Air Quality and Economic Benefits of Electric Vehicles in Arizona

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Executive Summary

Because electric vehicles (EVs) provide air quality and economic benefits to Maricopa County and the state of Arizona, the state should consider policies that overcome barriers to greater numbers of people acquiring EVs.

SWEEP has conducted an analysis which shows that in Maricopa County, EVs reduce emissions of criteria pollutants compared to a comparable gasoline-fueled vehicle. In 2013, the largest emissions reductions (99% compared to a gasoline-fueled vehicle) are for Volatile Organic Compounds and Carbon Monoxide with significant additional reductions in Sulfur Dioxide (93%), Nitrogen Oxides (76%) and Particulate Matter (60% for PM2.5 and 45% for PM10). The adoption of EVs will help the region address its current air quality challenges, especially its high levels of ground- level ozone (created by VOC and NOx). Reduction of all these pollutants provides public health benefits to the region by reducing respiratory ailments, especially in vulnerable populations such as children and the elderly.

Electric vehicles also provide an economic benefit to the state by reducing fuel costs and shifting consumption away from imported oil to more locally produced electricity sources. Electric vehicle drivers can expect to save between $700 and $1,400 annually on fuel costs. Net lifetime savings are estimated to be between $7,300 and $17,200.[1] Depending on the rate of adoption for EVs and the price of gasoline, the total economic benefit to the state of Arizona in reduced fuel costs would be between $75 million and $489 million per year by 2030. These fuel savings become additional disposable income that will be mostly spent in the local economy, creating additional jobs in the state.

Electric vehicle owners in Arizona already benefit from an extensive charging network and discounted charging rates from utilities. There are 519 stations (16 of which are DC fast chargers) located in metro Phoenix area providing EV drivers many convenient opportunities to

[1] The amount saved depends on the type of electric vehicle, and the future cost of gasoline.

charge away from their homes. The state's three largest utilities (Salt River Project, Arizona Public Service and Tucson Electric Power) all offer special time of use rates to their residential customers that allow them to charge their EVs during off-peak hours at significantly reduced rates.

To further spur the adoption of electric vehicles and maximize the benefits they bring, the state should consider creating an upfront incentive such as a rebate or tax credit to offset the incremental purchase cost of electric vehicles. Alternatively, the state could shift the amount of the license tax reduction it currently offers to electric vehicles owners to an entirely upfront incentive. The state should also expand its Alternative Fuel License Plate program to include plug-in hybrid electric vehicles as they offer significant economic and air quality benefits.

Benefits of Electric Vehicles

There are currently fifteen light-duty electric vehicles (EVs) available from large scale vehicle manufacturers, including plug-in hybrid electric vehicles (PHEVs), with seven more models expected by 2014.[2] With so many diverse models available over the next two years, electric vehicles have the potential to play an important part in the transportation future of Arizona. The benefits of EVs compared to gasoline fueled vehicles include the following:

- *Greater efficiency*: Compared to gasoline powered internal combustion engines, electric vehicles can travel the same distance using approximately 30% less energy.[3]
- *Locally produced energy source*: Essentially all of the petroleum and refined gasoline used in Arizona is imported, while electricity is produced almost entirely within the state.[4]
- *Reduced emissions*: EVs have the potential to reduce greatly harmful tailpipe emissions compared to gasoline powered vehicles.[5]
- *Reduced Fueling Cost*: Because of their higher efficiency and the low cost of electricity compared to gasoline per unit of energy, electric vehicles can travel the same distance as a typical conventional vehicle at the cost-equivalent of $1.20 per gallon.[6]

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[2] FuelEconomy.gov. 2013. Electric Vehicles and Plug-in Hybrids. Retrieved from http://www.fueleconomy.gov/feg/evsbs.shtml and http://www.fueleconomy.gov/feg/phevsbs.html

[3] Salisbury, M. and Toor, W. 2013. Transportation Fuels for the Southwest's Future: Life-cycle Energy Use and Environmental Impacts of Electric, Compressed Natural Gas, and Gasoline Vehicles. Available at www.swenergy.org

[4] Energy Information Administration. 2013. Arizona: State Profile and Energy Estimates. Retrieved from http://www.eia.gov/state/?sid=AZ

[5] Salisbury and Toor, 2013. Transportation Fuels.

[6] US Department of Energy. 2013. eGallon: Compare the costs of driving with electricity. Retrieved from http://energy.gov/maps/egallon

Furthermore, the energy and environmental benefits of electric vehicles are expected to increase as older power plants are retired and additional natural gas and renewable generation is constructed.[7] Maricopa County and surrounding areas suffer from serious air quality challenges, and mobile source emissions are a significant source of emissions that contribute to this problem. Supporting widespread adoption of electric vehicles is an important strategy for addressing air quality in the region.

Analysis of Air Emissions from Electric Vehicles in Maricopa County

Analysis Methodology

SWEEP performed an analysis comparing the emissions associated with three types of electric vehicles in 2013: a plug-in hybrid electric vehicle (PHEV) that has an electric range of 10 miles (PHEV10);[8] an extended range EV (PHEV40) with an electric range of 40 miles;[9] a battery electric vehicle (BEV) with a range of 70 miles;[10] a compressed natural gas (CNG) vehicle;[11] and a traditional gasoline passenger vehicle.[12] This analysis focused on air quality emissions around the Phoenix metropolitan area where approximately two-thirds of the state's population lives.[13]

The analysis evaluates emissions of the following criteria pollutants: ground-level ozone precursors, such as Volatile Organic Compounds (VOCs) and Nitrogen Oxides (NOx); Particulate Matter of 2.5 and 10 micrometers (PM2.5 and PM10); Carbon Monoxide (CO); and Sulfur Dioxide (SO_2). [14] The analysis also evaluates greenhouse gas emissions. *The PM10 and NOx and*

[7] Salisbury and Toor, 2013. Transportation Fuels.
[8] The PHEV10 was modeled on the 2013 Toyota Prius Plug-in Hybrid.
[9] The PHEV40 was modeled on the 2013 Chevy Volt.
[10] The BEV was modeled on the 2013 Nissan Leaf.
[11] The CNG vehicle was modeled on the Honda Civic Natural Gas
[12] A new average gasoline passenger vehicle has a fuel economy rating of 28 mpg.
[13] Arizona Indicators. 2013. Demographics: Population Basics. Retrieved from http://arizonaindicators.org/demographics/demographics-overview
[14] "The Clean Air Act requires EPA to set National Ambient Air Quality Standards for six common air pollutants. These commonly found air pollutants (also known as "criteria pollutants") are found all over the United States. They are particle pollution (often referred to as particulate matter), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. These pollutants can harm your health and the environment, and cause property damage. Of the six pollutants, particle pollution and ground-level ozone are the most widespread health threats. EPA calls these pollutants "criteria" air pollutants because it regulates them by developing human health-based and/or environmentally-based criteria (science-based guidelines) for setting permissible levels. The set of limits based on human health is called primary standards. Another set of limits intended to prevent environmental and property damage is called secondary standards." US EPA, *What are the Six Common Air Pollutants*, available at: http://www.epa.gov/airquality/urbanair/.

VOC emissions are particularly important as the region is currently in non-attainment for permissible levels of these pollutants. Note that NOx and VOCs are all also precursors for PM10. The US EPA is expected to issue new ozone standards in 2014, which may present additional challenges by lowering allowed ozone levels from 75 parts per billion (ppb) to 70 ppb or lower.

SWEEP performed analysis using the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) fuel-cycle model developed by the Argonne National Laboratory with funding from the U.S. Department of Energy.[15] The GREET model was used to make a comparison between the life-cycle emissions of three light-duty vehicle fuels: gasoline, electricity, and natural gas. New vehicles purchased in 2013 are analyzed to show which vehicles will have the most immediate impact regarding energy use and emissions (see Figure 1 and Table 1 below).

To estimate electricity generation mixes SWEEP relied on analysis conducted by Synapse Energy Economics for SWEEP's *$20 Billion Bonanza* study.[16] Also from the *$20 Billion Bonanza* study, we used NOx emission rates from coal power plants for 2013.

There are two major variables to consider when estimating what electricity sources will meet the marginal demand created by increased utilization of EVs. For most utilities, natural gas is expected to meet the majority of marginal electricity demand over the course of the year. However, as most EV charging is expected to take place during the evening and early morning hours at people's homes, this is also the time when there may be spare coal capacity that could be used to meet additional EV demand. These late hours are also when wind generation usually peaks. As the relative importance of these two variables is unknown and especially difficult to attempt to quantify for future years, we have decided to use the average generation mix forecast for 2013 for both base load and marginal electricity demand.

The GREET model calculates the amount of emissions occurring in urban areas to show which emissions would be most likely to contribute to air quality issues. To better represent the impact that electric and gasoline vehicles will have on air quality, SWEEP characterized the transportation energy system in Arizona to show exactly what emissions are likely to contribute to Maricopa County's airshed. Note that in July, SWEEP released a multi-state analysis of emissions from electric vehicles, which arrives at slightly different conclusions for Arizona, as it

[15] Argonne National Laboratory. 2012. Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation. Retrieved from http://greet.es.anl.gov/

[16] Geller H. et al, The $20 Billion Bonanza: Best Practice Utility Energy Efficiency Programs and Their Benefits for the Southwest, 2012.Retreved from http://www.swenergy.org/programs/utilities/20BBonanza.htm

analyzes *statewide* lifecycle emissions, and does not focus specifically on the Maricopa County non-attainment area.[17]

Regarding relevant upstream emissions from electricity, SWEEP has calculated that 0% of statewide coal plant emissions and 84% of natural gas plant emissions take place in the area around Maricopa County and contribute emissions into the County's airshed.[18] This is based on 84% of the state's natural gas generation occurring in the area in and around Maricopa County. For upstream emissions for gasoline vehicles, none of the emissions associated with gasoline refining take place in Arizona as there are no refineries located in the state.

Regarding the extraction of fuel (mining and drilling): there are no coal mines or oil and gas fields located near Maricopa County. For the purposes of the GREET model, it was assumed that oil and gas extraction and coal mining do not contribute to urban emissions.

Air Emissions Results

The analysis shows that in Maricopa County all types of electric vehicles reduce emissions of criteria pollutants compared to a comparable gasoline fueled vehicle. Except for greenhouse gases, the scale of the reductions in emissions depends on the amount of electricity used as a fuel. BEVs achieve the greatest level of reductions, with PHEVs having smaller level of reductions; PHEV40s (which travel 57% of their miles on electricity) have the second greatest level of reductions and PHEV10s (which travel 26% of their miles on electricity) have the least amount of emissions reduction compared to gasoline vehicles. The analysis also shows that EVs and CNG vehicles have comparable emissions profiles, with both having a clear advantage over gasoline-fueled vehicles pollutants.

In Table 1 and Figure 1 we break down the reductions in harmful air pollutants from EVs in Maricopa County. BEVs have essentially zero emissions of VOCs, SO2 and CO. The largest reductions (regarding net weight) are in the ozone precursors, VOC and NOx. Compared to CNG vehicles, the BEVs generally have lower emissions (except for NOx) while the PHEVs generally have higher emissions (except for CO) with PM2.5 emissions being almost equal.

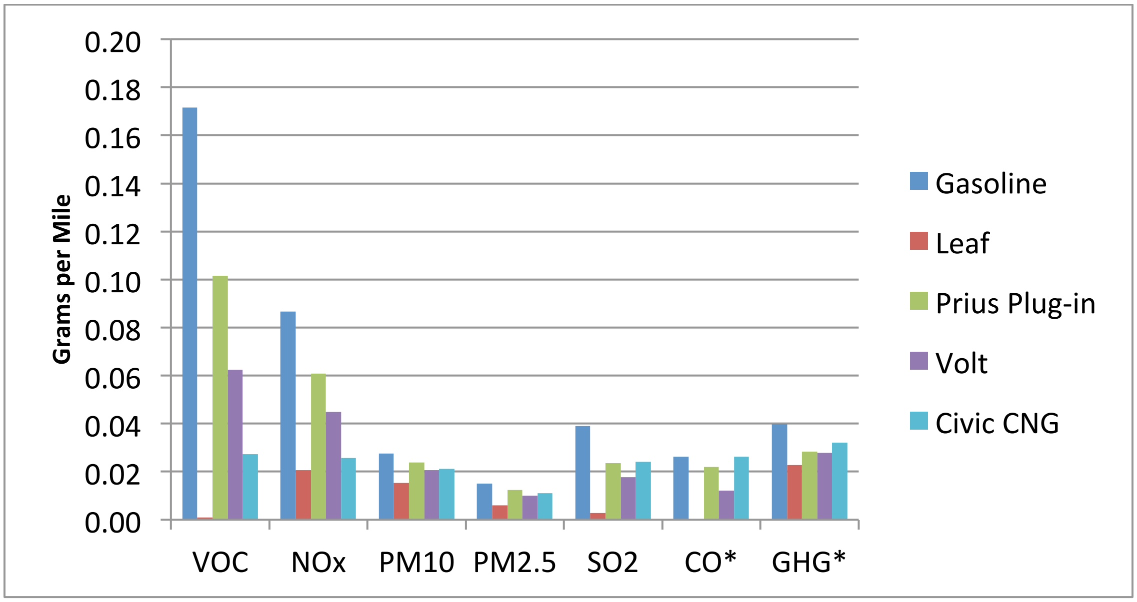
[17] Because almost all of the state's coal fired power plants are located well outside of Maricopa County, their emissions do not contribute to the emissions shown in this analysis.

[18] Environmental Protection Agency. 2013. eGRID2012 Version 1.0. Retrieved from http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

Table 1. Percent Reduction in Emissions in 2013 Compared to New Gasoline Vehicle

	BEV	PHEV10	PHEV40	CNG
VOC	99.5%	40.9%	63.7%	84.0%
NOx	76.1%	29.9%	48.3%	70.4%
PM10	44.8%	14.1%	25.6%	24.0%
PM2.5	59.9%	17.4%	34.0%	25.4%
SO_2	93.0%	39.5%	55.0%	38.0%
CO	99.6%	17.1%	53.9%	0.4%
GHG	42.6%	28.3%	30.2%	19.2%

Figure 1. Criteria Pollutant Emissions in Maricopa County by Vehicle Type, New 2013 Vehicles



*The scale of emissions from CO and GHG has been changed so that all the pollutants could be placed in one chart. CO emission rates have been reduced by a factor of 100 so in fact numbers are around 2.0 grams per mile and GHG emission rates have been reduced by a factor of 10,000 so in fact numbers are around 300 grams per mile.

Table 2. Sources of Pollutants as a Percent of Total Emissions in Maricopa County[19]

	PM10	PM2.5	NOx	SO_2	CO	VOC
Mobile Emissions	5.48%	16.79%	85.65%	34.98%	95.97%	42.36%
Light Duty Gasoline Vehicle Emissions	1.20%	2.18%	26.82%	15.02%	57.45%	26.15%

Currently, Maricopa County is in non-attainment for EPA standards for ground-level ozone and Particulate Matter of 10 micrometers (PM10).[20] Table 2 shows the contribution of mobile sources and light duty gasoline vehicles to overall emission levels in Maricopa County and helps to clarify which pollutants EVs can most effectively reduce.

Concentrations of ground level ozone in Maricopa County have increased in recent years with the number of ozone monitors that have exceeded the EPA standard of 0.075 parts per billion at least four times in a year increasing from zero in 2009, to four in 2010, to eleven in 2011 and to fourteen in 2012.[21] Due to these increasing ozone concentrations in recent years, monitors, which are in violation if their three year average exceeds the 0.075 ppb standard, are experiencing increasing numbers of violations. Only two monitors were in violation using the 2009 to 2011 averages, while 11 monitors were in violation using the 2010 to 2012 three-year averages. [22]

Electric vehicles can be effective at reducing ground level ozone (caused by VOCs and NOx) levels because of the scale of emission reductions and the amount of emissions contributed by light duty vehicles. Battery electric vehicles almost completely eliminate urban VOC emissions and reduce urban NOx emissions by 76%. In addition, light duty vehicles make up over a quarter of VOC and NOx emissions in Maricopa County as shown in Table 2.

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[19] Environmental Protection Agency. 2013. Air Emission Sources. Retrieved from http://www.epa.gov/air/emissions/index.htm

[20] Environmental Protection Agency. 2013. Currently Designated Nonattainment Areas for All Criteria Pollutants. Retrieved from http://www.epa.gov/oaqps001/greenbk/ancl.html

[21] Environmental Protection Agency. 2013. Monitor Values Report. Retrieved from http://www.epa.gov/airdata/ad_rep_mon.html

[22] The 4th highest 8-hour average during an annual period is the value used by EPA to determine if the national standard is exceeded. A violation occurs when the 3-year average of the 4th highest concentration is greater than 75 ppb. Comparing the number of monitors with exceedances from year to year, and the level of the 4th highest concentrations are two indicators showing whether ozone pollution is worsening in a large metropolitan area such as Maricopa County.

As Maricopa County develops plans to reduce ground level ozone levels, increasing the numbers of electric vehicles on the road can play an important part in reducing emissions. This is also important as the EPA is required to issue a new ground level ozone standard in 2014 which could make it more difficult for Maricopa County to be in compliance. This analysis demonstrates that a shift to electric vehicles will help the County comply with both the current and the new standard.

While Maricopa County and most of Arizona are not currently in non-attainment for CO and SO_2, electric vehicles do significantly reduce emissions of these pollutants.

Electric vehicles do provide reductions of PM2.5 and PM10 compared to gasoline vehicles, but because light duty vehicles make up such a small portion of PM emissions even with high levels of adoption electric vehicles would still be unable to significantly reduce overall emissions in Maricopa County.

Reducing the levels of all these criteria pollutants provides public health benefits to the region. Elevated levels of these pollutants leads to respiratory ailments such as aggravated and more frequent asthma attacks and decreased lung function all of which increase hospital and emergency room visits.[23] Vulnerable populations, such as children and the elderly, are at greater risk from exposure to these pollutants.

Economic Benefits from Electric Vehicles

Higher upfront costs for electric vehicles will be more than offset by significantly lower fuel costs than gasoline vehicles, bringing economic benefits to their owners that will in turn provide an economic benefit to the state. SWEEP has analyzed the economic benefits of EVs based on two forecasts for the price of gasoline developed by the Energy Information Administration (EIA), the Reference Case and the High Oil Price Case.[24] The current average price of residential electricity per kWh for Arizona customers is estimated at $0.1139 per kWh.[25] As the three largest utilities in the state (Arizona Public Service, Salt River Project and Tucson Electric Power) offer special time of use rates for electric vehicle owners it is reasonable to assume that most customers will take advantage of the lower rates. The weighted average of the off-peak electric vehicle rates for the three utilities is $0.069 per kWh. We assume that

[23] American Lung Association. 2013. Impacts on Your Health. Retrieved from http://www.lung.org/healthy-air/outdoor/protecting-your-health/impacts-on-your-health/

[24] In the last six years of the EIA's Annual Energy Outlook, the High Oil Price Case has actually more closely tracked with actual gasoline prices.

[25] Energy Information Administration. 2013. Electric Power Monthly. Retrieved from http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_b

electric vehicle owners would use this rate for 75% of their charging. The average rates were increased based on the expected increase in electricity prices for the Mountain region by EIA.[26]

Table 3. Economic Benefits of Individual EVs Compared to a Gasoline Passenger Vehicle[27]

	Incremental Cost (less federal tax credit)	Payback Period (years)		Lifetime Savings (Lifetime Fuels Savings Minus Incremental Cost)		Average Annual Fuel Savings	
		Reference	High	Reference	High	Reference	High
PHEV10[28]	$3,735	6	5	$7,316	$10,436	$737	$945
PHEV40[29]	$4,095	5	4	$7,366	$10,962	$764	$1,004
BEV[30]	$4,410	6	5	$11,903	$17,251	$1,088	$1,444

To estimate the total economic impact of EVs, we must consider the potential market penetration of EVs into the light duty vehicle fleet. To project the potential impact of EVs, SWEEP used two possible market penetration scenarios. The first comes from the U.S. Energy Information Administration and is their forecast of EV sales in the Mountain region. We estimate that based on the percentage of vehicle registrations, Arizona would make up 25.8% of vehicles sales in the region. By 2020, EIA forecasts that EVs will make up 1.2% of all new vehicles sales and by 2030, 2.8% of sales.[31] This translates to approximately 0.3% of all light duty vehicles in 2020 and 1.2% of all light-duty vehicles in 2030. A more aggressive market penetration scenario was also analyzed that assumed that by 2020 EVs would make up 2% of all light-duty vehicles and that by 2030 this percentage would rise to 5%, with a greater share of BEVs. Table 4 shows that adoption of EVs in Arizona has the potential to provide between $75 million and $490 million in economic benefits to Arizona in 2030.

Table 4. Annual Fuel Cost Savings Benefits (Millions of $)

	2020		**2030**	
	Reference	**High**	**Reference**	**High**
EIA Scenario	$15.8	$21.1	$75.3	$104.1
5% by 2030 Scenario	$105.7	$143.5	$349.9	$489.7

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[26] Energy Information Administration. 2013. Annual Energy Outlook, Reference Case. Table 3-8. Energy Prices by Sector and Source – Mountain. Retrieved from http://www.eia.gov/forecasts/aeo/data.cfm#enprisec
[27] A new gasoline passenger vehicle is estimated to have an on-road efficiency of 28 mpg.
[28] The PHEV10 is modeled on the 2013 Toyota Prius Plug-in Hybrid.
[29] The PHEV40 is modeled on the 2013 Chevy Volt.
[30] The BEV is modeled on the 2013 Nissan Leaf.
[31] Energy Information Administration. 2013. Annual Energy Outlook. Table 48. Light-Duty Vehicle Sales by Technology Type – Mountain. High Oil Price Case. Retrieved from http://www.eia.gov/forecasts/aeo/data_side_cases.cfm

Job Creation Benefits

Arizona only produces enough oil to satisfy less than one tenth of one percent (<0.1%) of its own demand, meaning that almost all of the money spent on fuel will leave the state's economy. The fuel savings from EVs compared to gasoline only 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 result in an increase in regional employment.[32] As Arizona is dependent on imported petroleum to satisfy its energy needs for transportation, almost all funds 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)[33] 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)[34] 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 5 shows the job creation potential for the two electric vehicle market penetration scenarios in the year 2030.

Table 5. Job Creation Potential in 2030 from Electric Vehicle Fuel Savings

	Laitner and McKinney	Goldberg and Geller
EIA Scenario	114	147
5% by 2030 Scenario	527	713

[32] 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

[33] 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

[34] 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

Policies to Address Barriers to Increased Adoption of Electric Vehicles

As a new transportation technology, EVs have to overcome a number of barriers to gain widespread adoption. One of the greatest barriers to EV adoption is higher upfront capital cost relative to gasoline vehicles. The lowest price for EVs currently on the market is just under $30,000, significantly higher than the price for comparable dedicated gasoline vehicles. Savings from reduced fuel costs will offset the higher purchase prices over the *lifetime* of the vehicle (as shown in Table 3), but consumers may not be willing or able to bear the additional *initial* cost. While the upfront purchase costs are expected to come down as battery technology improves and large scale production of batteries and EVs expands, EVs will continue in the short term to cost more than similar gasoline fueled vehicles.

Some of this incremental cost is offset by a federal tax credit, which offers up to $7,500 (depending on battery size) toward the purchase of an EV. The federal government also offers a tax credit of up to $1,000 for individuals and up to $30,000 for commercial entities for the purchase and installation of electric vehicle charging equipment. At the state level there are a number of policies that can make owning an EV more economical. Some policies focus on reducing the upfront cost, while others reduce annual operating costs.

The state of Arizona currently charges electric vehicles (and other alternative fuel vehicles) less for their annual license taxes than gasoline vehicles. For a vehicle such as the Nissan Leaf, this means that upon a vehicle's initial registration in the state, the owner would pay approximately $450 less than a comparably priced gasoline vehicle. Over the vehicle's lifetime, the electric vehicle owner would save approximately $2,200 in license taxes.

While this is an important incentive for the state to offer, SWEEP recommends that to better incentivize electric vehicles, an entirely upfront incentive such as a rebate or a tax credit be offered. A number of other states (including Utah and Colorado) offer upfront incentives to electric vehicle purchasers. Because electric vehicle owners will already be paying significantly less for fuel every year, the annual reduced license tax is less effective as an incentive. Focusing the incentive on the time of purchase helps to overcome one of the most significant barriers to EV adoption in Arizona. Alternatively, the total lifetime amount of the license tax incentive could be shifted so that the EV purchaser receives the entire incentive at the time of purchase rather than being spread out over the lifetime of the vehicle. Shifting the license tax to an upfront incentive would not require the state to expend additional revenue; it will simply shift when the revenue is expended.

Arizona could also expand access to its Alternative Fuel License Plate program to plug-in hybrid electric vehicles. Currently, vehicles such as the Chevy Volt are not eligible for the special plates that allow access to the state's HOV lanes even when there is only one passenger in the vehicle. As shown in this report, plug-in hybrids offer significant economic and air quality benefits to Arizona and should be considered for inclusion in the Alternative Fuel License Plate program.