SWEEP

SOUTHWEST ENERGY EFFICIENCY PROJECT

Saving Money and Protecting the Environment Through More Efficient Energy Use

The Potential for Electric Vehicles to Reduce Vehicle Emissions and Improve Air Quality in the Wasatch Front

Southwest Energy Efficiency Project and Utah Clean Energy

Executive Summary

This report shows that in the Wasatch Front region, light-duty electric vehicles reduce emissions of criteria pollutants compared to a comparable gasoline-fueled vehicle. In 2013, for battery electric vehicles, the largest emissions reductions (99% compared to a gasoline-fueled vehicle) are for Volatile Organic Compounds (VOCs) and Carbon Monoxide (CO) with significant additional reductions in Sulfur Dioxide (SO_2) of 96%, Nitrogen Oxides (NOx) of 76% and Particulate Matter (65% for PM2.5 and 49% for PM10). Table 1 shows what percentage of reduction each vehicle type provides in comparison to a new gasoline vehicle in 2013.

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

	BEV	PHEV10	PHEV40	CNG
VOC	99.7%	40.9%	63.6%	84.4%
NOx	76.1%	33.2%	53.4%	80.5%
PM10	49.3%	16.1%	28.0%	30.9%
PM2.5	64.8%	19.4%	36.5%	33.3%
SO_2	95.7%	42.0%	57.2%	88.0%
CO	99.8%	17.2%	54.0%	0.6%
GHG	1.8%	19.5%	1.1%	16.7%

All the vehicle types analyzed in this report provide reductions compared to gasoline vehicles. The scale of reduction for electric vehicles depends on the amount of driving that is powered by electricity. A battery electric vehicle (BEV) vehicle that is fully powered by electricity performs better than plug-in hybrid electric vehicles (PHEV) powered by a mix of gasoline and electricity. CNG vehicles perform better than PHEVs on most pollutants, with the notable exception of Carbon Monoxide; BEVs perform best in all categories except emissions of greenhouse gases.

Introduction

The Wasatch Front currently experiences significant air quality problems resulting in negative quality of life and health impacts for area residents. Parts of the region have been designated as non-attainment areas by the US Environmental Protection Agency for Particulate Matter (of both 2.5 and 10 micrometers, PM2.5 and PM10) and Sulfur Dioxide (SO_2).Ground level ozone and carbon monoxide levels are also monitored in the area as sections are currently designated as a maintenance areas. Light duty vehicles are significant contributors for each of these pollutants. The emissions inventories developed by the Utah Department of Environmental

Quality show mobile sources (of which light duty vehicles are a major component) account for significant percentages of the pollution in region (66% of NOx, 48% of PM2.5, 12% of SO_2 and 48% of VOCs),[1] so strategies that can reduce emissions from mobile sources have significant potential benefit. Over the next 30 years, population in the region is expected to increase 65%[2] which is estimated to result in nearly doubling the amount of automobile travel.[3] This increased level of vehicle travel will make it difficult for the region to maintain or improve emissions levels unless significant reductions are achieved from light-duty vehicles.

In 2013, state legislation was adopted (SB 275) that directed the Public Service Commission to open a docket to investigate "options and opportunities for advancing and promoting measures designed to result in cleaner air in the state through the enhanced use of alternative fuel vehicles." Electric vehicles, which are a subset of alternative fuel vehicles, offer the potential to significantly reduce criteria pollutants compared to regular gasoline-fueled vehicles. This report presents an analysis of the emissions levels of electric fueled vehicles compared with both gasoline and compressed natural gas vehicles in the Wasatch Front region.

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.[4] 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 Utah. In addition to the emission benefits discussed in detail in this report, 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 12% less energy.[5]
- *Locally produced energy source*: Almost half (44%) of the petroleum used in Utah is imported, while electricity is produced almost entirely from domestic sources of energy and within the state.[6]
- *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 $0.95 per gallon.[7]

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[1] Utah Department of Environmental Quality. 2013. http://www.airquality.utah.gov/Public-Interest/Current-Issues/pm2.5/presentations/index.html

[2] Wasatch Choice for 2040. 2013. Growth is Coming!. http://www.wasatchchoice2040.com/

[3] Wasatch Front Regional Council. 2011. 2011-2040 Regional Transportation Plan. Chapter 2 – Regional Visioning. http://www.wfrc.org/new_wfrc/index.php/plans/regional-transportation-plan

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

[5] 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

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

Table 2. Listing of Light Duty Alternative Fuel Vehicles

Currently Available in the US	Type of Vehicle
Scion IQ EV	EV
Chevy Spark EV	EV
Coda	EV
Fiat 500e	EV
Ford Focus	EV
Honda Fit	EV
Mitsubishi I-MIEV	EV
Nissan Leaf	EV
Smart for Two	EV
Tesla Model S	EV
Toyota RAV4	EV
Ford Fusion Energi	PHEV
Toyota Prius Plug-In	PHEV
Chevy Volt	PHEV
Ford C-MAX Energi	PHEV
Honda Civic Natural Gas	CNG
Available in 2014	
BMW i3	EV
Mercedes-Benz B-Class EV	EV
Kia Soul EV	EV
Volkswagen eGolf	EV
Honda Accord	EV
Mitsubishi Outlander Plug-in	PHEV
Cadillac ELR	PHEV

[7] Based on a gasoline fueled vehicle with a fuel economy of 28 mpg and an electric vehicle traveling 3 miles per kWh and a kWh costing $0.103.

Analysis of Air Emissions from Electric Vehicles in Utah

SWEEP performed analysis comparing the emissions associated with three types of electric vehicles, both in 2013 and 2020: a plug-in hybrid electric vehicle (PHEV) that has an electric range of 10 miles (PHEV10)[8]; an extended range plug-in hybrid electric vehicle (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 new gasoline passenger vehicle. This analysis focused on air quality emissions within Utah's current non-attainment areas: Box Elder County, Cache County, Davis County, Salt Lake County, Tooele County, Utah County, and Weber County.

The analysis evaluates emissions of the following criteria pollutants[12]: 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). The analysis also evaluates greenhouse gas emissions. *The PM2.5, PM10 and SO_2 emissions are particularly important as the region is currently in non-attainment for permissible levels of these three pollutants.* Note that SO_2, NOx and VOCs are all also precursors for PM2.5. For ground level ozone and CO, the region is a maintenance area[13]; however 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.

The analysis shows that in the non-attainment area 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

[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] "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/.
[13] "A maintenance area is an area that was once designated as nonattainment, and which subsequently demonstrated to EPA statistically that it will attain and maintain a particular standard for a period of 10 years." From *Utah Division of Air Quality 2012 Annual Report*, Retrieved from http://www.airquality.utah.gov/Public-Interest/annual-report/.pdf/2012Annual%20Report.pdf

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.

Emissions Scenarios

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.[14] 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. SWEEP analyzed the energy consumption and emissions of these three vehicle fuels in three different scenarios in order to assess the emissions impacts of two major trends: the planned improvements in fuel economy for new vehicles and the shift in the electrical generation sector away from coal and towards natural gas and renewables, as described below.

Scenario 1: 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, below.

Scenario 2: The same 2013 vehicles are then compared again assuming they are still operating in 2020. Because vehicles purchased in 2013 will remain on the road, consuming energy and emitting pollutants for many years, it is important to understand how they will perform in the future. While vehicle tailpipe emissions from internal combustion engines purchased in 2013 are expected to increase over time due to deterioration of engine performance and emission control systems, no change in tailpipe emissions has been assumed for this analysis. Therefore, this analysis presents a conservative estimate of tailpipe emissions, and actual tailpipe emissions are likely to be higher. See Figure 2, below.

Scenario 3: The analysis also looks at how new vehicles purchased in 2020 perform in that year. 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.[15] 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, which could lead to lower emissions from the operation of electric

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

[15] 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.

vehicles. We assumed new gasoline vehicles purchased in 2020 will meet the federal vehicle fuel economy standards that will be in effect in 2020. See Figure 3, below.

To estimate electricity generation mixes in the future, SWEEP relied on forecasts conducted by Synapse Energy Economics for SWEEP's *$20 Billion Bonanza* study.[16] We have used the "high efficiency scenario," which best fits our assessment of the region's trajectory regarding the retirement of coal power plants. Also from the *$20 Billion Bonanza* study, we used NOx emission rates from coal power plants for 2013 and 2020 to reflect the retirement of older plants and the installation of emission controls on remaining plants to meet existing Clean Air Act requirements.

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 regular generation mix forecast for 2020 for both baseload 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 Utah to show exactly what emissions are likely to contribute to the Wasatch Front's airshed. Note that on July 15, 2013 SWEEP released a multi-state analysis of emissions from electric vehicles, which arrives at different conclusions for Utah, as it analyzes *statewide* lifecycle emissions, and does not focus specifically on the Wasatch Front non-attainment area.[17]

Regarding relevant upstream emissions from electricity, SWEEP has calculated that 0% of statewide coal plant emissions[18] and 60% of natural gas plant emissions take place along the Wasatch Front. This is based on 60% of the state's natural gas generation occurring in counties

[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

[17] Because almost all of the state's coal fired power plants are located outside of the Wasatch Front area, their emissions do not contribute the emissions shown in the analysis for this report. While the statewide analysis mentioned above shows increased electric vehicle emissions compared to this analysis (since the electricity is sourced from Utah's statewide (mostly coal) power plants), electric vehicles are nevertheless estimated to result in long-term state-wide emissions reductions.

[18] While the Kennecott coal plant operates in the Wastach Front, its power is only used for operations at the Kennecott facility and is therefore not supplying electricity to EVs charging in the area.

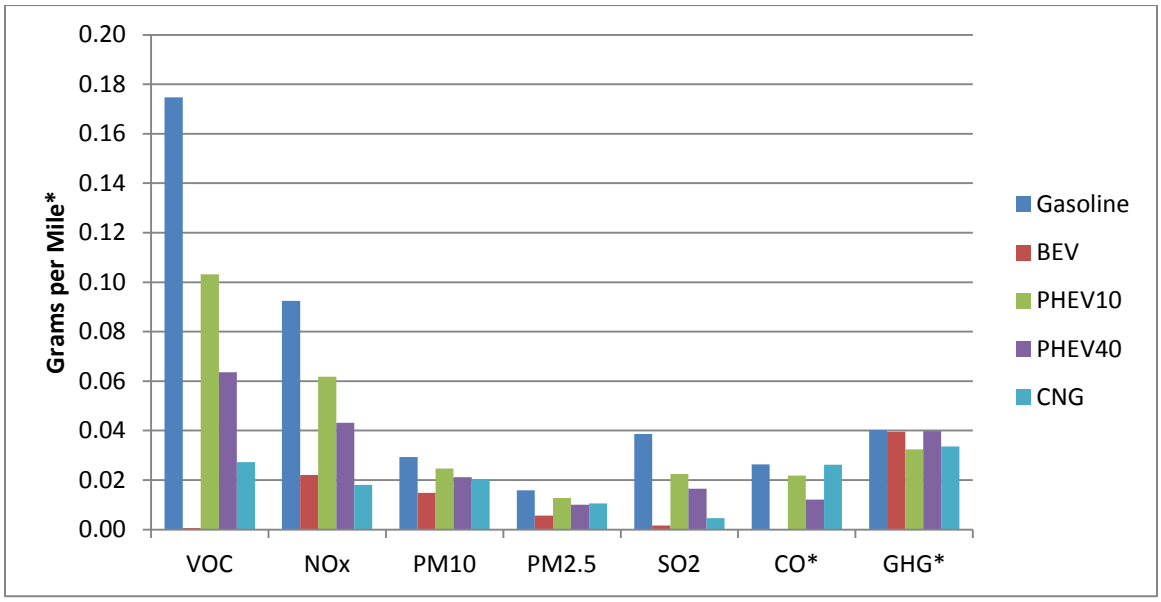
that are either in non-attainment or maintenance areas for criteria pollutants (Salt Lake, Utah, Davis, Weber, and Cache Counties all have natural gas plants). For upstream emissions for gasoline vehicles, 100% of the emissions associated with gasoline refining take place in the Wasatch Front as all five of the state's refineries (which produce more gasoline than the state consumes) are located in Salt Lake and Davis Counties.

Regarding the extraction of fuel (mining and drilling): all of the state's coal mines are located outside of the non-attainment area and a very small number of oil and gas fields are located in non-attainment counties. For the purposes of the GREET model, it was assumed that 1% of oil and gas extraction and 0% of coal mining contributes to urban emissions.

Findings

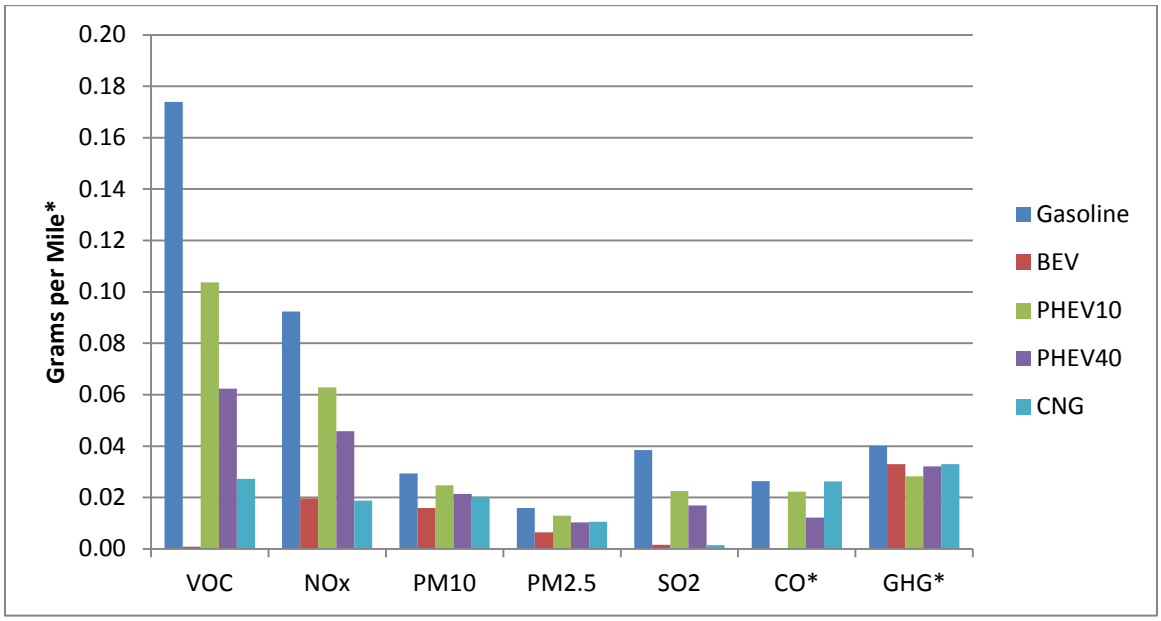
Below, we present a comparison of emissions levels from five different vehicle typres. Figures 1-3 show that all types of electric vehicles have lower levels of emissions for all the criteria pollutants compared to gasoline vehicles. The scale of the reductions corresponds to percentage of miles driven on electricity, with BEVs offering the greatest reductions and PHEV10s the least amount of emission reductions. BEVs have essentially zero emissions of VOCs, SO_2 and CO. The most significant reductions are in the ozone precursors, VOC and NOx. Compared to CNG vehicles, the BEVs generally have lower emissions (except for NOx) while the PHEVs have higher emissions of VOCs, NOx and SO_2, lower emissions of CO, and similar levels of emissions of PM2.5 and PM10.

Figure 1. Criteria Pollutant Emissions in Wasatch Front by Vehicle Type, New 2013 Vehicles



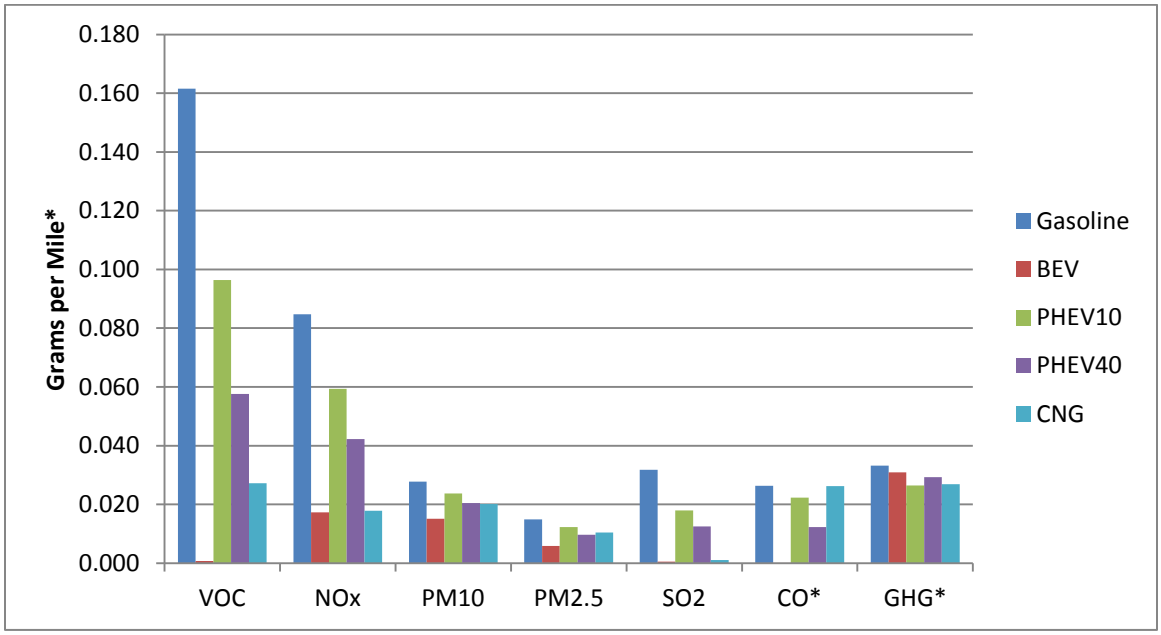
*The scale of emissions from CO and GHG has been changed so that all the pollutants could be placed in one chart. CO emissions have been reduced by a factor of 100 so in fact numbers are around 2.5 grams per mile and GHG emissions have been reduced by a factor of 10,000 so in fact numbers are around 300 grams per mile.

Figure 2. Criteria Pollutant Emissions in Wasatch Front by Vehicle Type, 2013 Vehicles in 2020



*The scale of emissions from CO and GHG has been changed so that all the pollutants could be placed in one chart. CO emissions have been reduced by a factor of 100 so in fact numbers are around 2.5 grams per mile and GHG emissions have been reduced by a factor of 10,000 so in fact numbers are around 300 grams per mile.

Figure 3. Criteria Pollutant Emissions in Wasatch Front by Vehicle Type, New 2020 Vehicles in 2020



*The scale of emissions from CO and GHG has been changed so that all the pollutants could be placed in one chart. CO emissions have been reduced by a factor of 100 so in fact numbers are around 2.5 grams per mile and GHG emissions have been reduced by a factor of 10,000 so in fact numbers are around 300 grams per mile.

Discussion of Federal Tier III Emissions Standards

The EPA's proposed Tier III standards, if implemented, will reduce the sulfur content of gasoline and reduce tailpipe emissions from gasoline fueled vehicles which would help to reduce emissions and improve urban air quality in the Wasatch Front.

Provided that tailpipe emissions are reduced via the Tier III standards, in 2020, battery electric vehicles will nevertheless offer emission advantages for criteria pollutants such as VOCs, SO2 and CO. And over the longer term, electric vehicles, when powered by renewable electricity sources, provide the opportunity to completely eliminate vehicle related emissions and will be one of the few ways to achieve emission reductions beyond the Tier III standards once they are in effect. In addition, Tier III standards will be phased in between 2017 and 2025 so they will take a number of years to improve air quality. Because of their availability in the market today, electric vehicles offer the opportunity to realize immediate air quality improvements from new vehicles along the Wasatch Front.

Finally, there are also potential federal regulations that will lead to additional reductions in emissions from electric vehicles. Power plants today are subject to regulations which are helping electricity generation become cleaner, such as regional haze rules, and will soon be subject to additional rules, including the mercury and air toxics standards and water regulations. In addition, the EPA has been directed to pursue new rulemakings on power plant greenhouse gas emissions for both new and existing power plants. Just as the Tier III standards will, if adopted, lead to reductions in emissions from gasoline vehicles, power plant standards will lead to further reductions in emissions from electric vehicles.

Conclusion

Electric vehicles can provide significant reductions in urban vehicle emissions. Battery electric vehicles significantly reduce all criteria pollutants and nearly eliminate emissions of VOCs, CO and SO_2. Plug-in hybrid vehicles offer less emission reduction than battery electric vehicles but still are cleaner and provide benefits compared to gasoline vehicles.

In the future, as electricity generation shifts to more renewable electricity sources, electric vehicles offer the potential for vehicles with close to zero emissions.

As state agencies, the legislature, the Public Service Commission and local governments consider new efforts to address air pollution in the Wasatch Front, policies to increase the use of EVs may be an important component of strategies to reduce urban air pollution and improve public health in the Wasatch Front. We have prepared a summary of potential policy options for consideration by policymakers and submitted these to the Utah Public Service Commission; these may viewed on the SWEEP website at:
http://www.swenergy.org/publications/documents/Initial%20Comments%20of%20SWEEP%20and%20UCE%20Docket%2013-057-02%20FINAL.pdf