, Kurani et al: 2008, and Heffner et al: 2008) all suggest that there is significant willingness to pay for qualitative characteristics in this vehicle category. This evidence helps explain why, regardless of relatively high initial adoption and uncertain operating costs, PEVs are enjoying rapid acceptance in certain demographic and geographic markets. In any case, as emphasized in the previous section, we do not model adoption behavior endogenously, but assume vehicle deployments correspond to the scenarios as defined.

4 Conclusions

Using a long-term economic forecasting model that details patterns of vehicle ownership and use across the state, this report evaluated alternative scenarios for accelerated deployment of plug-in electric vehicles (PEVs). In each case, PEV deployment translated into new demand for more job intensive goods and services, most of which were in sectors with less import dependence and more extensive in-state multiplier linkages. New vehicle adoption and fuel cost savings result in expenditure shifting, moving household and enterprise demand from the carbon fuel supply chain to demand-induced income and job creation across a broad spectrum of local activities and local jobs.

For these reasons, accelerated PEV deployment can be a catalyst for economic growth. Because, on average, household demand is 16 times more job intensive than the fossil fuel supply chain, every dollar saved at the gas pump and spent on the other goods and services consumers want adds stimulus to state incomes, employment, and real wages.

These results also support the conclusion that fuel cost savings confer economic security against volatile energy prices.[13] An economy the size of California's can affect energy prices modestly, but larger trends are outside our control. The smaller the share of energy costs in personal and commercial transport services, the less vulnerable we are to adverse income and profitability shocks from energy prices.

It must be noted that, although fuel cost savings promote growth and energy security for the vast majority of Californians, there are of course some actors linked to the fossil fuel supply chain that will be adversely affected – in the form of slower industry job growth -- by fuel cost savings. Since indirect economic benefits far outweigh these direct costs, temporary adjustment assistance could be considered to gain support in helping the state realize our efficiency potential, and it could be a small price to pay for the lasting benefits of transition to a diverse transportation fuels sector, particularly a transition towards greater deployment of PEVs.

The apparent importance of PEV deployment to the state's long-term economic growth suggests that this research should be extended in the future. Of particular relevance would be more

[13] Many researchers have made this argument, most recently and forcefully Fine, Busch, and Garderet (2010).

extensive analysis of program design: incentive policies, vehicle adoption patterns, and welfare effects.

5 Acronyms Used

AB32	California Assembly Bill No. 32
BEAR	Berkeley Energy and Resources (model)
BEV	Battery Powered Electric Vehicle
CAFÉ	Corporate Average Fuel Efficiency standard
CalEPA	California Environmental Protection Agency
CARB	California Air Resources Board
CO2	Carbon Dioxide
EIA	U.S. Energy Information Administration
EPA	United States Environmental Protection Agency
EPRI	Electric Power Research Institute
FTE	Full-time Equivalent, one full-time worker year
GHG	Greenhouse Gases
GSP	Gross State Product
ICE	Internal Combustion Engine
ICM	Indirect Cost Multiplier
IVC	Incremental Vehicle Cost
LCFS	Low Carbon Fuel Standard
MPG	Miles Per Gallon
MT	Metric Tonne
MY	Model Year
NADA	National Automobile Dealers Association
NAS	National Academy of Sciences
NTHSA	National Transportation and Highway Safety Administration
PEV	Plug-in Electric Vehicle
PHEV	Plugin Electric Hybrid Vehicle
PHEV20, 40, 100	PHEV with 20%, 40% , or 100% of total driving on electric power
VMT	Vehicle Miles Travelled
ZEV15	Policy scenario for 15% ZEV in 2025 new vehicle sales
ZEV45	Policy scenario for 45% ZEV in 2025 new vehicle sales

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