Colorado Public Utilities Commission

Docket No. 11I-704EG

Comments of Southwest Energy Efficiency Project

Exhibit 3

ELECTRIC VEHICLES CAN BUFFER COLORADO FROM THE ECONOMIC SHOCKS OF RISING FUEL PRICES, CREATE JOBS AND REDUCE POLLUTION CONTROL COSTS

Southwest Energy Efficiency Project
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October 21, 2011

Rising Petroleum Fuel Prices Will Have Significant Adverse Impact on Colorado's Economy.

In Colorado, the average nominal retail gasoline price has risen by 32% over the last year, from $2.65 per gallon in October 2010 to $3.50 per gallon in October 2011 (in real 2009 dollars). According to the federal Energy Information Administration's (EIA) High Oil Price Scenario, prices will increase by another 45% to $5.10 per gallon in 2020 and 57% to $5.52 in 2030, compared to $3.83 by 2030 in the EIA's Reference Case Scenario (see dotted and dashed lines in Figure 1).[1] Given that 2011 prices are now equal to the EIA's reference case price estimate for 2020 ($3.51), the High Price scenario is likely a more realistic estimate of future fuel prices.

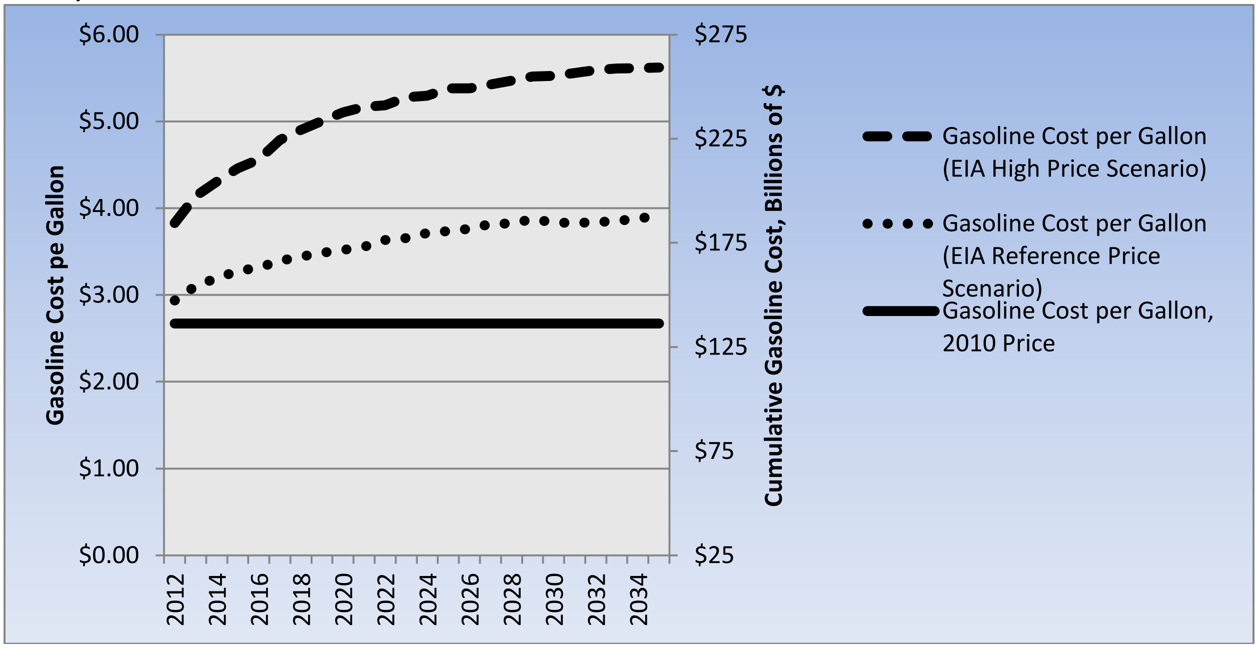
At these prices, the annual cost of gasoline to the statewide economy will rise from $5.5 billion in 2010, to between $8.4 and $11.5 billion (in real 2009 dollars) in 2035 depending on the price of gasoline.[2] Assuming the EIA price scenarios, cumulative gasoline costs for the state are expected to range between $186 and $258 billion for the period from 2012 and 2035. This is compared to a cumulative fuel cost of $138 billion over the same period if gasoline prices were to remain at 2010 levels. This projected near doubling of the cost of transportation fuels will impose a significant negative impact on the State's economy, unless petroleum fuels in the transport sector can be replaced with less expensive alternative fuels.

Figure 1 shows both the expected increase in gasoline prices over the next 25 years and the expected

[1] The EIA provides a reference price and a high price scenario for gasoline costs. The current gasoline price, $3.50 per gallon, is near the high price scenario for 2012 and the reference price scenario for 2020, indicating that the high price scenario for gasoline is a more likely estimation of the future price of gasoline.
[2] Estimated fuel consumption in 2035 assumes 1) that population grows at rates forecast by the Colorado State Demography Office, 2) that annual VMT per vehicle increases from 10,900 in 2011 to 14,000 in 2035, and 3) that fuel efficiency for gasoline vehicles will be at the average level required to meet current federal fuel efficiency standards, which are estimated at 54 mpg by 2025. If VMT per vehicle is held constant at 2011 level, annual gasoline expenditures in 2035 would be $8.9 billion under the high price gasoline scenario.

cumulative cost of gasoline to the state over this time period. The three lines represent three different scenarios for the price of gasoline (left side axis) which show how much would be spent cumulatively in each scenario (right side axis) by 2035.

Figure 1. EIA Estimated Gasoline Price per Gallon and Cumulative Fuel Costs for Colorado (constant 2009 $): 2012-2035



As a result of the anticipated rise in driving costs, families will be required to pay an increasing share of household income for transportation. In response to these higher transportation costs, households will reduce spending on other goods and services, and reduce the discretionary miles they drive. Together, less disposable income and less willingness to drive will negatively impact economic activity in the State. In addition, much of the economic resources spent on motor fuels will leave the State and not contribute significantly to economic activity in the State. A report by Next 10 found that fuel savings are spent on local goods and services and have a strong multiplier effect, creating more jobs than are displaced.[3]

Colorado Can Buffer its Economy from Impacts of Petroleum Fuel Price Shocks by Promoting Alternatives to Petroleum-Powered Transportation.

Petroleum prices are determined by global market forces that can no longer be controlled by the United States. Economic growth in developing nations has increased global demand for personal vehicles and petroleum fuels. In 2009, China replaced the U.S. as the largest market for motor vehicles. Vehicle sales in China alone are expected to exceed 20 million units in 2011, nearly double expected U.S. sales. In China 20 of every 1,000 people own a vehicle, and in India ownership is 8 per 1,000, compared to nearly 800 vehicles per 1,000 people in the U.S. Almost all vehicles purchased in Asia are replacing bicycles and mopeds, adding more vehicles to the highway and driving up global demand for petroleum fuels. In the U.S. 19 of 20 new vehicles are replacing existing vehicles. Because of more stringent national fuel efficiency standards, new vehicles sold in the U.S. use less fuel than the vehicles they replace. U.S. demand for petroleum fuels has stabilized. But global long-term factors are driving both higher demand

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[3] Roland-Holst, D. (2011, May). How Fuel Economy and Emissions Standards Will Impact Economic Growth and Job Creation. Retrieved from http://next10.org/next10/publications/vehicle_efficiency.html

and prices for petroleum fuels.

The economies of U.S. States and metropolitan areas need not be victimized by global forces if actions are taken to buffer these impacts by reducing dependence on petroleum fuels.

U.S. states and metropolitan regions that promote alternatives to petroleum powered transport will develop an economic advantage over areas that remain primarily dependent on oil for their transportation needs. By investing today in alternative modes of travel and locally produced domestic sources of energy for motor vehicles, decision makers will lay the groundwork for substantial economic benefits over the next 25 years. States and metropolitan regions that make these investments will buffer their economies from the adverse economic shocks of expected increases in the global price of petroleum fuels.

Transportation is the second largest cost in the family budget after housing. In April 2011, the average Colorado resident was estimated to spend 5.5% of his/her annual income ($2,352) on gasoline.[4] For a family with two cars, this cost is nearly doubled. For low income families, this cost is a significantly larger share of the family budget. The percentage of fuel cost as a share of the family budget will increase as fuel prices rise faster than the inflation rate for all goods and services. At the gasoline prices estimated by EIA, families will pay $8,000 or more annually for gasoline by 2035.

By adopting policies that reduce petroleum consumption, Colorado will benefit economically by retaining greater financial resources in the State's economy. Currently, Colorado produces enough oil to satisfy approximately one-third of its consumption.[5] By replacing petroleum consumption with local sources of energy less money will be spent on imported fuel and more money will remain in the state's economy both to produce the energy locally, and because the cost of locally produced fuel is less. Most funds not spent on importing fuel are expected to remain in the local economy to be spent on food, housing, entertainment, education and other goods and services which will, in turn, generate employment opportunities. Reducing oil consumption for transportation will also reduce the United States' dependence on imported petroleum and strengthen our national energy security.

Replacement of Gasoline Vehicles with Plug-in Electric Vehicles is the Most Available Option for Reducing Petroleum Dependence.

SWEEP considered three options for reducing petroleum dependence in Colorado: 1) plug-in electric vehicles (PEVs), 2) natural gas vehicles, and 3) increased domestic petroleum production. PEVs are the best available option for a number of reasons.

First, the state is not a net petroleum producer, and cannot protect its economy from global price increases by expanding local petroleum production. Second, even if the U.S. were to expand domestic petroleum production by 20% (a very aggressive target) from 10 to 12 million barrels/day, these additional 2 million barrels/day would not be enough to offset demand growth in developing economies, and would have little impact on oil price in a global market where 89 million barrels/day are now consumed. Aggressive policies to increase U.S. domestic production will not protect U.S. consumers from future global petroleum market price shocks.

Second, consumers have no choice but to buy only one natural gas light duty vehicle offered by an original

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[4] Natural Resources Defense Council. (2011). Fighting Oil Addiction: Ranking States' Gasoline Price Vulnerability and Solutions for Change. Retrieved from http://www.nrdc.org/energy/states/files/Oil_Vulnerability_May_2011.pdf, Table 2.

[5] In 2009, Colorado produced 28.3 million barrels of oil and consumed 89.8 million barrels. See http://www.eia.gov/state/state-energy-profiles.cfm?sid=CO.

equipment manufacturer in the U.S.[6] Consumers will soon be able to choose from as many as 55 models of PEVs that are expected on the market by 2015.[7] Manufacturer commitments to produce PEVs are driven, in part, by the requirement in California's clean car standards requiring that original equipment manufacturers achieve minimum sales targets for "zero emission vehicles" (ZEVs). This program is also in effect in eleven other states. Together with California, these states comprise nearly one-third of the U.S. vehicle market. All major vehicle manufacturers are marketing PEVs to meet ZEV sales targets in these states. This is one reason why Nissan and Chevy dealers have not previously been able to offer the Leaf and Volt in Colorado.

Third, consumers are reluctant to invest in natural gas vehicles because few fueling stations exist, and access to fuel is not convenient. By comparison, virtually every home has access to the power grid. EVs can be charged from standard 110 volt outlets, or from higher voltage charging stations with faster charging times. Charging units are easy to install for most homeowners. Garages are not needed. Charging stations can be installed wherever a vehicle is routinely parked.

For these reasons, and the air quality and GHG emission benefits demonstrated in Exhibit 2: "Ozone Precursor and GHG Emissions from Light Duty Vehicles: Comparing Electricity and Natural Gas as Transportation Fuels," SWEEP asks the PUC to focus primary attention on the benefits to the Colorado economy from fuel cost savings, and the net reduction in transportation costs to families that can be achieved from the lower life-cycle costs of owning and operating PEVs compared to vehicles fueled only by gasoline or by natural gas.

Economic Benefits of Replacing Gasoline Vehicles with PEVs.

Both the reduction in family transportation costs and the statewide economic benefits of increasing the share of light duty vehicles that operate on batteries powered from the electric power grid are large. Taking into account both the savings that result from using locally generated electricity instead of petroleum as the energy source, and the incremental capital cost of purchasing a battery operated vehicle, the incremental net benefits to the state (compared to the baseline cost of gasoline vehicles) will range from $1.1 billion to $10.4 billion between now and 2035, depending on the price of gasoline and the penetration rate of electric powered vehicles. In addition, fuel savings that are reinvested in Colorado's economy will create thousands of local jobs.

Fuel Cost Savings.

Electric vehicles' achieve significant reductions in fuel costs both because electric motors use less energy, and because the electricity used to power a vehicle costs nearly 2/3 less per mile driven than petroleum fuels. Electric motors use energy more efficiently than gasoline-powered internal combustion engines. Electric powered vehicles can cover the same distance as gasoline powered vehicles using between 35% and 60% less energy (measured in BTUs), depending on the efficiency of the source generating the electricity.

Pure electric vehicles (EVs) operate entirely on power from the grid. Plug-in hybrid EVs (PHEVs) operate on battery power until the battery is empty (PHEV-10s have a 10 mile electric range and PHEV-40s have a 40 mile electric range), and then switch to liquid fuel. Both pure EVs and hybrid PEVs reduce gasoline consumption and will provide significant savings to drivers by reducing fuel costs and overall lifecycle vehicle costs.

At the current average residential electricity price ($0.095 per kwh) in the Xcel service area,[8] compared to an average new gasoline powered passenger vehicle, an EV driver in Colorado will spend $1.08 on

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[6] Honda Civic.

[7] Citi. (2011, February 23). Electric Vehicles: Perspectives on a Growing Investment Theme. Retrieved from http://www.ceres.org/resources/reports/electric-vehicles-report

[8] http://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/psco_elec_entire_tariff.pdf.

electricity to travel the same distance covered by a gallon of gasoline (32.3 miles).[9] If time of use rates for nighttime charging were set moderately above the average cost of production, the rate would be near half the current residential kwh charge ($0.0485 per kwh). If EV owners were allowed an off-peak rate at half of the residential rate, the cost per gallon-equivalent of electricity would be $0.55.[10] The driver of a CNG vehicle would spend $1.02 on natural gas to travel 32.3 miles.[11] At current electricity, natural gas and gasoline prices, both an electric and a CNG vehicle driver travelling 11,000 miles/year would each save around $900 annually in fuel costs compared to a gasoline vehicle. But if the PUC were to adopt time-of-use rates for off-peak nighttime EV charging at levels near half, or less, than the average residential rate (see the discussion of the proposed methodology for allocating system benefits in SWEEP's comments in response to the Commission's Docket Order), then the fuel cost for the average EV owner would be reduced to about $187 annually compared to a gasoline cost of nearly $1200 annually at the current price ($3.50/gallon). This fuel savings will increase year-by-year as petroleum prices rise faster than electricity prices.

During the average 15 year life of an EV, these energy savings will more than offset the additional cost of a battery powered vehicle. The average lifecycle benefit of an EV purchased in 2012 compared to a gasoline powered vehicle is between $16,390 and $25,092 depending on the cost of gasoline. For a CNG vehicle the lifecycle benefit is between $8,890 and $17,592. As gasoline prices are expected to increase at much greater rates than electricity and natural gas prices, electric and natural gas vehicles will achieve a significantly greater fuel price advantage in future years even as new gasoline powered light duty vehicles become more efficient due to the proposed federal fuel efficiency standard that will be fully in effect by 2025.

Table 1 shows the annual fuel cost savings of PEVs and a compressed natural gas (CNG) vehicle compared to an average new gasoline vehicle that achieves 32 mpg.

Table 1. Individual Vehicle Lifecycle Cost Benefits Compared to New Gasoline Vehicle

	Reference Fuel Price		**High Fuel Price**	
	Average Annual Fuel Cost Savings	Lifetime Net Benefits (15 years operation less incremental vehicle costs)	Average Annual Fuel Cost Savings	Lifetime Net Benefits (15 years operation less incremental vehicle costs)
Purchased in 2012[12]				
PHEV-10	$391	$3,776	$575	$7,384
PHEV-40	$886	$10,816	$1,284	$17,187
BEV	$1,095	$16,390	$1,639	$25,092
CNG	$931	$8,890	$1,475	$17,592
Purchased in 2016[13]				
PHEV-10	$347	$1,761	$525	$4,609
PHEV-40	$841	$1,171	$1,289	$8,340
BEV	$1,189	$10,354	$1,817	$20,401
CNG	$958	$9,329	$1,541	$18,658

[9] A new passenger vehicle has an estimated efficiency of 32.3 mpg. To travel 32.3 miles, an electric vehicle will require 11.33 kwh (32.3 mpg*.3508 kwh/mile) which will cost $1.08 (11.33 kwh * $0.095), based on Xcel's current residential rate.

[10] This price/kwh is the assumed cost of electricity for PEVs used for fuel cost calculations throughout this analysis.

[11] A CNG vehicle will require 163 cubic feet of natural gas (32.3/.19 miles per cubic foot) which will cost $1.05 (163 cubic feet*$0.006245). Based on Xcel's current gas residential rate, retrieved from: http://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/psco_gas_entire_tariff.pdf.

[12] Capital cost reduced by federal and state tax credits.

[13] Under current law, federal and state tax credits for PEVs would expire by mid-2016.

Table 4 and Figure 2 show the billions of dollars that the state could be expected to save in fuel costs under three different scenarios for the market penetration of PEVs over the next 25 years. The three Electric Vehicle Market Penetration Scenarios are --

1) expected minimum PEV sales from meeting the sales targets in California's new proposed Zero Emission Vehicle (ZEV) standard;
2) expected minimum PEV sales under markets influenced by aggressive marketing strategies undertaken by motor vehicle manufacturers; and
3) expected PEV sales if aggressive manufacturer marketing strategies were supported by public policies designed to provide direct market incentives such as tax credits and fee-bate programs, along with user benefits such as free or preferential parking at high traffic destinations (e.g., airports, sporting venues, and commercial facilities), access to HOV lanes, etc.

The estimated PEV sales in the state under each scenario, in addition to baseline estimates, in five selected years are shown in Table 2. Table 3 shows the total number of PEVs in Colorado.

Table 2. Annual PEV Sales Under Electrification Penetration Scenarios

	2015	2020	2025	2030	2035
Baseline	2,482	3,211	6,307	9,298	11,780
Baseline-High Oil Price	5,899	6,036	11,282	15,363	19,807
ZEV Proposal	4,914	20,436	33,281	37,133	40,372
Aggressive Marketing	5,899	25,941	61,236	97,604	133,409
Very Aggressive Marketing with Market Incentives and User Benefits	8,642	46,929	96,227	159,421	224,522

Table 3. Total PEVs in Light Duty Fleet Under Each Electrification Penetration Scenario

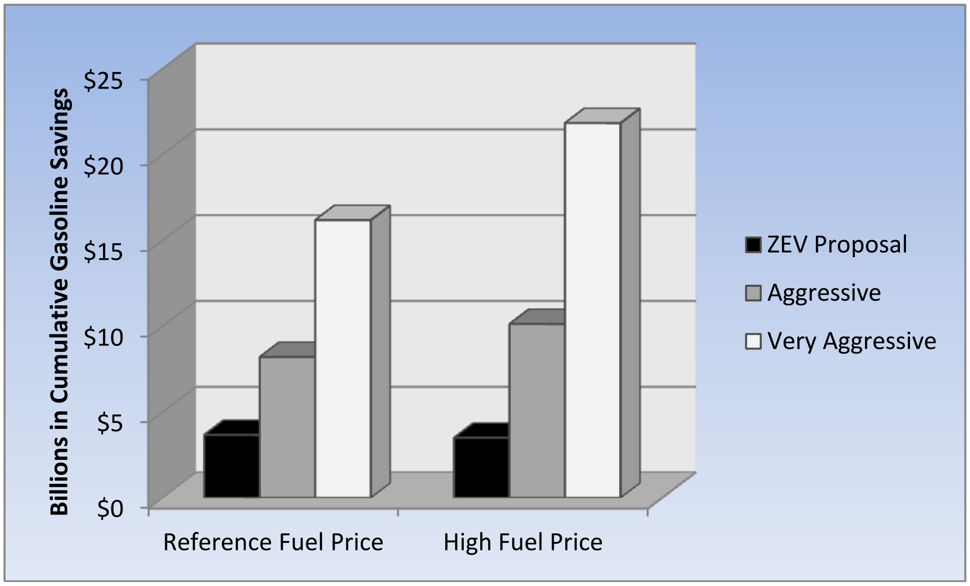
	2015	2020	2025	2030	2035
Baseline	8,365	21,583	45,887	80,788	121,811
Baseline-High Oil Price	26,130	53,702	98,073	146,754	208,428
ZEV Proposal	8,512	71,030	217,481	391,773	539,960
Aggressive Marketing	26,130	101,836	334,411	701,807	1,241,887
Very Aggressive Marketing with Market Incentives and User Benefits	28,872	172,379	557,716	1,191,218	2,074,903

Assumptions for each Scenario and future fuel price estimates from the U.S. DOE, Energy Information Administration, are described in more detail in the Methodology section (below).

Table 4. Cumulative Incremental Net Fuel Savings (Billions of $), 2012 – 2035.

	Reference Fuel Price	High Fuel Price
ZEV Proposal	3.6	3.5
Aggressive Marketing	8.2	10.1
Very Aggressive Marketing with Market Incentives and User Benefits	16.1	21.8

Figure 2. Cumulative (2012-2035) Incremental $ Fuel Cost Savings from Different Electrification Scenarios



Cumulative Net Fuel Savings Less the Estimated Incremental Cost of Plug-in Electric Vehicle.
The fuel cost savings more than pay for the incremental capital cost of purchasing electric vehicles. When the estimated incremental vehicle cost of Plug-in Electric vehicles (PEVs) is deducted from the fuel savings, each scenario would still achieve a significant net economic benefit to the state.[14] See the Methodologies section for a detailed explanation of the estimated incremental capital costs of PEVs.

Table 5. Net Incremental Fuel Cost Savings After Deducting Incremental Capital Cost (Billions of $), 2012-2035.

	Reference Fuel Price	High Fuel Price
ZEV Proposal	1.4	1.8
Aggressive Marketing	2.6	5.0
Very Aggressive Marketing with Market Incentives and User Benefits	5.6	11.8

Job Creation Benefits.
The fuel savings from PEVs compared to gasoline vehicles will result in consumers spending less disposable income on imported energy and more on goods and services in the regional economy. Producing and supplying energy is one of the least employment intensive sectors of the economy so shifting expenditures away from this sector will increase the multiplier effect of every dollar spent and

[14] The expected cost of electric vehicle charging infrastructure is not estimated in this analysis because of unknown variables which make it difficult to accurately estimate. While the incremental purchase price of PEVs is expected to be borne by market participants (either the individual purchaser pays the incremental cost or all new car purchasers share the capital cost if fee-bates are offered, or the public shares the cost if tax credits), and the cost of electric power will be paid by users, it is unclear who will pay the initial capital cost (EV owners, utilities seeking to expand power sales, power retailers, employers, or governments) for the provision of electric vehicle charging infrastructure. The amount of charging infrastructure needed to support a significant penetration of PEVs is also unknown. Once a better understanding of who will bear the costs and a reasonable estimate of costs becomes available, SWEEP will develop estimates of electric vehicle charging infrastructure costs.

result in an increase in regional employment.[15] As Colorado is mostly dependent on imported petroleum to satisfy its energy needs for transportation, almost two-thirds of resources spent on petroleum products will leave the state's economy.

Without the development of a detailed model based on regional and statewide data that could predict the employment benefits of PEVs, it is not possible to provide precise estimates of this impact. However, two methodologies provide an approximate estimate of the scale of employment benefits offered by PEVs fuel savings.

One methodology taken from a 2008 metastudy (Laitner and McKinney[16]) of 48 energy efficiency assessments from states across the country estimates that, on average, for every trillion BTUs of energy saved 49 jobs are created. Another study focusing on Colorado's economy (by Goldberg and Geller[17]) found that every 3,700 barrels of oil saved from improved efficiency standards would result in one additional job in the state's economy. Table 6 shows the job creation potential for each electric vehicle market penetration scenario in the year 2030.

Table 6. Statewide Job Creation in 2035

	Laitner and McKinney		Goldberg and Geller	
	Reference Price	High Price	Reference Price	High Price
ZEV Proposal	554	399	796	585
Aggressive Marketing	1,291	1,519	1,902	2,190
Very Aggressive Marketing with Market Incentives and User Benefits	2,584	2,922	3,861	4,262

Impact on Employment in Colorado's Energy Industries.
In 2010, Colorado consumed 2.97 billion gallons of petroleum fuels. Gasoline consumption, at 2.16 billion gallons, made up the majority of this demand, with 617 million gallons of diesel fuel and 188 million gallons of aviation fuel making up the remainder.[18] In 2010, statewide oil production reached 1.3 million gallons which is close to the highest level of statewide production over the last 30 years.[19]
Increases in statewide population and VMT per capita are expected to offset increased federal fuel economy standards (proposed to reach 54 mpg for the 2025 model year). If the light duty vehicle fleet in Colorado continues to be almost entirely fueled by petroleum fuels in 2035, statewide gasoline consumption is expected to be at the same level of 2.1 billion gallons.

Under the most aggressive vehicle electrification scenario analyzed by SWEEP, annual gasoline consumption would fall to 1.5 million gallons in 2035. If the state were able to maintain its historical peak level of oil production there would still be greater levels of gasoline consumption in the state than could

[15] Roland-Holst, D. (2011, May). How Fuel Economy and Emissions Standards Will Impact Economic Growth and Job Creation. Retrieved from http://next10.org/next10/publications/vehicle_efficiency.html
[16] Laitner, J. and McKinney, V. (2008, June). Positive Returns: State Energy Efficiency Analyses Can Inform U.S. Energy Policy Assessments. *American Council for an Energy-Efficient Economy*. Retrieved from http://www.aceee.org/sites/default/files/publications/researchreports/e084.pdf
[17] Geller, H. and Goldberg, M. (2009). Energy Efficiency and Job Creation in Colorado. *Southwest Energy Efficiency Project*. Retrieved from http://www.swenergy.org/pubs/EE_and_Jobs_Creation_in_Colorado-April_2009.pdf
[18] Colorado Department of Revenue. (2011, January 11). 2010 Annual Report. Retrieved from http://www.colorado.gov/cs/Satellite?blobcol=urldata&blobheader=application%2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1251686144349&ssbinary=true
[19] Energy Information Administration. (2011, July 28). Colorado Field Production of Crude Oil. Retrieved from http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPCO1&f=A The EIA estimated that Colorado produced 30,870,000 barrels of oil, which at 42 gallons per barrel translates to 1,296,540 gallons.

be supplied by in state production. In addition, the state's annual consumption of diesel and aviation fuel is expected to grow to 1.2 billion gallons by 2035, which would provide additional markets for any in-state oil production. No job loss would be expected in the oil and gas production sector of the Colorado economy.

Increased demand for electricity to power plug-in electric vehicles could be entirely supplied by domestic resources produced from within Colorado including natural gas and solar and wind power. Based on a model developed by Electric Power Research Institute (EPRI) each additional $100 million spent on electricity will create 74 new jobs in the power generation and supply sector.[20] Based on this analysis, the scenarios analyzed by SWEEP would produce between 73 (ZEV scenario) and 576 (Very Aggressive Scenario) additional jobs in the power generation and supply sector.

Air Quality and Public Health Benefits, and Reduced Pollution Control Costs.

Electric vehicles also provide important air quality and public health benefits in the areas where they are adopted. These benefits are valuable because they reduce health costs in the region, and reduce the costs for emission reductions that are not needed from other sources in the region. The health cost savings are not included in the scope of this analysis. The costs of most emission control measures are in the range of $1,000 to $5,000 per ton of emissions reductions. Depending on where EPA sets the revised national ambient air quality standard (NAAQS) for ozone in 2013, the reductions needed for attainment by 2020 could range from millions to hundreds of millions of dollars annually. Few other control measures available to the State will achieve emission reductions while providing a net economic benefit to the region by reducing costs.

Table 7 shows the annual tons of reduction of the ozone precursors Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOC) achieved by replacing gasoline powered vehicles with PEVs in Colorado along with the potential economic savings from these reductions.

Table 7. Ozone Precursor Reductions in Annual Tons and Ozone Precursor Control $ Savings, 2020[21]

	Tons Reduced		Savings at $1,000 per ton	Savings at $5,000 per ton
	NOx	**VOC**		
ZEV Proposal	37	32	$69,000	$345,000
Aggressive Marketing	65	67	$132,000	$660,000
Very Aggressive Marketing with Market Incentives and User Benefits	129	143	$272,000	$1,360,000

Depending on the magnitude of emissions reductions needed to attain the revised ozone NAAQS, it is possible that the expanded ownership and operation of PEVs between now and 2020 could achieve a significant portion of the emission reductions needed for attainment thereby relieving other industries of the costs of additional pollution controls.

Greenhouse Gas Emission Reductions.

Replacing gasoline vehicles with PEVs achieves large reductions in GHG emissions per mile driven, even if the electricity used to power PEVs is generated using the current fuel mix (60% coal). Table 8 shows the percentage reduction in CO_2 emissions that would be expected due to the electrification of the light duty fleet, assuming that the electric grid becomes 30% less carbon intensive by 2030 (compared to 2005 levels). Because Colorado currently requires that 30% of electric power provided by investor owned utilities be generated from renewable sources (i.e., solar, wind, geothermal and hydro) by 2020, it is

[20] Electric Power Research Institute. (2006). Regional Economic Benefits from Electric Transportation. Retrieved from www.epri.com

[21] Please see the Methodologies section for a description of how NOx and VOC emissions reductions were estimated.

reasonable to assume that the statewide system will reach this level by 2030. Electrification of light duty vehicles makes it possible to reduce CO_2 emissions from these vehicles by more than 80% if electric power is generated from renewable sources (i.e., wind, solar, hydro and geothermal), and 75% of VMT is operated by batteries powered from the grid or roof-top collectors.

Table 8. CO_2 Emission Reduction Compared to Baseline Scenarios[22]

	Reference Fuel Price	High Fuel Price
ZEV Proposal	3.2%	2.3%
Aggressive Marketing	8.6%	7.5%
Very Aggressive Marketing with Market Incentives and User Benefits	16.4%	14.8%

Some policy options for the region to implement are discussed in the report: "**What can Cities and Counties do to Promote the Deployment of Electric Vehicles?**" (SWEEP, March 2011, prepared with funding and support from the U.S. DOE [available at swenergy.org]).

Methodologies and Assumptions

Electric Vehicle Market Penetration Scenarios

Three electrification scenarios (California's proposed ZEV mandate for model years 2017-2025, aggressive marketing, and very aggressive marketing combined with public policies that provide incentives for EV ownership and use) were analyzed by SWEEP. These scenarios are an attempt to reflect the potential for electric vehicles to achieve significant market penetration over the next 25 years. The ZEV requirements used to estimate sales in the first scenario establishes a predictable baseline for EV sales. The two marketing scenarios are subject to greater uncertainty. The three scenarios are compared to the EIA's current estimate of the number of PEVs expected to be sold in the current reference case scenario and their high fuel price scenario.

The two marketing scenarios were developed by the U.S. EPA in their analysis of strategies for reducing GHG emissions from the transportation sector.[23] EPA considers these scenarios to be technologically feasible if supportive policies are in place or market conditions stimulate greater consumer demand. The first scenario, described as 'aggressive', assumes that by 2030, PEVs would make up 14% of the light duty fleet (one third battery-only electric vehicles (BEVs) and two-thirds plug-in hybrid electric vehicles (PHEVs)), with sales of PHEVs making up 17% of new sales and BEVs 13%. The second marketing scenario, described as 'very aggressive,' assumes that by 2030 PEVs would make up 21% of the light duty fleet (two thirds BEVs and one-third PHEVs), with sales of BEVs making up 30% of new vehicle sales and PHEVs 19% of new vehicles sales by 2030. These estimates were projected backwards to estimate the percentage of annual vehicle sales and share of the total light duty fleet for each year 2012 to 2030.

California's new ZEV proposal requires the following percentages of ZEVs to be sold in these years: 2012-2014: 0.2% BEV and 0.3% PHEV; 2015-2017: 0.9% BEV and 1.1% PHEV. After 2017 the percentage of BEVs sold is required to increase from 1.2% in 2018 to 4.4% in 2025 and the percentage of PHEVs to increase from 4.1% in 2018 to 7.0% in 2025. These percentages for each year are then multiplied by the estimated

[22] CO_2 reductions are lower in the high price scenario because higher fuel prices are expected to lead to consumer decisions to purchase vehicles with slightly higher average fuel economy which will reduce the amount of fuel consumed and CO_2 emitted compared to the baseline scenario.
[23] Environmental Protection Agency (2010, February 10). EPA Analysis of the Transportation Sector. Retrieved from http://www.epa.gov/oms/climate/GHGtransportation-analysis03-18-2010.pdf.

number of annual light duty vehicle sales for Colorado (determined on a per capita basis from EIA's projections for vehicles sales in the Mountain region) to estimate the number of PHEVs and BEVs that would be sold in Colorado annually.

All three scenarios assume that all electric vehicles will travel the same average number of miles annually as gasoline vehicles, and that 25% of miles traveled by PHEV-10s are battery powered and 75% of miles traveled by PHEV-40s are battery powered.

Fuel Price Scenarios.

Two scenarios for gasoline prices were considered based on the EIA's estimates of future gasoline prices in the Mountain region, their reference scenario and high oil price scenario. The reference case scenario is based on EIA's assumption that "current practices, politics and levels of access will continue in the near to mid-term, whereas long-term developments will be determined largely by economics."[24] In this scenario gasoline prices reach $3.90 per gallon by 2035. For the high oil price scenario, EIA assumes that major producing countries "use quotas, fiscal regimes, and varying degrees of nationalization to further increase revenues from oil production, and the consuming countries turn to domestic production of high-cost unconventional liquids to satisfy demand."[25] In this scenario gasoline prices reach $5.52 per gallon by 2035. Both of these scenarios significantly underestimate the price of gasoline in 2011, placing it at $2.91 per gallon compared to the current state average of $3.50 per gallon. EIA predicts that prices will not rise to reach the current price until 2020 in the reference scenario, and by 2012 in the high price scenario. This underestimation of current prices suggests that the high price scenario is a more realistic estimate of future gasoline prices.

The base prices for electricity and natural gas were taken from Xcel's most current rate filings. The future estimated increase in prices of electricity and natural gas was taken from the EIA's estimate of the change in prices for these fuels in the transportation sector for the Mountain region.[26] Electricity is expected to increase from $0.095 per kwh in 2010 to $0.145 per kwh in 2035, although for this analysis half of this cost is used to simulate the off-peak Time of Use rates available for EV charging. EIA estimates that natural gas is expected to increase from $0.6245 per 100 cubic feet to $0.7354 per 100 cubic feet by 2035.

Fuel Economy.

The assumed average efficiency of a battery powering an electric vehicle is 0.3508 kwh/mile which is the average of the EPA rated efficiency for the Chevy Volt and the Nissan Leaf. The assumed average efficiency of a PHEV's gasoline fueled charger is 37 mpg, the efficiency EPA recognizes for the Chevy Volt. The assumed average efficiency of a CNG vehicle is based on the Honda Civic CNG vehicle which averages 0.197 per cubic foot of natural gas.

Plug-in Electric and Compressed Natural Gas Vehicles' Incremental Capital Costs

Estimates of the future cost of PEVs are heavily dependent on assumptions about the cost of batteries. Battery costs per kWh have fallen nearly one-third from over $650 per kWh in 2009 to around $450 per kWh in 2011. This rapid drop in costs is much greater than was assumed in most earlier analyses of future battery costs. In response to this decrease in prices, Deutsche Bank recently revised their estimate for

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[24] Energy Information Administration. (2010, May 11). *Annual Energy Outlook 2010*. World Oil Prices and Production Trends in AEO2010. Retrieved from http://www.eia.doe.gov/oiaf/archive/aeo10/woprices.html

[25] Energy Information Administration. (2010, May 11). *Annual Energy Outlook 2010*. World Oil Prices and Production Trends in AEO2010. Retrieved from http://www.eia.doe.gov/oiaf/archive/aeo10/woprices.html

[26] Energy Information Administration. (2010, December 16). Annual Energy Outlook 2011. Energy Prices by Sector and Source, table 18. Retrieved from http://www.eia.doe.gov/forecasts/aeo/tables_ref.cfm

future battery costs to $250 per kWh in 2020.[27] Given the rapid decrease in prices over the last two years as battery technologies have advanced, and vehicle production has come online, it is likely that further cost reductions will be achieved. Future estimates of the incremental costs for electric powered vehicles are given in the table below. The original figures were taken from the U.S. DOT's report on greenhouse gas emissions from the transportation sector.[28] DOT's expected decline in battery costs have been accelerated by ten years compared to the DOT report which had not estimated battery costs reaching $250 per kWh before 2030. The cost estimates below may be conservative.

Projected Incremental Purchase Price for Electric Vehicles Compared to Comparable Gasoline Vehicle.

	2011	**2030**
PHEV 10	$4,600	$3,000
PHEV 40	$20,000	$5,700
BEV	$12,000	$5,600

The amount of the federal and state tax credit has been subtracted from the incremental cost of electric powered vehicles sold between 2011 and 2015 at which point consumers would bear the entire incremental cost of these vehicles.

The incremental cost of Compressed Natural Gas vehicles ($6,000) was also taken from the above Department of Transportation report on greenhouse gas emissions in the transportation sector.

Tailpipe Criteria Pollutant Reductions.

To estimate the potential reduction from electric vehicles, the total stock of battery electric vehicles was multiplied by the average VMT for light duty vehicles and then multiplied by the average emission rate for new vehicles (0.07 grams per mile for NOx and 0.09 grams per mile for VOCs). This gives the tailpipe emissions (in grams per year, which was then converted to tons per day) avoided by all electric vehicles expected to be purchased under each scenario rather than an ICE gasoline powered vehicle. To estimate emissions from plug-in hybrid electric vehicles, half of the VMT is assumed to operate on the battery. The total stock of plug-in hybrid vehicles was multiplied by 0.05 (for NOx) and 0.035 (for VOCs), which is half of the EPA-tested emission rates of the Chevy Volt's current gasoline engine. This would give the total emissions removed from battery powered VMT for plug-in electric vehicles Current federal tailpipe emission standards are assumed to remain unchanged through 2025.

Glossary.

BEV – electric vehicle powered exclusively by power drawn from the grid when the battery is plugged in.
EIA – The Energy Information Agency which is the part of the U.S. Department of Energy responsible for tracking energy use by sector of the economy, and for the development of estimates of expected future energy demand and supplies.
EPA – The U.S. Environmental Protection Agency.
kWh – kilowatt hour, a measure of electric energy.
LEV II – the second set of standards established for "low emission vehicles" in 2005 by the California Air Resources Board.
NAAQS – national ambient air quality standard.

[27] Deutsche Bank. (2010, December 22). The End of the Oil Age 2011 and Beyond: A Reality Check. Retrieved from http://bioage.typepad.com/files/1223fm-05.pdf
[28] U.S. Department of Transportation. (2010, April). *Transportation's Role in Reducing U. S. Greenhouse Gas Emissions*. Retrieved from http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf

NMOG – non-methane organic gases, which are a subset of **VOC**s.
NOx – oxides of nitrogen, one of the pollutants emitted by motor vehicles that is a primary precursor in the formation of atmospheric ozone.
PEV – plug-in electric vehicle, which includes both **BEVs** and **PHEVs.**
PHEV – plug-in hybrid electric vehicle which operates by battery power drawn from the grid when the vehicle is plugged in until the battery is empty, and then is powered by electricity generated by an on-board liquid fueled motor.
PHEV-10—PHEV which has an electric range of 10 miles
PHEV-40—PHEV which has an electric range of 40 miles
VMT – vehicle miles travelled.
VOC – volatile organic compounds, one of the pollutants emitted by motor vehicles that is a primary precursor in the formation of atmospheric ozone.
ZEV – zero emission vehicles which are vehicles that do not emit pollutants from a tailpipe.