Air Quality Benefits of Electric Vehicles in the Denver Metro and North Front Range Area

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Executive Summary

SWEEP has conducted an analysis showing that in the Denver metro and North Front Range area, light-duty electric vehicles (EV) reduce emissions of criteria pollutants compared to a comparable gasoline-fueled vehicle. In 2013, EVs will effectively eliminate emissions of Volatile Organic Compounds (VOC) and Carbon Monoxide (CO) while also reducing Nitrogen Oxides (NOx) and Particulate Matter (PM). As the electric grid in Colorado becomes cleaner over time, so will EVs: By 2020 they will provide even greater air quality benefits to the region.

The air quality benefits to the metropolitan region are greater than one would conclude by looking at statewide averages, because many power plants that supply electricity to the metropolitan region are located outside the urban airshed and thus have minimal contribution to air pollution in the ozone non-attainment area.

Table ES-1. Percent Reduction in Emissions for an EV Compared to a New Gasoline Vehicle in the Denver Metropolitan Region

	2013	2020
VOC	99.1%	99.5%
NOx	4.5%	70.1%
PM10	14.7%	35.4%
PM2.5	16.5%	49.5%
SO_2	-370.6%	3.6%
CO	99.4%	99.4%
GHG	13.3%	32.6%

Policies to encourage a higher level of market penetration of EVs will help the region address current and future air quality challenges, especially high levels of ground-level ozone (created by photochemical reactions between 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.

Benefits of Electric Vehicles

There are currently 15 light-duty electric vehicle models (EVs) available from large scale vehicle manufacturers, including plug-in hybrid electric vehicles (PHEVs), with seven more models expected by 2014.[1] 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 Colorado. 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 17% less energy.[2]
- *Locally produced energy source*: Approximately half of the petroleum used in Colorado is imported, while electricity is produced using locally abundant energy resources.[3]
- *Reduced emissions*: EVs have the potential to reduce greatly harmful tailpipe emissions and climate changing greenhouse gas emissions compared to gasoline powered vehicles.[4]
- *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 $1.14 per gallon.[5]

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.[6] Denver and the surrounding areas suffer from serious air quality challenges, and mobile source emissions contribute significantly to this problem. Supporting widespread adoption of electric vehicles is an important strategy for addressing air quality in the region.

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[1] 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.shtml

[2] 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

[3] Energy Information Administration. 2013. Colorado: State Profile and Energy Estimates. Retrieved from http://www.eia.gov/state/data.cfm?sid=CO

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

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

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

Analysis of Air Emissions from Electric Vehicles in Denver and the North Front Range

Analysis Methodology

SWEEP performed an analysis comparing the emissions associated with three vehicle technologies in 2013 and 2020: an electric vehicle (EV) with a range of 70 miles,[7] a compressed natural gas (CNG) vehicle[8] and a traditional gasoline passenger vehicle.[9] This analysis focused on air quality emissions around the Denver metropolitan area and the North Front Range where approximately two-thirds of the state's population lives.[10]

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).[11] The analysis also evaluates greenhouse gas emissions. *The NOx and VOC emissions are particularly important as the region is currently in non-attainment for permissible levels of these pollutants.* 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.[12] The GREET model was used to make a comparison between the life-cycle emissions of three light-duty vehicle fuels: gasoline,

[7] The BEV was modeled on the 2013 Nissan Leaf.
[8] The CNG vehicle was modeled on the Honda Civic Natural Gas
[9] A new 2013 gasoline fueled passenger vehicle is assumed to have a fuel economy of 28 mpg.
[10] Colorado Department of Local Affairs. 2013. Population Totals for Colorado Counties. Retrieved from http://www.colorado.gov/cs/Satellite?c=Page&childpagename=DOLA-Main%2FCBONLayout&cid=1251593346867&pagename=CBONWrapper
[11] "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/.
[12] Argonne National Laboratory. 2012. Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation. Retrieved from http://greet.es.anl.gov/

electricity, and natural gas. New vehicles purchased in 2013 are analyzed in 2013 to show which vehicles will have the most immediate impact regarding energy use and emissions (see Figure 1 and Table 1).

The analysis also looks at how new vehicles purchased in 2020 perform in that year (see Table 2 and Figure 2). We only considered regulations that have been adopted, so did not assume emissions reduction in 2020 for gasoline vehicles from the EPA's proposed new Tier III emissions and fuel standards, which will impact 2017 and later model years if they are adopted.[13] If the Tier III standards are adopted, the emissions associated with new gasoline vehicles sold after 2017 will decline significantly. We also did not assume new EPA rules that may further reduce emissions from electric power plants. We assumed new gasoline and CNG vehicles purchased in 2020 will meet the CAFE fuel economy standards that will be in effect in 2020.

To estimate electricity generation mixes, SWEEP used Xcel Energy's (the utility serving the majority of the Denver metropolitan area) latest numbers from 2012.[14] 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, we have decided to use the average generation mix for 2012 for both base load and marginal electricity demand in 2013.

For base load electricity generation in the 2020 scenario, we relied on analysis conducted by Synapse Energy Economics for SWEEP's *$20 Billion Bonanza* study.[15] We also used an analysis of the generation mix for the marginal demand created by EVs. This came from work conducted by researchers at the National Renewable Energy Laboratory and the University of Colorado Mechanical Engineering Department for the Colorado Electric Vehicles Infrastructure Research

[13] Assuming, the federal Tier III emissions and fuel standards are implemented, beginning in 2017 all new passenger vehicles will have the same tailpipe emissions as the Honda Civic CNG. Therefore, beginning in 2017 EVs will represent the primary opportunity for additional reductions in tailpipe emissions in new passenger vehicles.
[14] Xcel Energy. 2013. 2012 Owned and Purchased Energy. Retrieved from http://www.xcelenergy.com/About_Us/Our_Company/Power_Generation/Power_Generation_Fuel_Mix_-_PSCo
[15] 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

Project (CEVIRP).[16] Also from the *$20 Billion Bonanza* study, we used NOx emission rates from coal power plants for 2013 and 2020.

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 Colorado to show exactly what emissions are likely to contribute to the Denver metro and North Front Range area airshed. Note that in July, SWEEP released a multi-state analysis of emissions from electric vehicles, which arrives at slightly different conclusions for Colorado, as it analyzes *statewide* lifecycle emissions, and does not focus specifically on the Denver and North Front Range non-attainment area.

Regarding relevant upstream emissions from electricity, SWEEP has calculated that in 2013, 21% of statewide coal plant emissions and 78% of natural gas plant emissions take place in the area around Denver and contribute emissions into the region's airshed.[17] In 2020, due to the planned retirement of the area's coal plants, 9% of statewide coal plant emissions would take place in this area and 85% of natural gas emissions would come from this region. [18] For upstream emissions for gasoline vehicles, 35% of the emissions associated with gasoline refining take place in the Denver metro area due to the Suncor refineries located in Adams County which process approximately 35% of the gasoline used in the state.

Regarding the extraction of fuel (mining and drilling): it is estimated that 81% of the state's oil drilling and 17% of natural gas extraction take place in the Denver metro and North Front Range area (the vast majority of which takes place in Weld County).[19] In addition, it was assumed that 0% of coal mining contributes to urban emissions.

Air Emissions Results

In 2013, the analysis shows that in the non-attainment area, electric vehicles reduce emissions of criteria pollutants (with the exception of SO_2 emissions) compared to a comparable gasoline

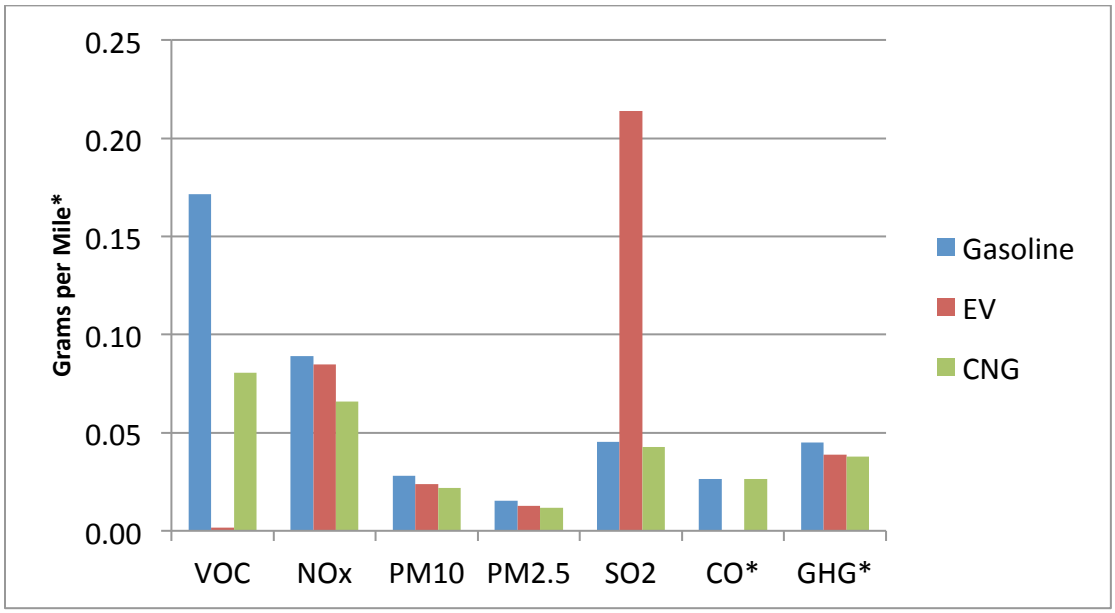
[16] Jorgensen et al. 2012. Emissions Changes from Electric Vehicle Use in Colorado, Appendix 24 to Colorado Electric Vehicle and Infrastructure Readiness Plan.
[17] Environmental Protection Agency. 2013. eGRID2012 Version 1.0. Retrieved from http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
[18] The coal emissions are coming entirely from the Rawhide plant northeast of Fort Collins. The other coal plants that are currently in the area are expected to be retired or shifted to natural gas as part of the Clean Air, Clean Jobs Act.
[19] Colorado Oil and Gas Conservation Commission. 2013. COGIS – Production Data Inquiry. Retrieved from http://cogcc.state.co.us/

fueled vehicle. The analysis also shows that CNG and electric vehicles both have clear advantages over gasoline-fueled vehicles regarding pollutants. In Table 1 and Figure 1 we break down the reductions in harmful air pollutants from EVs in the non-attainment area. EVs have essentially zero emissions of VOCs and CO.

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

	EV	CNG
VOC	99.1%	53.0%
NOx	4.5%	25.7%
PM10	14.7%	22.1%
PM2.5	16.5%	22.7%
SO_2	-370.6%	6.2%
CO	99.4%	0.4%
GHG	13.3%	17.4%

Figure 1. Criteria Pollutant Emissions in Denver Metro 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.

By 2020, as a result of the significant changes that are being made to Colorado's electricity generation system between 2013 and 2020 (due mainly to the *Clean Air, Clean Jobs* bill[20] and

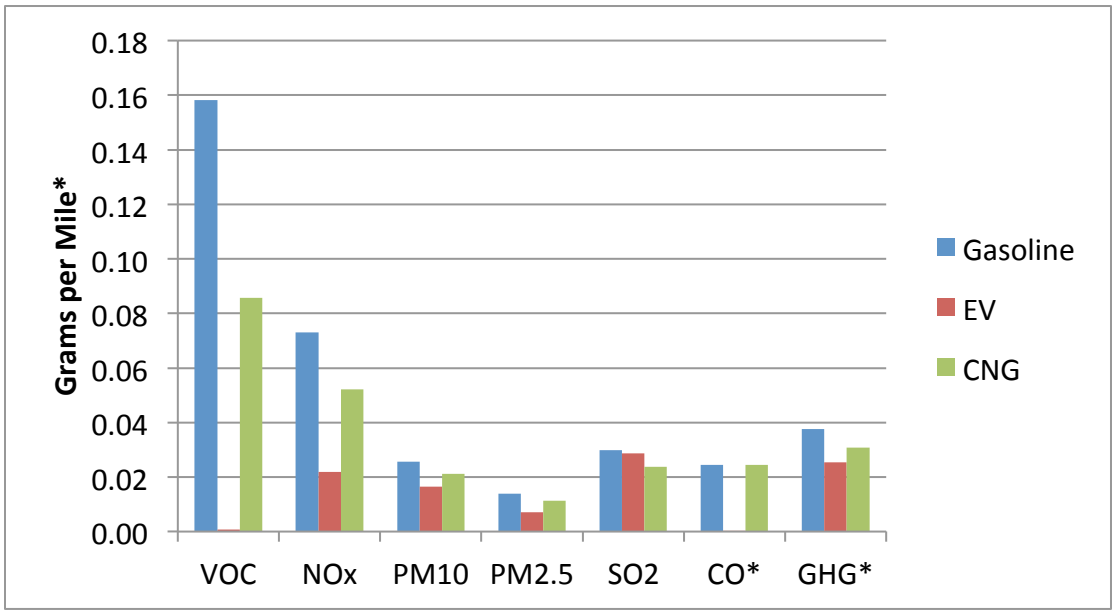
[20] Colorado House Bill 10-1365. Clean Air, Clean Jobs is expected to result in an 88% reduction in NO_x emissions and a 28% reduction in CO_2 emissions from the electricity generating sector. Retrieved from http://rechargecolorado.org/images/uploads/pdfs/Colorado_Clean_Air_Clean_Jobs_Act_GEO_White0Paper.pdf

the Renewable Portfolio Standard[21]) a new EV driven in 2020 will have significantly greater benefits than in 2013. EVs still eliminate almost all urban emissions of VOCs and CO. They have much lower NOx emissions and now have a slight advantage regarding SO_2 emissions compared to a new gasoline vehicle. By 2020, SO_2 is the only criteria pollutant where CNG vehicles retain an emission advantage over EVs.

Table 2. Percent Reduction in Emissions in 2020 Compared to New Gasoline Vehicle

	EV	CNG
VOC	99.5%	45.9%
NOx	70.1%	28.7%
PM10	35.4%	17.1%
PM2.5	49.5%	18.4%
SO_2	3.6%	20.2%
CO	99.4%	0.4%
GHG	32.6%	20.4%

Figure 2. Criteria Pollutant Emissions in Denver Metro by Vehicle Type, New 2020 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.

[21] Colorado's Renewable Portfolio Standard calls for 30% of investor-owned utility electricity generation to come from renewables and 20% of generation from cooperatives and municipal utilities to come from renewables.

Table 3. Sources of Pollutants as a Percent of Total Emissions in Non-Attainment Area[22]

	NOx	VOC
Mobile Emissions	67.3%	42.3%
Light Duty Gasoline Vehicle Emissions	26.8%	27.0%

Currently, the region is in non-attainment for EPA standards for ground-level ozone.[23] Table 3 shows the contribution of mobile sources and light duty gasoline vehicles to overall emission levels in the region.

Concentrations of ground level ozone in the non-attainment area 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 one to two in 2010, to 10 in 2011 and to 12 in 2012.[24] So far in 2013, nine monitors have exceeded the EPA standard at least four times.[25] 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 six monitors were in violation using the 2010 to 2012 three-year averages. [26]

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 70% by 2020. In addition, light duty gasoline vehicles make up over a quarter of VOC and NOx emissions in the area as shown in Table 3.

As the state 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

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

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

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

[25] Regional Air Quality Council. 2013. 4th Maximum Values Table (ppb) through September 2, 2013. Retrieved from http://raqc.org/news/detail/4th_maximum_ozone_values_table_ppb_through_july_28_2013/

[26] 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 Denver and the Front Range.

could make it more difficult for the region to be in compliance. This analysis demonstrates that a shift to electric vehicles will help the area comply with both the current and the potential new standard.

While the Denver metro area is not currently in non-attainment for CO, SO_2 PM2.5 and PM10, electric vehicles do reduce emissions of these pollutants. 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.[27] Vulnerable populations, such as children and the elderly, are at greater risk from exposure to these pollutants.

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