Transportation Fuels for the Southwest:

Life-cycle Energy Use and Environmental Impacts of Electric, Compressed Natural Gas and Gasoline Vehicles

What is the cleanest car in each of the six southwestern states? This report shows that the comparable performance of electric vehicles improves as renewables and natural gas increase their share of electricity generation over coal.

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Southwest Energy Efficiency Project

July 2013

SWEEP
SOUTHWEST ENERGY EFFICIENCY PROJECT

About SWEEP: The Southwest Energy Efficiency Project is a public interest organization dedicated to advancing energy efficiency in Arizona, Colorado, Nevada, New Mexico, Utah and Wyoming. For more information, visit www.swenergy.org.

SWEEP's Transportation Program seeks to identify and promote the implementation of policies designed to achieve significant energy savings and reductions in greenhouse gas emissions from the transportation sector. SWEEP's work focuses on two general strategies: reducing vehicle miles traveled and improving vehicle fuel efficiency.

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Executive Summary

Plug-in electric vehicles are no longer a thing of the future. They are becoming more common on roads today, and every year now automobile manufacturers are announcing more new models to appeal to buyers in every price range.

As electric vehicles (EVs) become more widespread in the Southwest, it is important for policy-makers as well as consumers to understand the cars' lifecycle energy consumption and emissions. Are the cars cleaner than conventional gasoline and natural gas fueled vehicles? How do the three fuels compare?

This report provides answers for the Southwest states of Arizona, Colorado, Nevada, New Mexico, Utah and Wyoming. It is intended to contribute data and analysis needed by policymakers.

This report also is a logical next step to an earlier May, 2013, report released by the Southwest Energy Efficiency Project (SWEEP), *Policies to Promote Electric Vehicles in the Southwest.*[1] The earlier report provided analysis of the policies that have been adopted to support electric vehicles by state governments across the Southwest, and found a wide variation in policy support. This new report identifies the states where electric vehicles offer the greatest emissions benefits. These are the states where supportive policies make the most sense.

What becomes clear is that the emissions benefits of EVs compared to traditional gasoline-fueled and compressed natural gas (CNG) vehicles vary significantly from state to state and are highly dependent upon the fuels used to generate electricity in each state. For instance, today EVs are much cleaner in Arizona and Nevada, which use relatively low amounts of coal to generate their electricity supply, than in Wyoming, which produces almost all of its electricity from coal. Because coal-fired power plants are a major contributor to smog and greenhouse gas emissions in the Southwest, coal's use in the production of electricity consumed in each state is a key determinant—though not the only one—of whether EVs are cleaner or not.

What's more, over the next several years the electricity fuel mix in the Southwest is expected to shift towards less coal and more natural gas and renewable electricity. Because of these more

[1] Salisbury, M. 2013. Policies to Promote Electric Vehicles in the Southwest. Retrieved from http://www.swenergy.org/publications/documents/EV%20Report%20CardFNLwithCover.5.15.13.pdf

efficient and cleaner fuel sources, electric vehicles will use less energy and produce fewer emissions every year they are on the road. During the same time frame, new gasoline, CNG and electric vehicles will also become more efficient.

This report considers all of these factors. Table ES-1 below illustrates the top performing vehicle types by parameter in each of three scenarios analyzed for each state. From this table it is easy to see that by 2020, EVs will outperform CNG and gasoline vehicles on almost every measure in Arizona, Colorado and Nevada, where coal is or will become less prevalent for electricity generation. The results are not so clear in New Mexico, Utah and Wyoming, where—because coal remains the primary source of electricity generation—CNG vehicles retain some advantages.

A word of caution on interpreting these results: for emissions that contribute to smog, the location where the pollution is emitted is very important. Gasoline and CNG vehicles driven in urban areas emit pollution directly into urban airsheds; in many cases, the power plants that supply EVs are located outside of these urban areas. For example, we have conducted a more fine-grained analysis of emissions from EVs in Utah, which concluded that EVs provide significant air quality benefits to the Salt Lake City area, because most of the emissions are outside of the urban airshed.[2]

SWEEP performed this analysis using the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) fuel-cycle model developed by Argonne National Laboratory with funding from the U.S. Department of Energy.[3] The GREET model was used to make a comparison between the life-cycle energy use and emissions of three light-duty vehicle fuels: gasoline, compressed natural gas (CNG) and electricity.

Comparing the current performance of vehicles purchased in 2013 with how those same vehicles are expected to perform in 2020 provides additional context for evaluating the three fuel and vehicle technologies.[4] Therefore, we analyzed the energy consumption and emissions of the three vehicle fuels in three different scenarios: new vehicles in 2013, 2013 vehicles in 2020, and new vehicles in 2020. The three scenarios demonstrate the effects 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. While the fuel economy improvements are a federal requirement and therefore expected to be consistent across the southwestern states, the changes in the electrical generation vary considerably by state.

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[2] Southwest Energy Efficiency Project and Utah Clean Energy. 2013. Initial Comments for the Utah PSC on SB 275 Energy Amendments, Docket No. 13-057-02. Available at www.swenergy.org.

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

[4] The GREET model is designed to run only through 2020, so it is not possible to extend the comparison over the full operating life of the vehicle.

Table ES-1. Summary of Best Performing Vehicles in Each State, 2013-2020

Parameter	New vehicles in 2013	2013 vehicles in 2020	New vehicles in 2020
ARIZONA			
Energy consumption	EV	EV	EV
GHG	EV	EV	EV
NO_x	CNG	EV	EV
VOC	EV	EV	EV
COLORADO			
Energy consumption	EV	EV	EV
GHG	CNG	EV	EV
NO_x	CNG	EV	EV
VOC	EV	EV	EV
NEVADA			
Energy consumption	EV	EV	EV
GHG	EV	EV	EV
NO_x	CNG	EV	CNG
VOC	EV	EV	EV
NEW MEXICO			
Energy consumption	EV	EV	CNG
GHG	CNG	EV	CNG
NO_x	CNG	EV	CNG
VOC	EV	EV	EV
UTAH			
Energy consumption	EV	EV	CNG
GHG	CNG	CNG	CNG
NO_x	CNG	EV	CNG
VOC	EV	EV	EV
WYOMING			
Energy consumption	EV	EV	CNG
GHG	CNG	CNG	CNG
NO_x	CNG	EV	EV
VOC	EV	EV	EV

Comparison Across Southwest States

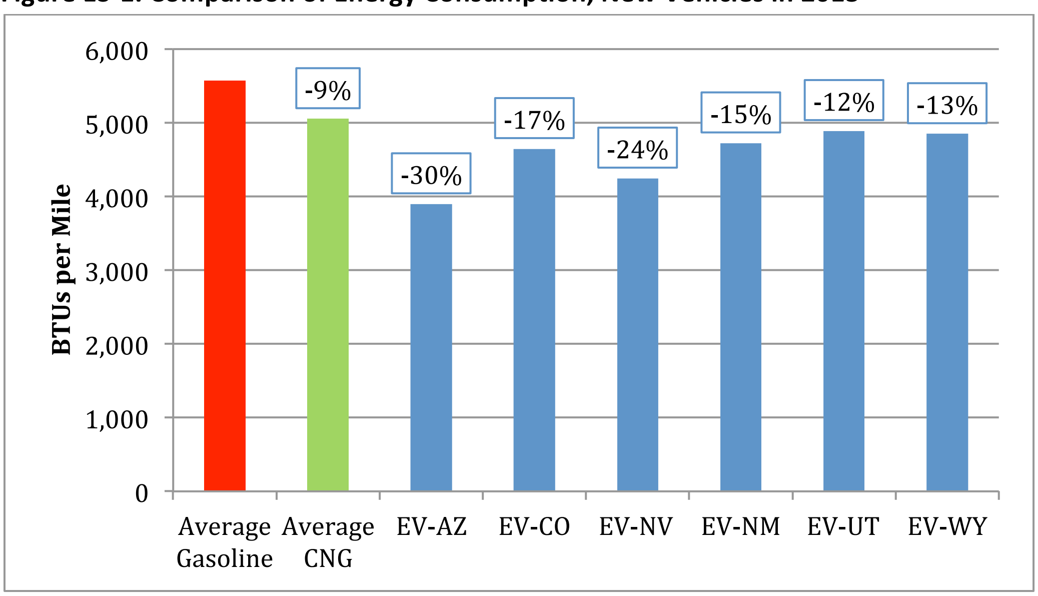
The following figures compare energy consumption and emissions from gasoline, CNG and electric vehicles in each of the southwestern states. Because results for gasoline and CNG vehicles are quite consistent across states and electric vehicles vary significantly, the average of all six states' results for gasoline and CNG vehicles is shown. The numbers above each bar in the graphs below represent the percent change (positive or negative) of that vehicle compared to the gasoline fueled vehicle.

Energy Use

Electric motors are approximately three times more efficient than internal combustion engines at converting energy stored in the vehicle to miles driven.[5] However, our measure of energy efficiency is based upon source energy, so we must factor in the efficiency of conversion of energy to electricity at the power plant to get the net "well to wheels" efficiency. Fossil fuel power plants have varying levels of efficiency, depending upon the fuel mix for electricity generation. Even in 2013, vehicles that are powered by relatively inefficient coal power plants will outperform gasoline and CNG vehicles in energy efficiency. By 2020, as inefficient and high-polluting coal power plants are replaced by cleaner natural gas and renewable sources, the efficiency advantage of electric vehicles will increase (even for EVs purchased prior to 2020).

For new vehicles in 2020, expected improvements in the efficiency of vehicles will make EVs more efficient in Arizona, Colorado and Nevada, while CNG will be more efficient than EVs in New Mexico, Utah and Wyoming. Gasoline vehicles will remain the least efficient vehicle technology in all six states.

Figure ES-1. Comparison of Energy Consumption, New Vehicles in 2013



[5] US Department of Energy. 2013. Electric Vehicles. Retrieved from http://www.fueleconomy.gov/feg/evtech.shtml

Figure ES-2. Comparison of Energy Consumption, 2013 Vehicles in 2020

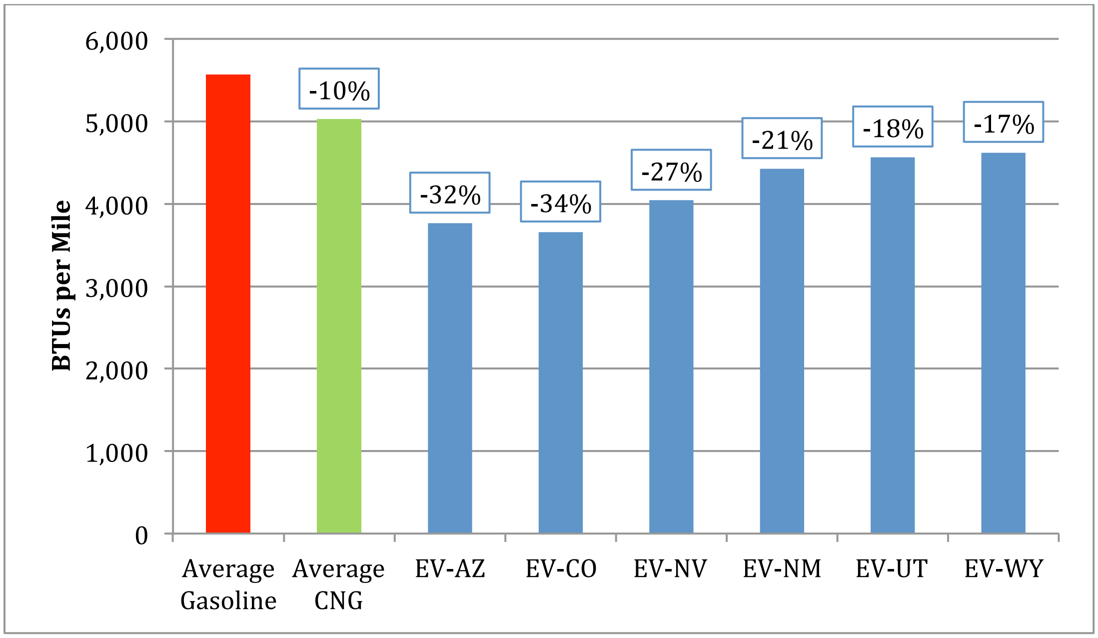
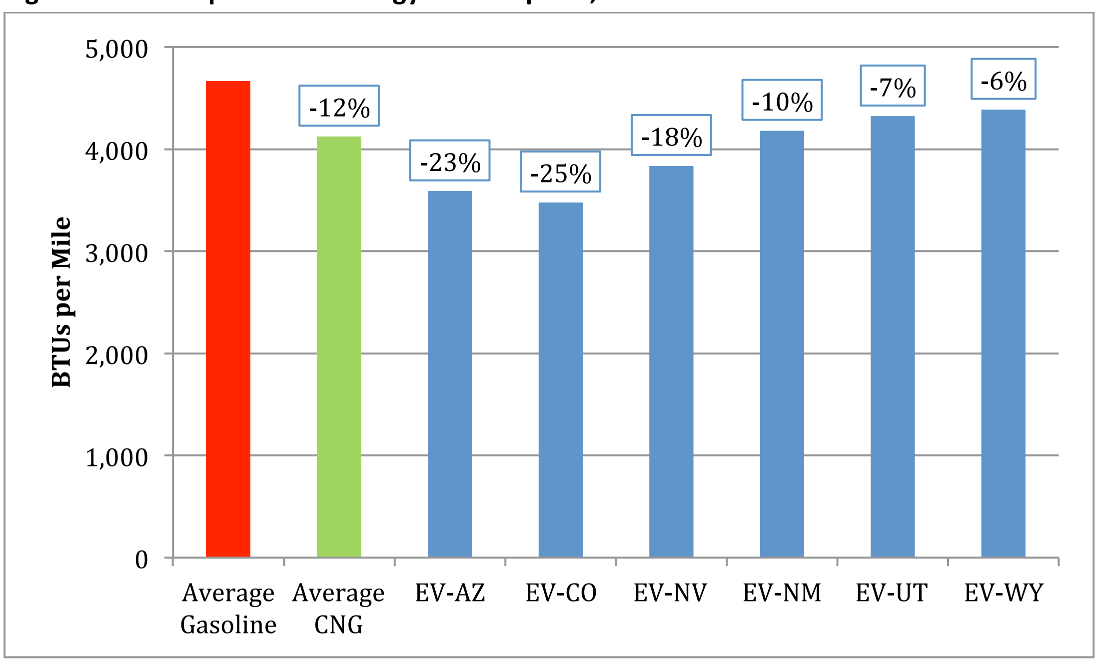


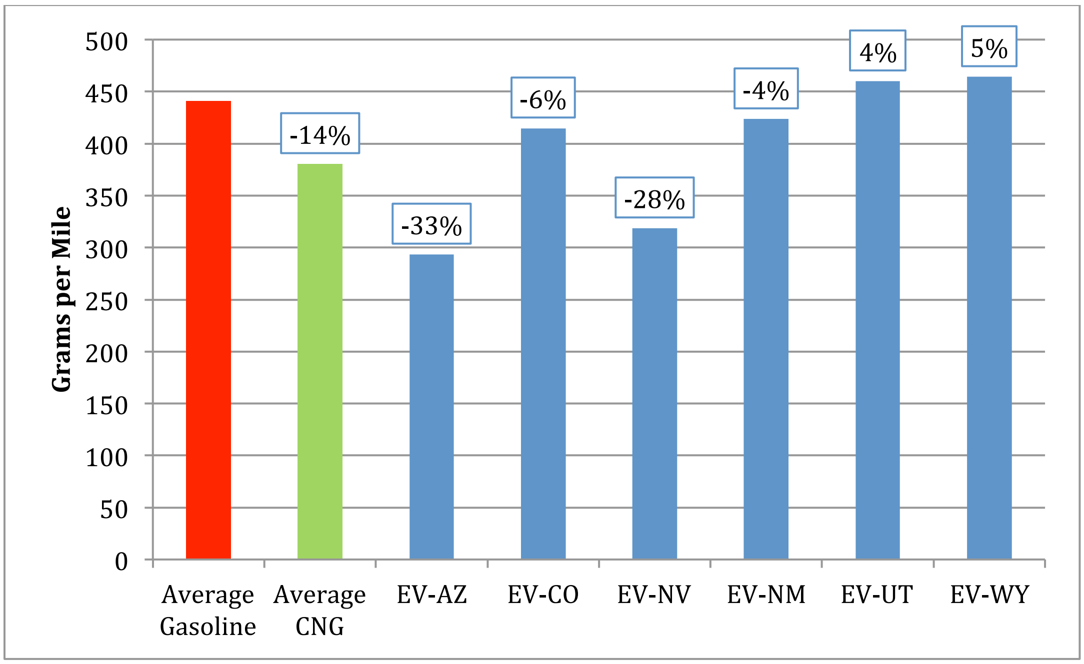
Figure ES-3. Comparison of Energy Consumption, New Vehicles in 2020



Greenhouse Gas Emissions

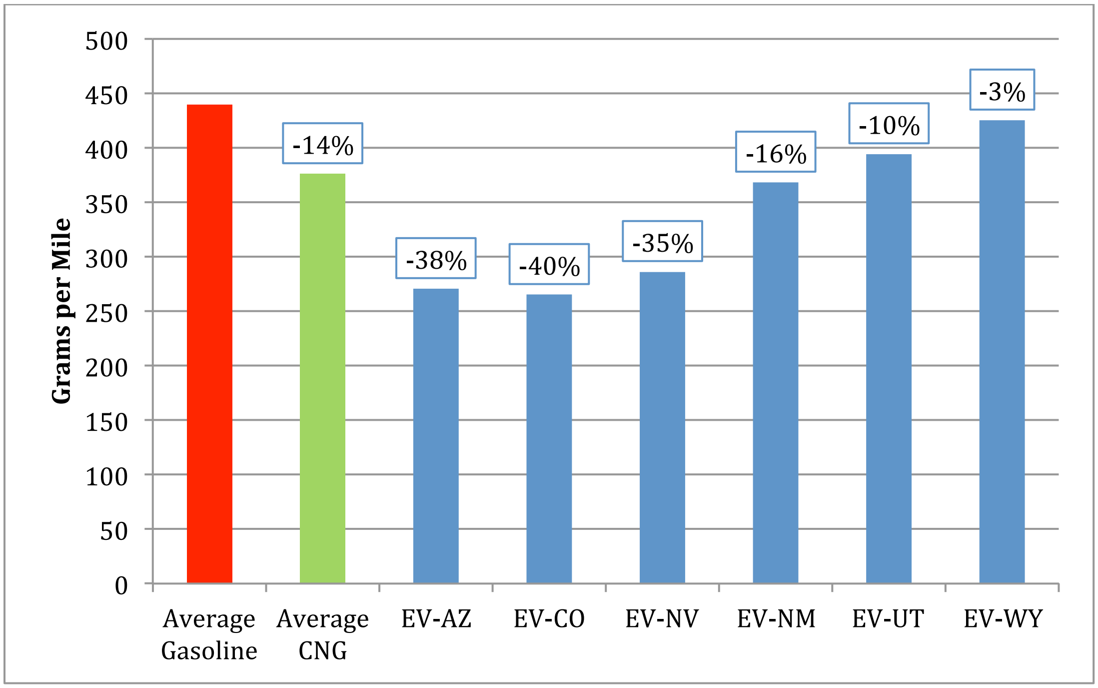
Regarding lifecycle greenhouse gas emissions, the relative emissions of EVs compared to gasoline and CNG vehicles depends on the fuels used to generate electricity. In states where the majority of electricity is produced by coal (Wyoming, Utah, Colorado and New Mexico), EVs in 2013 have no advantage over CNG vehicles regarding lifecycle GHG emissions. In Nevada and Arizona, where coal makes up a much smaller share of electricity generation, 2013 electric vehicles have the lowest lifecycle greenhouse gas emissions.

Figure ES-4. Comparison of GHG Emissions, New Vehicles in 2013



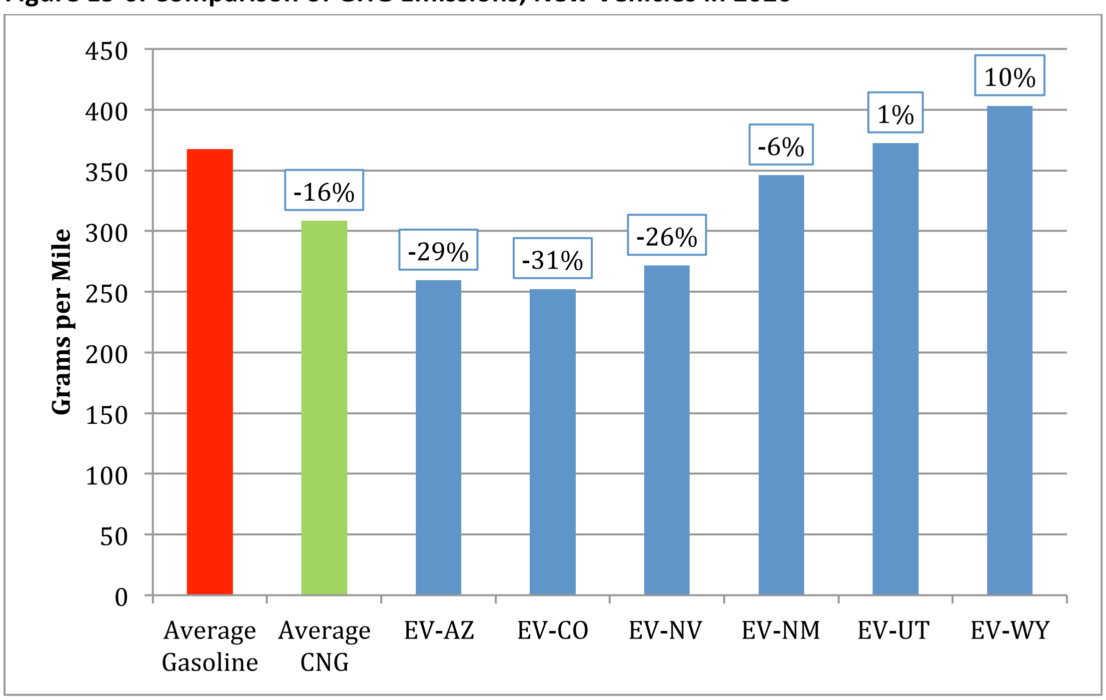
By 2020, cleaner electricity sources improve the performance of EVs depending on the magnitude of the shift away from coal. In Wyoming and Utah, where coal continues to be used to produce over 50% of the electricity, 2013 CNG vehicles retain an advantage compared to electric vehicles. However, in Colorado and New Mexico, which are phasing out coal-fired electricity production, EVs become the lowest emitter of greenhouse gases by 2020. In Arizona and Nevada, states with already low amounts of coal generation, the advantage of electric vehicles becomes even greater by 2020.

Figure ES-5. Comparison of GHG Emissions, 2013 Vehicles in 2020



In 2020, new EVs have the lowest greenhouse gas emissions in Arizona, Colorado and Nevada. CNG vehicles are the lowest emitting vehicle type in all other states, and in Utah and Wyoming EVs have the highest emissions.

Figure ES-6. Comparison of GHG Emissions, New Vehicles in 2020



Ozone Precursors

For emissions of the pollutants that contribute to ground level ozone—Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOCs)—no vehicle type performs better than the others for both pollutants. In general, EVs have the lowest VOC emissions and gasoline vehicles the highest VOC emissions across all states and time frames. In 2013, CNG vehicles emit the least amount of NO_x, with electric vehicles emitting the most (except in Arizona and Nevada). By 2020, as coal is replaced by natural gas and renewables and emission controls are installed on remaining coal plants, NO_x emissions from EVs will decline significantly until they are lower than CNG vehicles in Arizona, Colorado and Wyoming and essentially equal to CNG vehicles in the other states. By 2020, gasoline vehicles will be greatest emitters of NO_x in every state. Comparing new vehicles in 2020 generally shows the same pattern, although EVs have lost some of the advantage they had with 2013 vehicles in 2020. (Note that these analyses are based upon current federal regulations. The Environmental Protection Agency (EPA) has proposed new "Tier III" auto emissions standards. If these are adopted, there will be reductions in the level of emissions of ozone precursors from new gasoline vehicles in 2020.)

Figure ES-7. Comparison of NO_x Emissions, New Vehicles in 2013

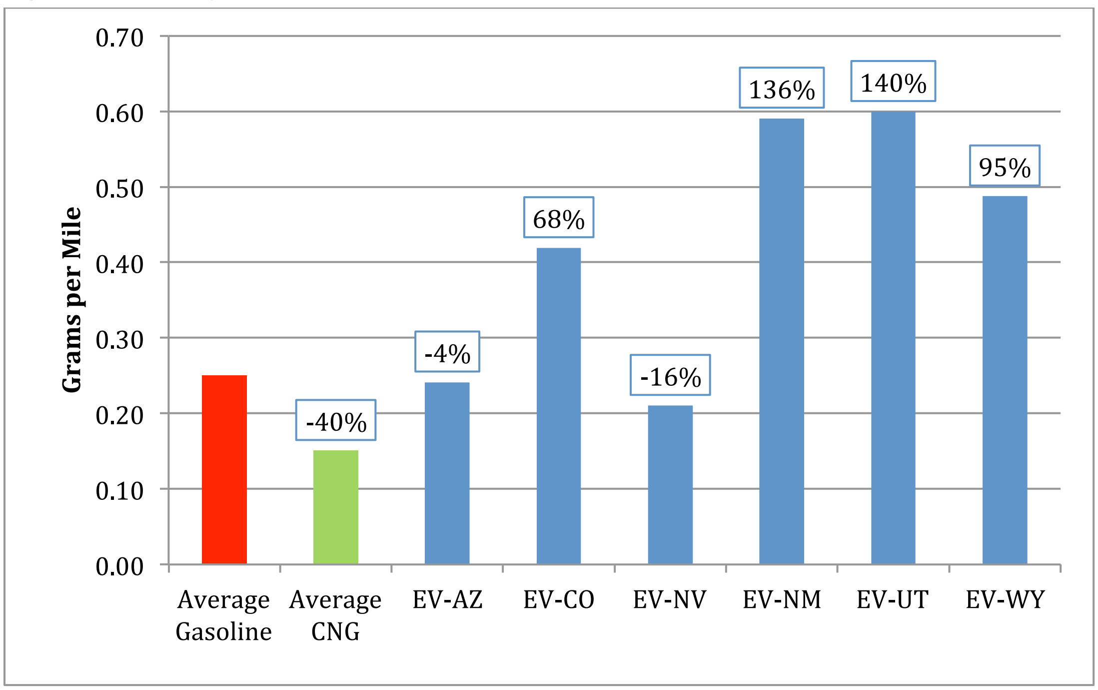


Figure ES-8. Comparison of NO_x Emissions, 2013 Vehicles in 2020

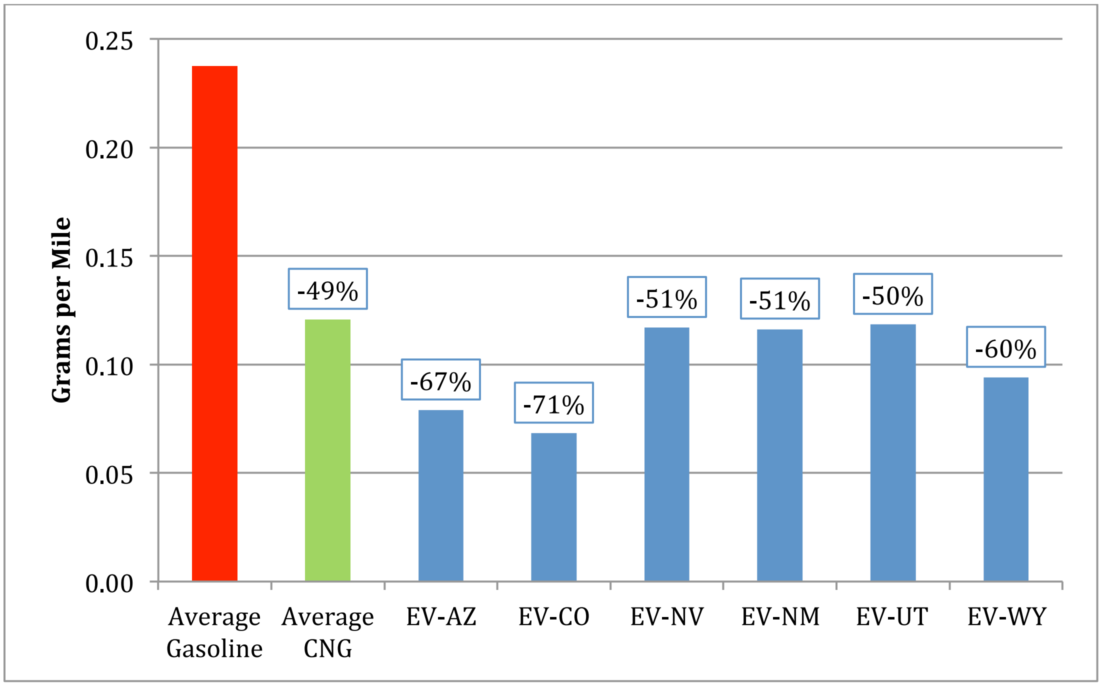


Figure ES-9. Comparison of NO_x Emissions, New Vehicles in 2020

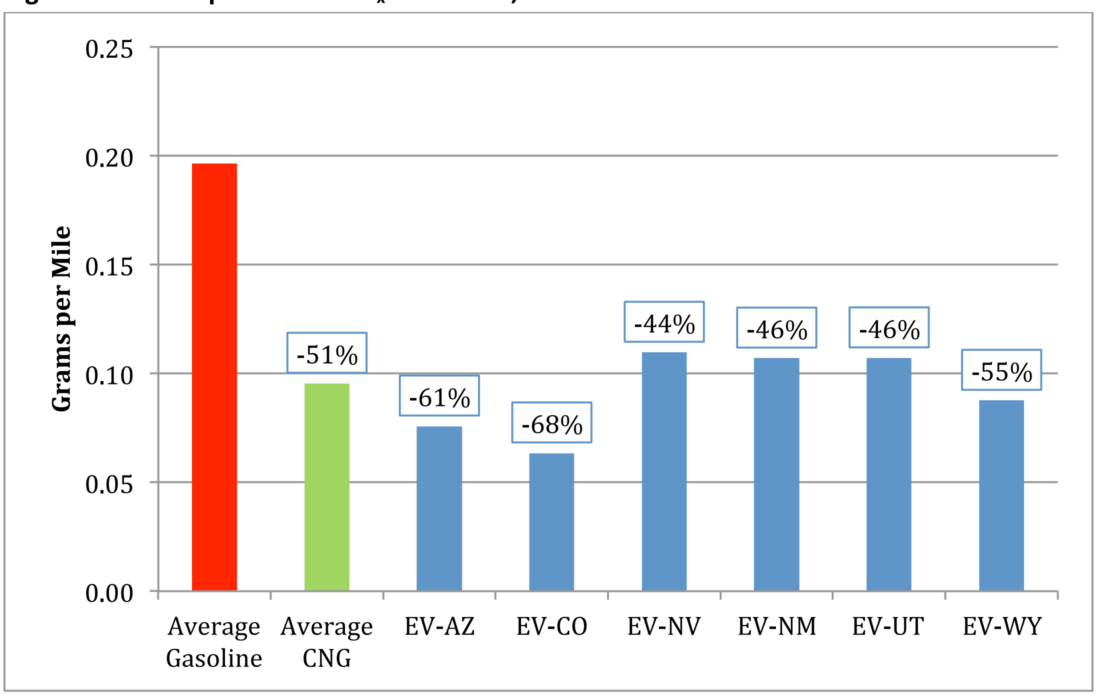


Figure ES-10. Comparison of VOC Emissions, New Vehicles in 2013

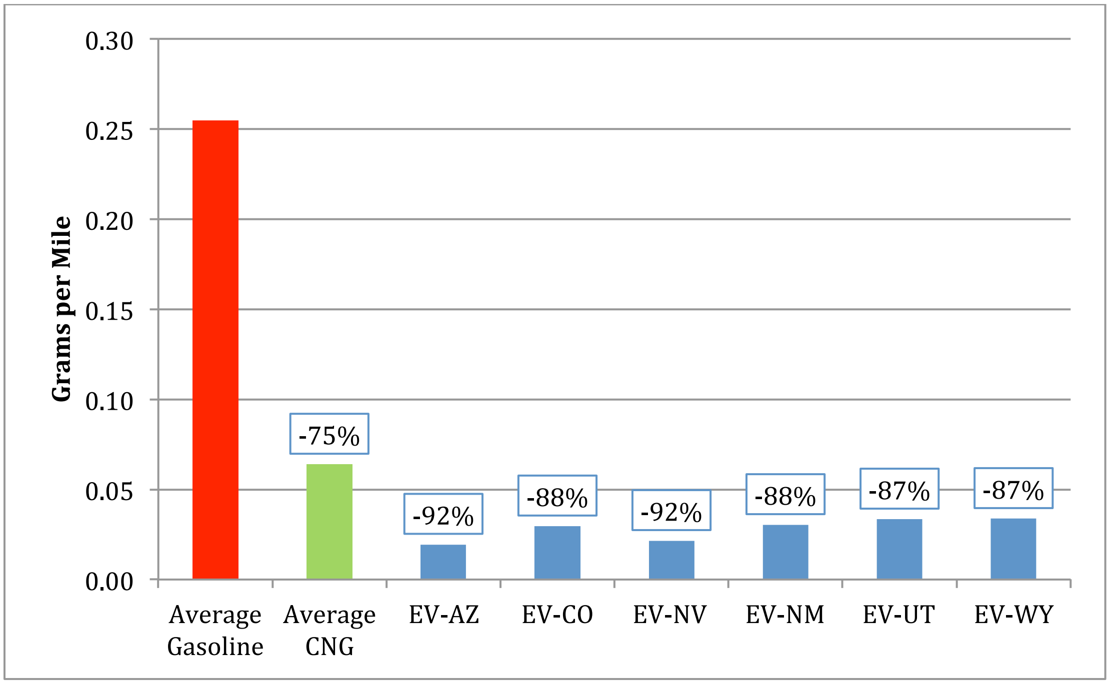


Figure ES-11. Comparison of VOC Emissions, 2013 Vehicles in 2020

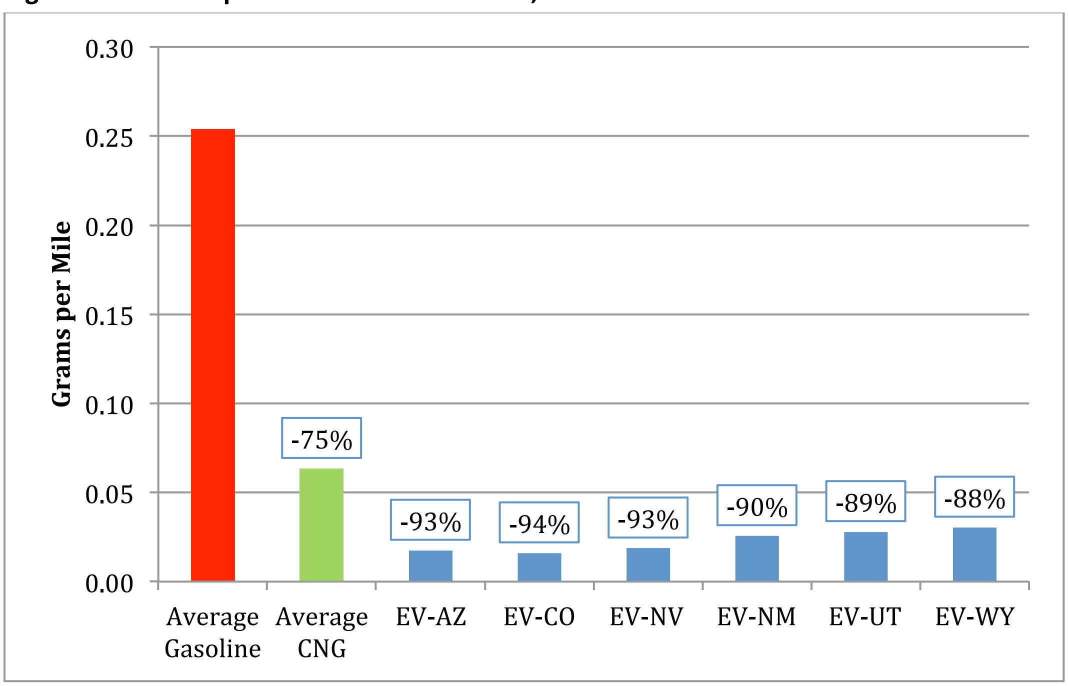
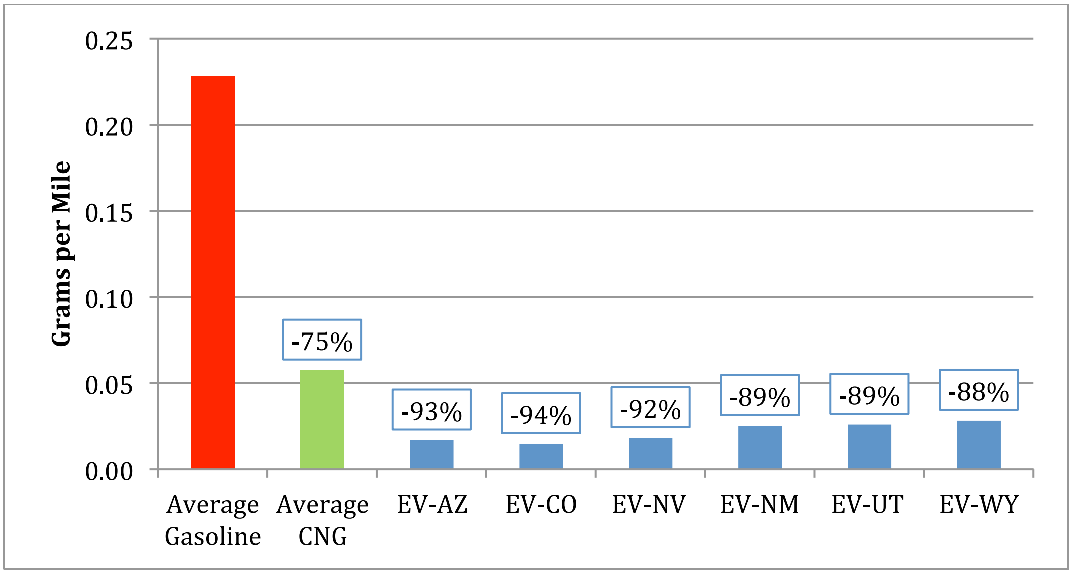


Figure ES-12. Comparison of VOC Emissions, New Vehicles in 2020



Conclusion

The potential benefits of electric vehicles compared to gasoline and CNG vehicles are highly dependent on the sources of electricity that fuel the vehicles. EVs are more efficient than gasoline vehicles in every scenario and more efficient than CNG vehicles in most scenarios in most states. This clear efficiency advantage makes EVs a clear choice for those interested in conserving energy resources, improving energy security and reducing energy costs.

In all six states, electric and CNG vehicles offer significant benefits by 2020 in reduced emissions of ozone precursors compared to gasoline vehicles. By 2020, EVs in Arizona, Colorado and Wyoming provide a greater reduction in NO_x emissions compared to CNG vehicles; in Nevada, New Mexico and Utah NO_x emissions are relatively similar by 2020. In all states, EVs have the lowest level of VOC emissions. Policies to increase the use of EVs may be an important component of strategies to reduce urban air pollution and improve public health in all of the southwestern states. This is also important for states that will be required to show compliance by 2020 with an expected new ground-level ozone standard from the EPA.

Emissions of greenhouse gases vary widely between states. Our analysis shows significant GHG reductions from EVs in Arizona, Colorado, and Nevada compared to gasoline and CNG vehicles, suggesting that policies designed to increase the use of EVs in these states could be an important strategy to reduce greenhouse gas emissions and mitigate the impacts of climate change.

In Wyoming, New Mexico and Utah, however, it is not as easy to draw broad conclusions about the best vehicle technology for reducing greenhouse gas emissions, although electric vehicles tend to have lower emissions than gasoline vehicles and CNG vehicles tend to have lower emissions than electric vehicles. In these states, in order to have a positive climate benefit, policies to increase use of EVs should be coupled with additional efforts to shift electricity generation from coal to natural gas and renewables. There may also be opportunities to encourage customers to acquire EVs and solar photovoltaic systems together, allowing the vehicles to be at least partially charged by electricity with very low levels of GHG emissions.

Policymakers, fleet managers, new car buyers and any other interested parties should use the information from this report to make a more informed decision about what type of vehicle best fits their needs and goals.

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Introduction

As plug-in electric vehicles become more widespread and more models become available each year, it is important to have a clear understanding of the lifecycle energy consumption and emissions associated with this emerging technology.

Improving the energy efficiency of the transportation system (by using less energy to power our vehicles) conserves resources, saves money and helps achieve greater energy security for the Southwest and the nation.

Reducing emissions of ozone precursors improves air quality and provides a public health benefit, especially in the Southwest's metropolitan areas. Several regions in the Southwest are currently in non-attainment for the EPA's ozone standard and additional areas would likely no longer be in attainment if a stricter ozone standard is issued in 2014 by the EPA. As compliance with the standard would be necessary by 2020, this report informs policymakers on what types of vehicles would be best able to help meet ozone standards and improve air quality.

Rising concentrations of greenhouse gases in the atmosphere are accelerating changes in the Earth's climate which will be manifested in the Southwest through higher average temperatures, more severe droughts, reduced water supplies and shorter ski seasons.[6] The transportation sector accounts for approximately 28% of the United States' greenhouse gas emissions and light-duty vehicles make up over 60% of emissions from the transportation sector.[7] This means that a reduction in emissions from light-duty vehicles will be critical if the US is to significantly reduce overall GHG emissions. While improving fuel economy standards will help reduce GHG emissions from light-duty vehicles, alternative fuels such as compressed natural gas and electricity offer the potential for even greater reduction. This report attempts to show in the short and medium-term which vehicle types have the greatest potential to reduce GHG emissions for each southwestern state.

SWEEP performed this analysis to help inform policymakers, fleet managers, new car buyers and other interested parties about the comparable energy consumption and emissions from different types of light-duty vehicles. While other factors (such as economics and performance) will also

[6] Environmental Protection Agency. 2013. Climate Change: Southwest Impacts & Adaption. Retrieved from http://www.epa.gov/climatechange/impacts-adaptation/southwest.html
[7] Environmental Protection Agency. 2013. Sources of Greenhouse Gas Emissions. Retrieved from http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html

influence decision making regarding vehicles, we feel this is an important component that should be well understood by those wishing to make informed decisions.

The costs and benefits of electric vehicles (EVs) compared to traditional gasoline fueled vehicles and compressed natural gas (CNG) vehicles vary significantly across the southwestern states and are highly dependent on the fuels used to generate electricity. Over the next several years, the electricity fuel mix in the Southwest is expected to shift towards less coal and more natural gas and renewable sources, which will improve the performance of electric vehicles compared to gasoline and CNG vehicles.

In May of 2013, SWEEP released *Policies to Promote Electric Vehicles in the Southwest,*[8] an analysis of the policies that have been adopted to support electric vehicles by state governments across the region. The report found a wide variation in policy support across the states. Now, this emissions analysis helps to identify the states where electric vehicles offer the greatest emissions benefits.

SWEEP performed this analysis using the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) fuel-cycle model developed by Argonne National Laboratory with funding from the U.S. Department of Energy.[9] 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. In addition to using the GREET fuel-cycle model to show the life-cycle or well-to-wheels emissions of different vehicle fuels, we completed the GREET vehicle-cycle model that calculates the life-cycle emissions associated with manufacturing and disposing of different vehicle technologies.[10]

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[8] Salisbury, M. 2013. Policies to Promote Electric Vehicles in the Southwest. Retrieved from http://www.swenergy.org/publications/documents/EV%20Report%20CardFNLwithCover.5.15.13.pdf

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

[10] This vehicle cycle model does not contain data for CNG vehicles, so for the purposes of this comparison, CNG vehicles are assumed to have the same manufacturing impacts as a regular gasoline vehicle.

Methodology

Comparing the current performance of vehicles purchased in 2013 with how those same vehicles are expected to perform in 2020 provides additional context for evaluating the three fuel and vehicle technologies.[11] Therefore, we analyzed the energy consumption and emissions of the three vehicle fuels in three different scenarios:

1. *New Vehicles in 2013:* New vehicles purchased in 2013 are analyzed in 2013 to show what vehicles will have the most immediate impact regarding energy use and emissions. We compare gasoline-fueled passenger vehicles at the average 2013 fuel efficiency of 28 mpg; a 2013 CNG Honda Civic getting 31 mpg; and a typical EV getting the equivalent of 99 mpg.

2. *2013 Vehicles 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. Gasoline and CNG vehicles purchased in 2013 and still running in 2020 will have similar energy use and emission profiles. They will have slightly improved profiles due to changes in the feedstock and fuel phases as the systems for bringing fuel to market (along with the overall energy system) are expected to become more efficient. 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. As electricity generation moves toward increasingly efficient and cleaner fuel sources, 2013 electric vehicles will use less energy and produce fewer emissions every year they are on the road.

3. *New Vehicles in 2020:* New vehicles purchased in 2020 are analyzed in 2020. We assume that fuel efficiency of new vehicles increases due to the CAFE standards, but we do not assume that these new vehicles meet the Tier III emissions standards that have been proposed, but not yet adopted, by the United States EPA.

The three scenarios demonstrate the effects 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. While the fuel economy improvements are a federal requirement and therefore expected to be consistent across the southwestern states, the changes in the electrical generation vary considerably by state.

To estimate electricity generation mixes in the future, we rely upon forecasts conducted by Synapse Energy Economics for SWEEP's *$20 Billion Bonanza* study, published in 2012.[12] We used forecasts for the "high efficiency scenario" which best fits the trajectory of the region regarding the

[11] The GREET model is designed to run only through 2020, so it is not possible to extend the comparison over the full operating life of the vehicle.

[12] 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

retirement of coal power plants.[13] For example, Nevada recently decided to close all its remaining coal fired power plants[14] and New Mexico is proposing to retire two units at its San Juan plant.[15] Also from the *$20 Billion Bonanza* study, we used NO_x 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 Clean Air Act requirements.

There are several major factors to consider when estimating which electricity sources would make up the marginal demand for EVs. For most utilities, natural gas is expected to meet the majority of its marginal electricity demand over the course of the year. However, as most PEV 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 it is especially difficult to estimate which of these factors will be most important for supplying marginal demand for EVs for future years, we decided to use the regular generation mix forecast for 2020 for both the base load and the marginal electricity demand.

The one exception is Colorado, where more fine-grained information was available. We 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 Project (CEVIRP).[16]

We would note that there is considerable debate about the appropriate methodology for evaluating the emissions impacts of electric vehicles. Some observers have used the average electricity mix for larger aggregated regions of the grid.[17] Others have attempted to model the marginal power on an hourly basis across entire grid interconnection regions taking into account potential flows of electricity over large multi-state regions.[18] However, since many decisions about both policies to support electric vehicles and about the mix of power in the electricity generation mix are made at the state level, we do believe that the state level analysis contained in this report is a useful addition to the literature.

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[13] The reference case scenario was used in Colorado as the state already has agreements on coal plant retirements in place.
[14] Clarke, C. 2013. Nevada to Phase Out Energy Produced by Coal: Enviros and Tribes Applaud Move. KCET. Retrieved from http://www.kcet.org/news/rewire/coal/enviros-tribe-applaud-nevada-move-off-coal.html
[15] Bryan, S. 2012. Plan Call for Shuttering Part of PNM Power Plant. Bloomberg Business Week. Retrieved from http://www.businessweek.com/ap/2012-10-03/plan-calls-for-shuttering-part-of-pnm-power-plant
[16] Jorgensen et al. 2012. Emissions Changes from Electric Vehicle Use in Colorado, Appendix 24 to Colorado Electric Vehicle and Infrastructure Readiness Plan.
[17] Union of Concerned Scientists. 2012. State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings Across the United States. Retrieved from http://www.ucsusa.org/assets/documents/clean_vehicles/electric-car-global-warming-emissions-report.pdf
[18] Zivin et al. 2012. Spatial and Temporal Heterogeneity of Marginal Emissions: Implications for Electric Cars and Other Electricity-Shifting Policies. University of California Center for Energy and Environmental Economics Working Paper 47. Retrieved from http://www.uce3.berkeley.edu/WP_047.pdf

Sensitivity Analysis Regarding Methane

This analysis also considers alternative scenarios for natural gas emissions, based on different methane leakage rates during extraction and on assessments of methane's global warming potential on a 20-year, rather than a 100-year time frame.

Recent estimates of methane leakage rates from the extraction of natural gas range from 0.4% to 2.0% for conventional natural gas and from 0.6% to 4.0% for shale gas.[19] In addition, recent research by the National Oceanic and Atmospheric Administration (NOAA) in Colorado and Utah has shown actual leakage rates of 4% and 9% respectively, although there is significant debate on the accuracy of these findings and how they may apply to natural gas production in other parts of the country.[20] The GREET model's default assumptions for methane leakage during extraction are 2.0% for conventional gas and 1.3% for shale gas.[21]

Therefore, we used the GREET default values for the base analysis, and then doubled them to provide a range of values. Note that these doubled values are still well below NOAA's high end observations of actual leakage rates.

However, new EPA regulations (the New Source Performance Standards, section OOOO regulations, issued in April 2012), as well as a number of state regulatory rulemakings on oil and gas emissions, may lead to reductions in fugitive emissions. Additional research providing more certainty on leakage rates will be very helpful in developing a better understanding of the life-cycle greenhouse gas emissions from natural gas. Efforts to minimize methane leakage during the extraction process are critical to reducing the greenhouse gas emissions from the use of natural gas vehicles, as well as from the use of natural gas power plants to generate electricity.

As part of our sensitivity analysis, we include the impact of methane emissions if the global warming potential of methane is calculated on a 20- rather than 100-year time frame. Each molecule of methane (CH_4) absorbs much more infrared radiation than a molecule of carbon dioxide (CO_2). However, methane also has a much shorter atmospheric lifetime, so the relative climate impact of a pulse of methane and a pulse of carbon dioxide depends on the timescale over which we measure the impact. Measured over one year, an equal weight of methane is considered 102 times more potent than carbon dioxide; measured over 20 years it has 72 times the impact; and measured over 100 years it has 25 times the impact. With significant global temperature changes forecast between now and 2050,[22] the100-year global warming potential may not be the most relevant measure to consider when evaluating the importance of methane as a driver of climate change over the next few decades.

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[19] Howarth, R. et al. 2012. Methane Emissions from Natural Gas Systems. Retrieved from http://www.eeb.cornell.edu/howarth/Howarth%20et%20al.%20--%20National%20Climate%20Assessment.pdf

[20] Tollefson, J. 2013. Methane Leaks Erode Green Credentials of Natural Gas. Retrieved from http://www.nature.com/news/methane-leaks-erode-green-credentials-of-natural-gas-1.12123

[21] These assumptions are based on Burnham A. et al. 2011. Life-Cycle Greenhouse Gas Emissions of Shale Gas, Natural Gas, Coal, and Petroleum. *Environmental Science and Technology. 46 (2), pp 619-627.*

[22] Rowlands, D. et al. 2012. Broad Range of 2050 Warming from an Observationally Constrained Large Climate Model Ensemble. Nature Geoscience 5, 256-260. Retrieved from http://www.nature.com/ngeo/journal/v5/n4/abs/ngeo1430.html

Therefore, for the base analysis, we used GREET's default assumption on the climate forcing potential of methane (25 times more potent than CO_2, which corresponds with a 100-year time frame). For the additional analysis, the climate forcing potential was changed to 72 times more potent than CO_2, reflecting its impact on a 20-year time frame.[23]

We note that there is another approach, which was outlined in an important study published in 2012 in the Proceedings of the National Academy. This paper, "Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure",[24] computes the total radiative forcing as a function of time due to the emissions of both carbon dioxide and methane. This paper concluded that for light duty vehicles, well-to-wheels methane emissions must be less than 1.6% to achieve short term climate benefits from switching from gasoline to natural gas. We did not attempt a similar analysis.

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[23] Intergovernmental Panel on Climate Change. 2007. IPCC Fourth Assessment Report. Chapter 2.10.2. Retrieved from http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

[24]Alvarez, R. et al. 2012. Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure. Proceedings of the National Academy. Retrieved from http://www.pnas.org/content/early/2012/04/02/1202407109.abstract

Results

The results of our analysis are presented below for each of six southwestern states included in the study: Arizona, Colorado, Nevada, New Mexico, Utah and Wyoming. Each state section includes results for each of the three scenarios we analyzed: new vehicles in 2013, 2013 vehicles in 2020, and new vehicles in 2020.

For each state, we present a summary table which simply identifies the top performing vehicle type in each scenario in each parameter of the study:

- Energy consumption
- GHG emissions
- GHG emissions with methane sensitivity analysis
- Ozone precursor emissions (NO_x and VOC)

For each scenario, we provide a set of four charts illustrating detailed results for each parameter listed above. Our analysis considers life-cycle energy consumption and emissions, and we believe it could be helpful for policymakers to understand more precisely how each stage contributes to the overall measure. Therefore, the energy use and emission rates in each chart are broken down into four categories representing different stages of the life-cycles for fuels and vehicles:[25]

- *Vehicle Production* encompasses the emissions from the manufacturing and disposing of vehicles;
- *Feedstock* represents the extraction, transportation and storage of the fuel base (for example, the mining of coal or drilling for oil and its transportation to where it will be converted to fuel);
- *Fuel Production* represents the "production, transportation, storage and distribution" of the fuel used in the vehicle (for example the combustion of coal into electricity and its transmission to the end user or the refining of gasoline and its transportation to a gasoline station);
- *Vehicle Operation* represents energy used and emissions from the vehicle when it is being driven.

The vehicle production stage is not shown in the ozone precursor charts because it is unlikely that any of the resulting emissions would take place within the same area as the fuel life-cycle stages.

Ground level ozone, which is the main component of smog, is formed by reactions between NO_x, VOCs and sunlight. Formation of unhealthy levels of ground level ozone is most prevalent in urban areas where there are greater concentrations of vehicles, electricity generating units and other stationary sources (although there are exceptions, such as the wintertime ozone problem that has been linked to oil and gas emissions in rural areas of Northeastern Utah). Upstream emissions (from the fuel and feedstock categories) which do not take place in the same general area where the

[25] Wang, M, Wu, Y, and Elgowainy, A. 2007. Operating Manual for GREET. Retrieved from http://greet.es.anl.gov/publication-ycrv02rp

vehicle will be driven could reasonably not be considered as contributing to the overall emission rates.

The GREET model does calculate the amount of emissions occurring in urban areas to show which emissions would be most likely to contribute to unhealthy levels of ozone formation. However, as the assumptions are based on national averages, and a detailed assessment of each state's energy system is beyond the scope of this report, it is not clear that the model would accurately represent the situation in each state. Therefore, while the total life-cycle emissions shown in the figures for each state may over-represent the importance of upstream emissions of the ozone precursors, this is the most accurate representation that we can make at this time.

Ozone precursor emissions from transportation fuels will be critical information in 2020, because at that time states will be required under the Clean Air Act to demonstrate attainment of the revised National Ambient Air Quality Standard for ozone that the Environmental Protection Agency is required to issue in 2014. Our analysis demonstrates that a shift to electric vehicles will help some states comply with the new standard.

A word of caution on interpreting these results: as discussed above, for emissions that contribute to ozone, the location where the pollution is emitted is very important. Gasoline and CNG vehicles driven in urban areas emit pollution directly into urban airsheds; in many cases, the power plants that supply electricity for EVs are located in more remote areas. For example, we have conducted a more fine-grained analysis of emissions from EVs in Utah, which concluded that EVs provide much more significant air quality benefits to the Salt Lake City area than the statewide numbers suggest, because most of the emissions are outside of the urban airshed.[26]

[26] Southwest Energy Efficiency Project and Utah Clean Energy. 2013. Initial Comments for the Utah PSC on SB 275 Energy Amendments, Docket No. 13-057-02. Available at www.swenergy.org.

Arizona

New Vehicles in 2013

In Arizona, electric vehicles are the most efficient at converting energy into miles traveled. With the same amount of energy that powers an EV 100 miles, a CNG vehicle can travel 78 miles and a gasoline vehicle only 70 miles. EVs emit the least amount of greenhouse gases due to the clean electricity mix in the state, with only 35% of electricity coming from coal. Gasoline vehicles emit the highest amount of greenhouse gases. For pollutants leading to ground level ozone, EVs emit the least amount of VOCs and CNG vehicles emit the least amount of NO_x. EVs and gasoline vehicles emit the same amount of NO_x and gasoline vehicles emit the highest amount of VOCs.

Table 1. Best Performing Vehicles in Arizona

Parameter	New vehicles in 2013	2013 vehicles in 2020	New vehicles in 2020
Energy consumption	EV	EV	EV
GHG *(base analysis)*	EV	EV	EV
GHG *(doubled CH4 leakage rates)*	EV	EV	EV
GHG *(20-year time horizon)*	EV	EV	EV
NO_x	CNG	EV	EV
VOC	EV	EV	EV

Figure 1. Energy Consumption, New Vehicles in 2013 – Arizona

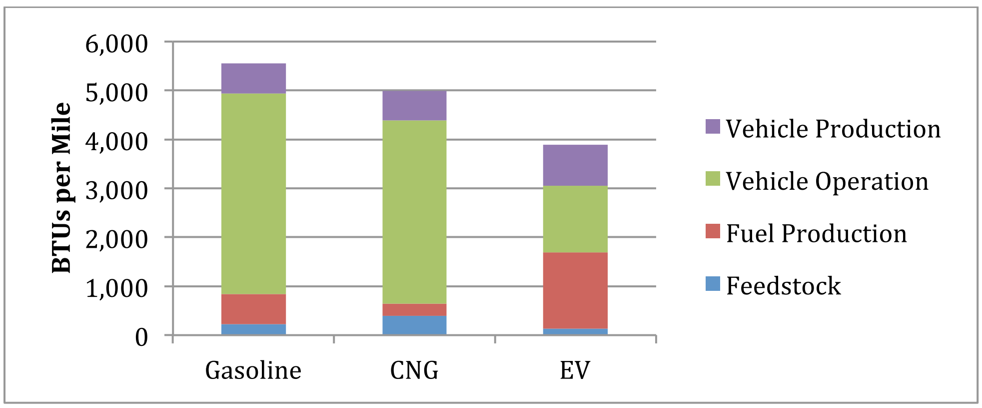


Figure 2. Ozone Precursor Emissions, New Vehicles in 2013 – Arizona

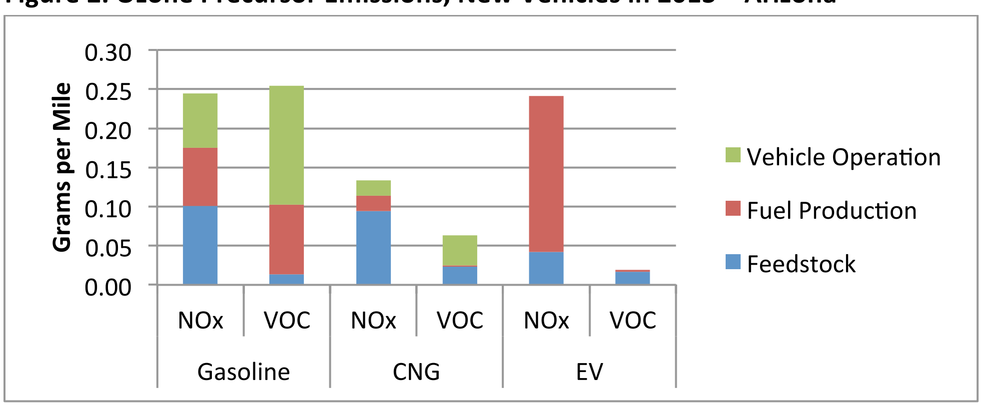
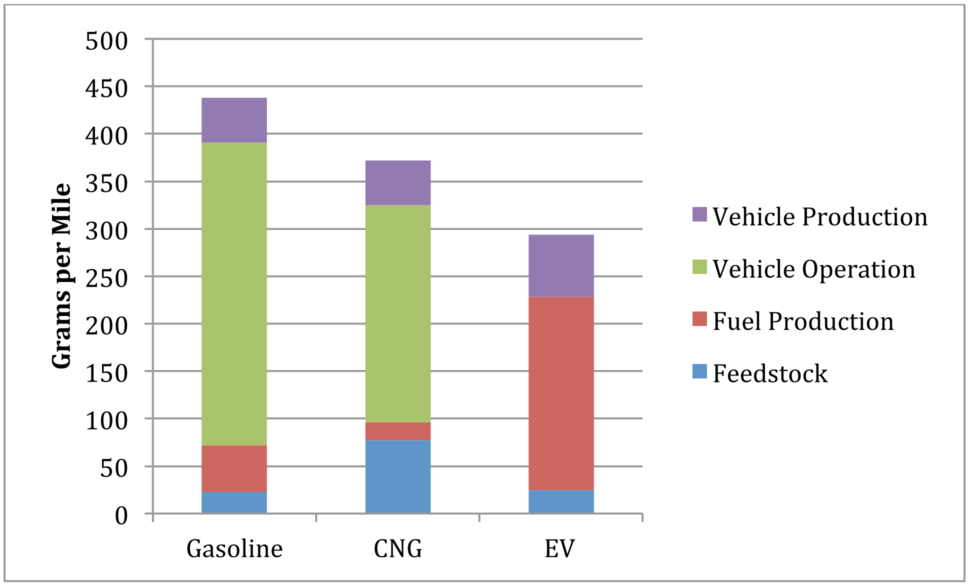
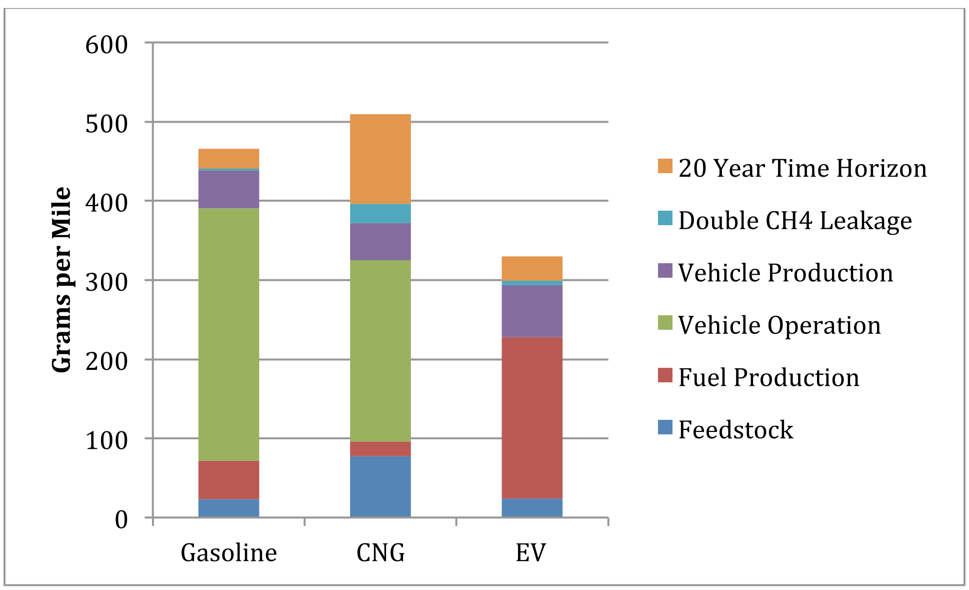


Figure 3. GHG Emissions, New Vehicles in 2013 – Arizona



If rates of methane emissions are doubled, EVs still have the lowest life-cycle GHG emissions and gasoline vehicles the most. But in the case of a 20-year time horizon for methane emissions, CNG vehicles emit the most greenhouse gases.

Figure 4. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2013 – Arizona



Note: The additional emissions from doubling methane leakage rates and shortening the time horizon are exclusive of each other and are not additive.

2013 Vehicles in 2020

For 2013 vehicles being used in 2020, EVs have increased their efficiency advantage due to projected changes in electricity generation, with CNG and gasoline vehicles now only traveling 75 and 68 miles respectively with the same amount of energy an EV uses to travel 100 miles. By 2020, due to renewable electricity sources replacing coal, the advantages for EVs increase and they emit the lowest amount of greenhouse gases, VOCs and NO_x. Gasoline vehicles have the highest level of GHG emissions in the base analysis; however, if a 20-year time horizon is used, CNG vehicles emit the greatest amount of greenhouse gases. In either case, EVs have by far the lowest GHG emissions. Of the three vehicles types, gasoline vehicles emit the highest levels of NO_x and VOCs, while EVs emit the lowest levels of both pollutants.

Figure 5. Energy Consumption, 2013 Vehicles in 2020 – Arizona

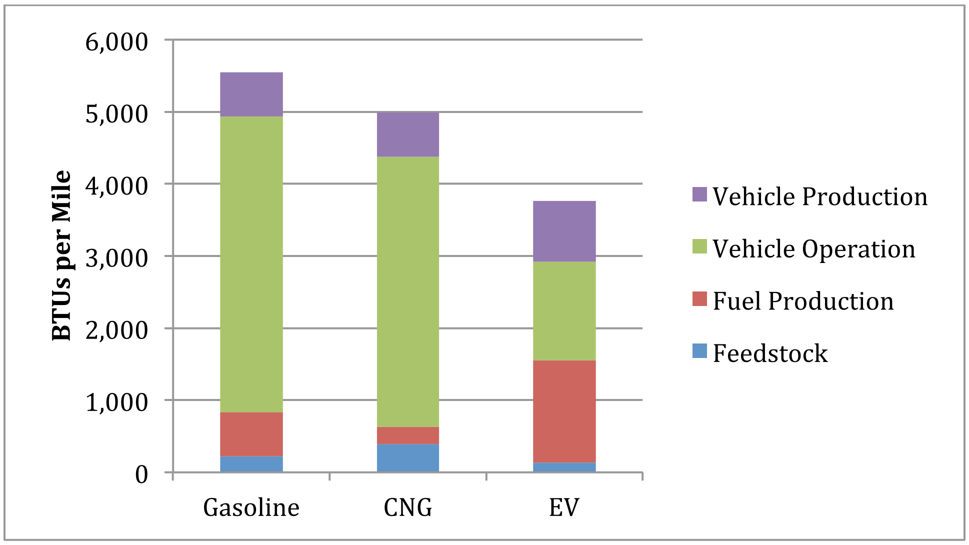


Figure 6. Ozone Precursor Emissions, 2013 Vehicles in 2020 – Arizona

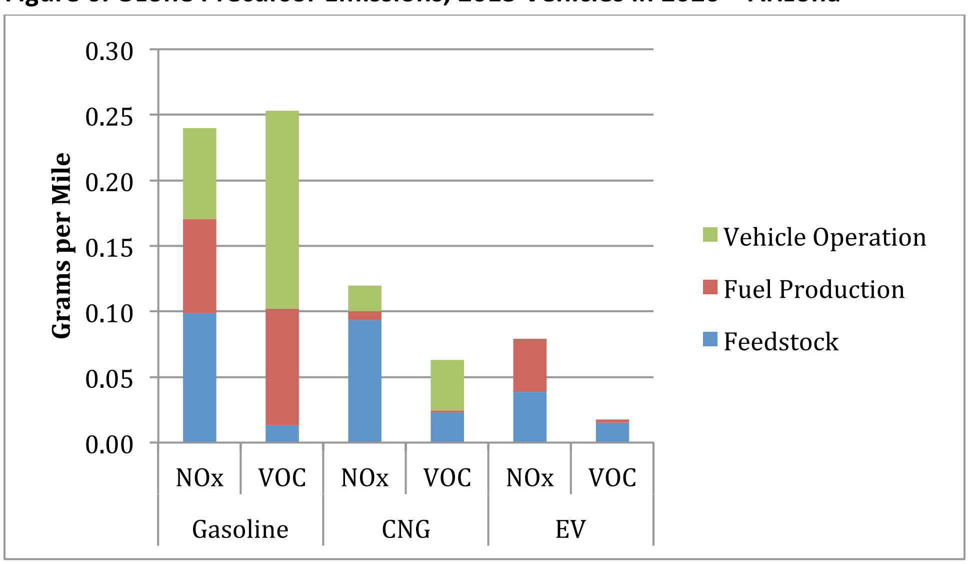


Figure 7. GHG Emissions, 2013 Vehicles in 2020 – Arizona

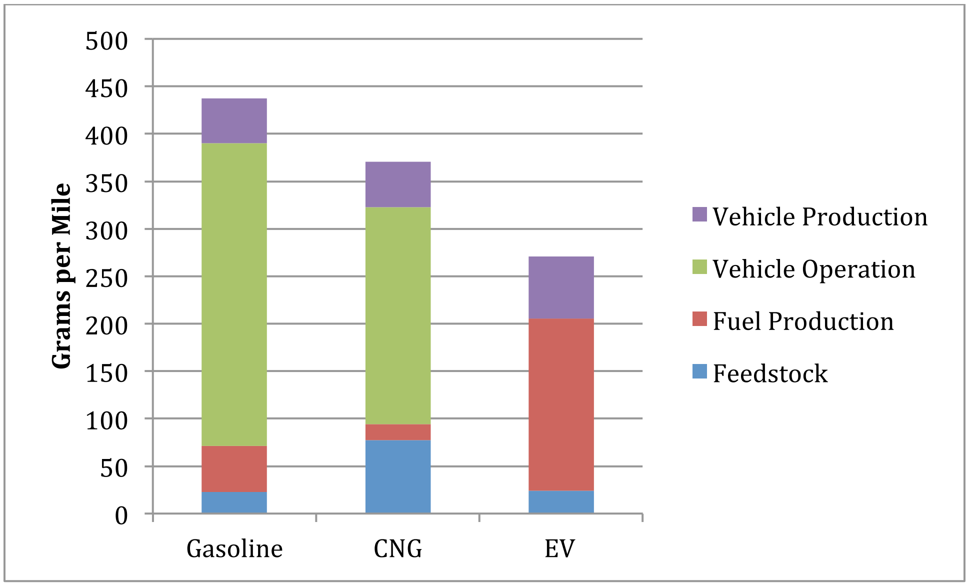
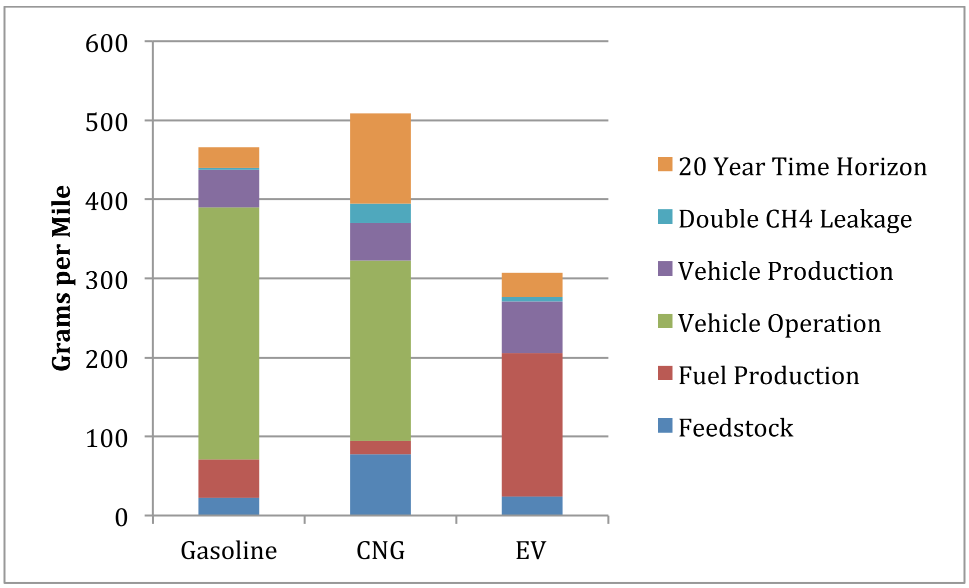


Figure 8. GHG Emissions with Methane Sensitivity Analysis, 2013 Vehicles in 2020 – Arizona



Note: The additional emissions from doubling methane leakage rates and shortening the time horizon are exclusive of each other and are not additive.

New Vehicles in 2020

Comparing new vehicles in 2020, EVs maintain their advantage in all areas compared to gasoline and CNG vehicles. Greater increases in vehicle efficiency for gasoline and CNG vehicles help close the performance gap with EVs compared with 2013 vehicles in 2020. Gasoline vehicles have the highest levels of energy use and emissions in the base analysis; however, when considering greenhouse gas emissions on a 20-year time horizon CNG vehicles have the highest level of emissions. Using the same amount of energy an EV uses to travel 100 miles, CNG vehicles can travel 87 miles and gasoline vehicles only 77 miles. Of the three vehicle technologies, EVs have the lowest level of NO_x and VOC emissions.

Figure 9. Energy Consumption, New Vehicles in 2020 – Arizona

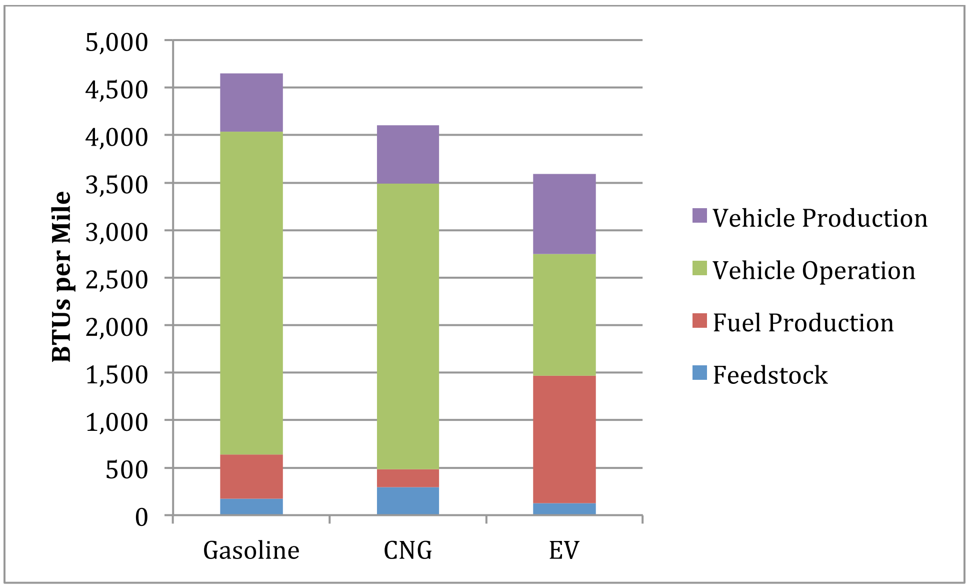


Figure 10. Ozone Precursor Emissions, New Vehicles in 2020 – Arizona

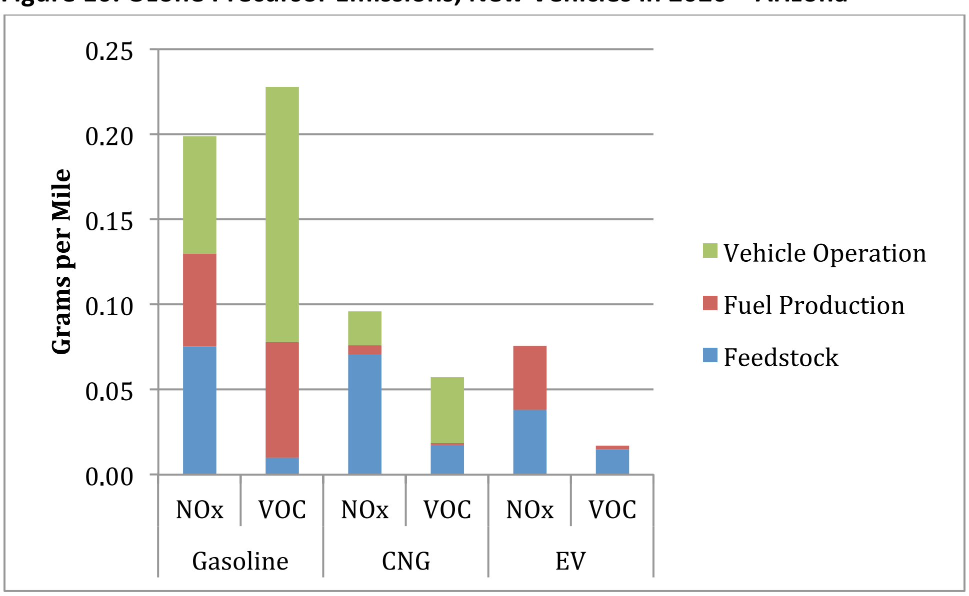


Figure 11. GHG Emissions, New Vehicles in 2020 – Arizona

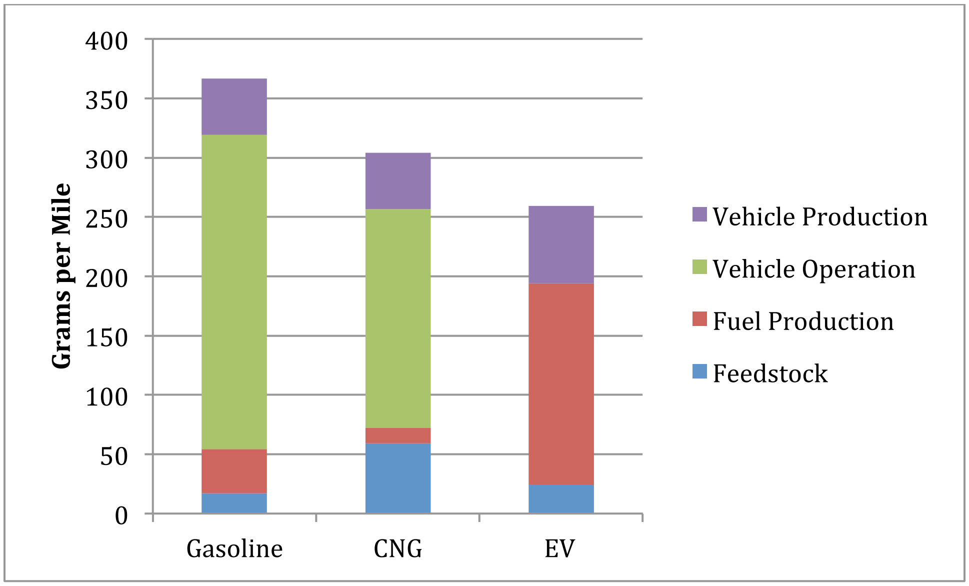
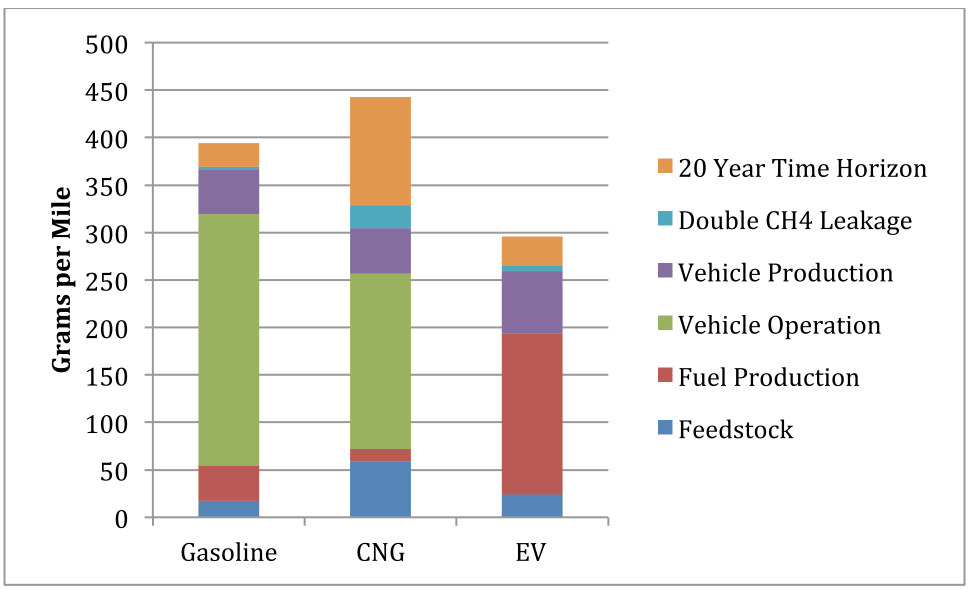


Figure 12. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2020 – Arizona



Note: The additional emissions from doubling methane leakage rates and shortening the time horizon are exclusive of each other and are not additive.

Colorado

New Vehicles in 2013

In 2013, both the CNG and electric vehicles are more energy efficient than gasoline vehicles, with EVs performing the best overall in Colorado. With the same amount of energy that an EV uses to travel 100 miles, a CNG vehicle can travel 92 miles and a gasoline vehicle only 83 miles. The CNG vehicle has the lowest emissions of NO_x and the EV has the lowest emissions of VOCs.

Table 2. Best Performing Vehicles in Colorado

Parameter	New vehicles in 2013	2013 vehicles in 2020	New vehicles in 2020
Energy consumption	EV	EV	EV
GHG *(base analysis)*	CNG	EV	EV
GHG *(doubled CH_4 leakage rates)*	CNG	EV	EV
GHG *(20 year time horizon)*	EV	EV	EV
NO_x	CNG	EV	EV
VOC	EV	EV	EV

Figure 13. Energy Consumption, New Vehicles in 2013 – Colorado

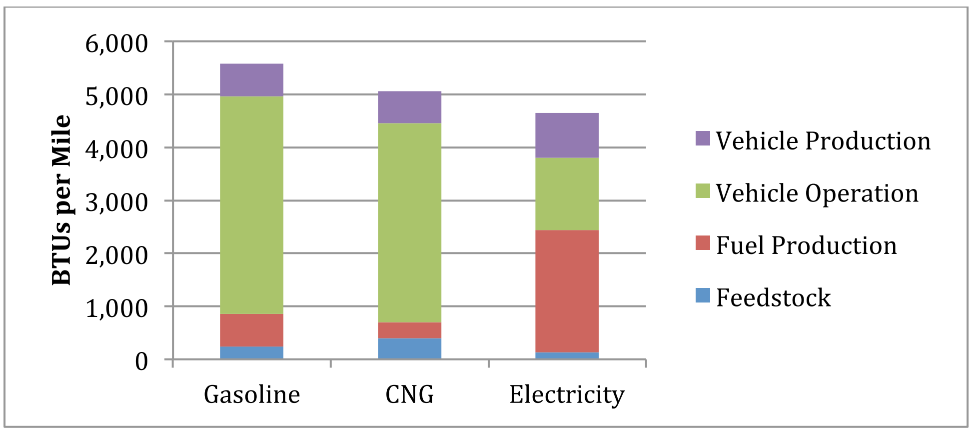
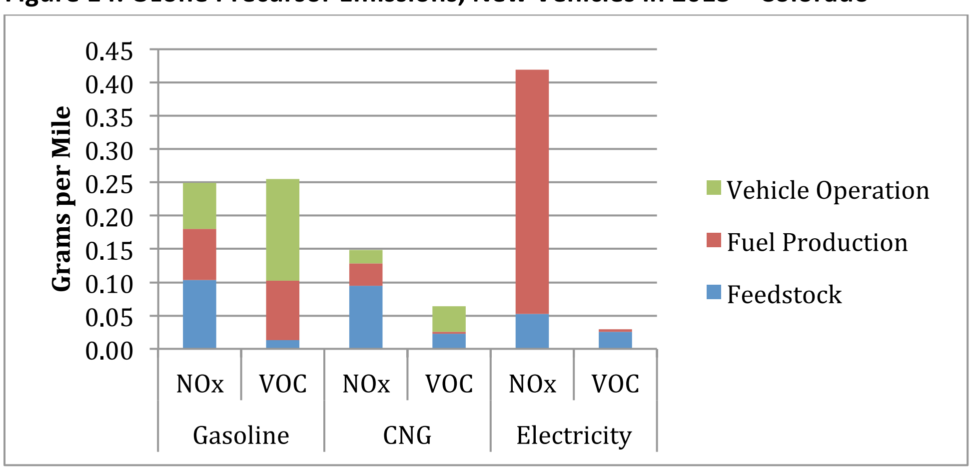


Figure 14. Ozone Precursor Emissions, New Vehicles in 2013 – Colorado



CNG vehicles have the lowest life-cycle greenhouse gas emissions while gasoline vehicles having the highest level of emissions. If methane leakage rates are doubled, CNG loses almost all of its GHG emission benefit compared to electricity, and the two fuels are at relative parity. If methane emissions are considered on a 20-year time frame rather than 100 years, the GHG emissions for the EV show the best result.

Figure 15. GHG Emissions, New Vehicles in 2013 – Colorado

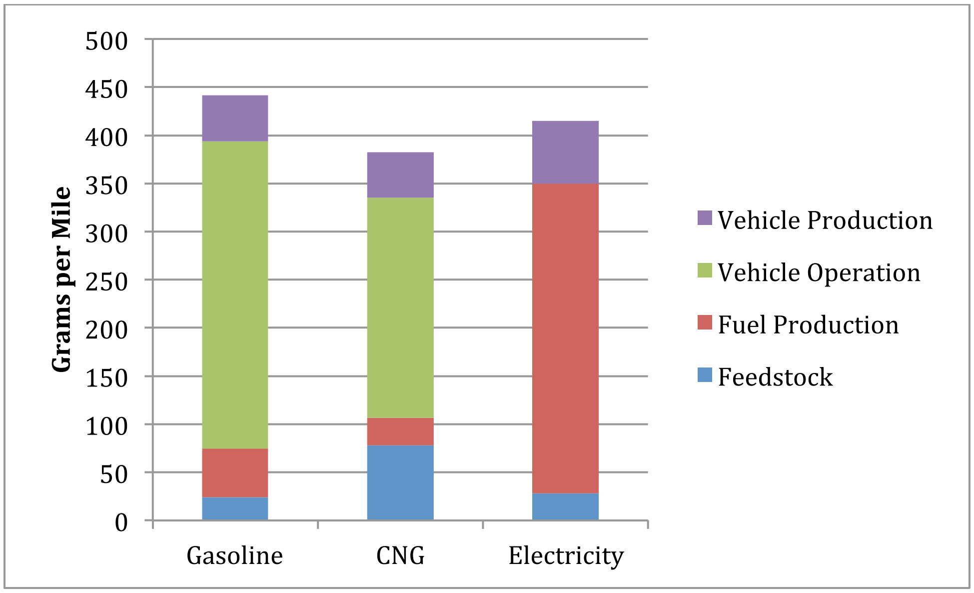
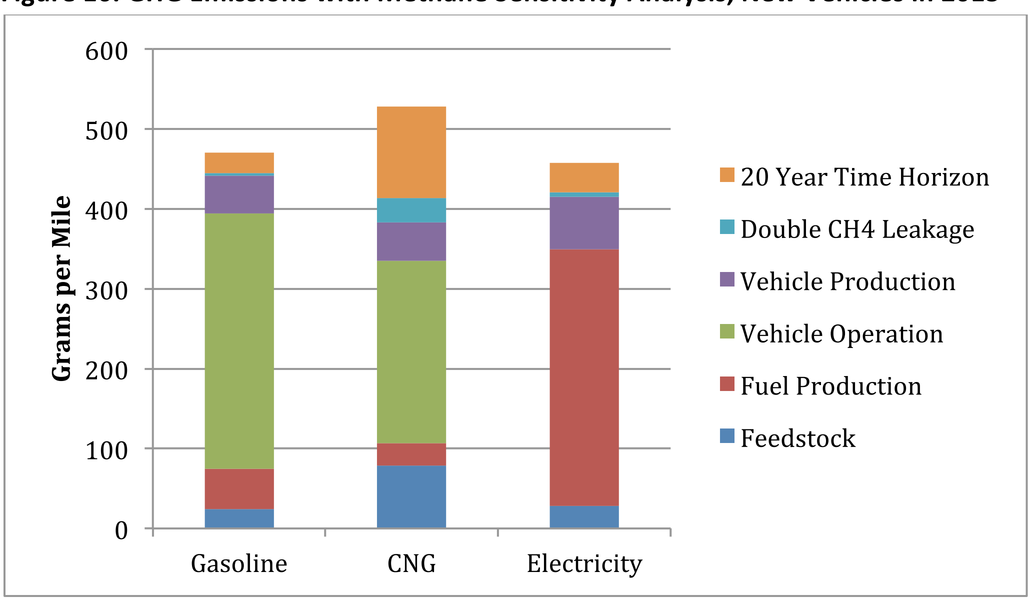


Figure 16. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2013 – Colorado



2013 Vehicles in 2020[27]

As a result of the significant changes that will be made to Colorado's electricity generation system between 2013 and 2020 (due mainly to the *Clean Air, Clean Jobs* bill[28] and the Renewable Portfolio Standard[29]) an EV purchased in 2013 will have significantly lower energy use and emission rates by 2020. All vehicle types exhibit a similar pattern of energy consumption in 2020 as in 2013, with EVs increasing their advantage. Using the same amount of energy that would allow an EV to travel 100 miles, a CNG vehicle travels 73 miles and a gasoline vehicle only 64 miles.

Figure 17. Energy Consumption, 2013 Vehicles in 2020 – Colorado

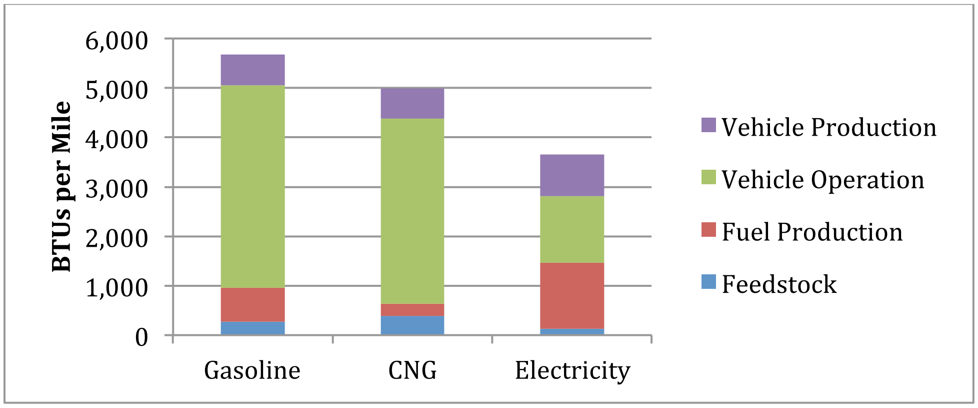
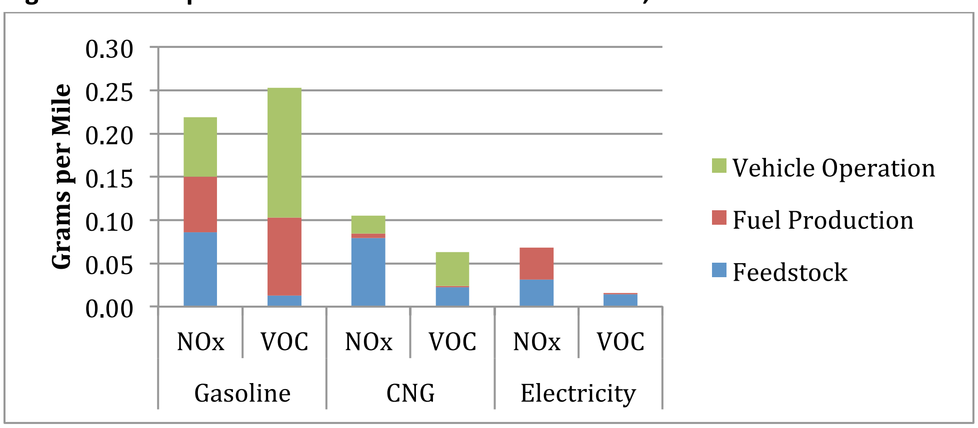


Figure 18. Comparison of Ozone Precursor Emissions, 2013 Vehicles in 2020 – Colorado



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27 Since this analysis was conducted, there have been two major developments: 1) Xcel Energy, the largest electricity provider in the state, filed with the state Public Utilities Commission to add over 500 MW of additional wind generation to their system; and 2) the Colorado legislature passed Senate Bill 252, which doubles the renewable portfolio standards from 10% to 20% for the larger rural electricity suppliers in the state. Because of these changes, our analysis likely underestimates the emissions benefits of electric vehicles in 2020.

28 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

29 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.

Regarding greenhouse gas emissions, EVs purchased in 2013 will be the lowest emitting of the three vehicle types. Regardless of the sensitivity analysis, EVs have the lowest GHG emissions in 2020.

Figure 19. GHG Emissions, 2013 Vehicles in 2020 – Colorado

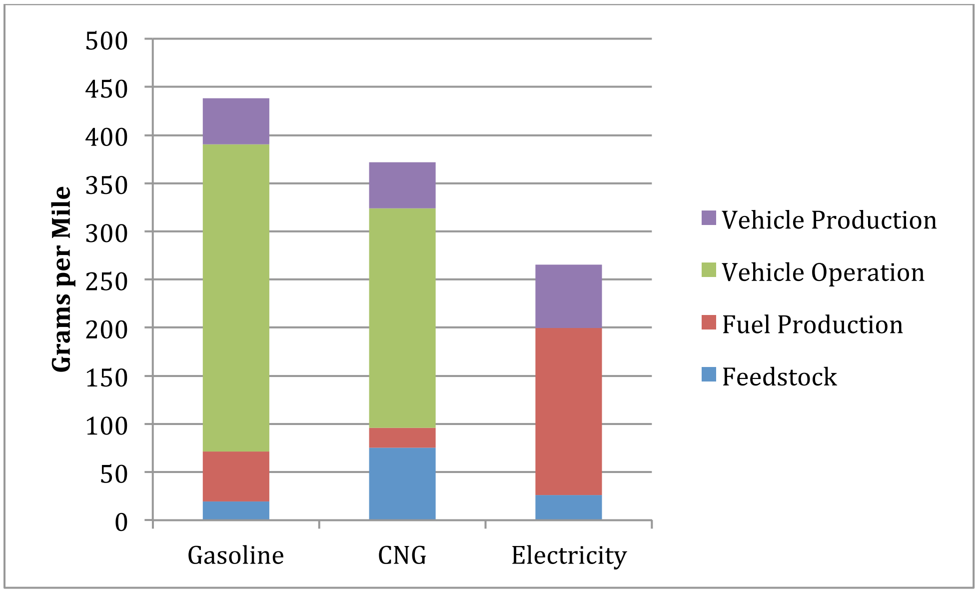
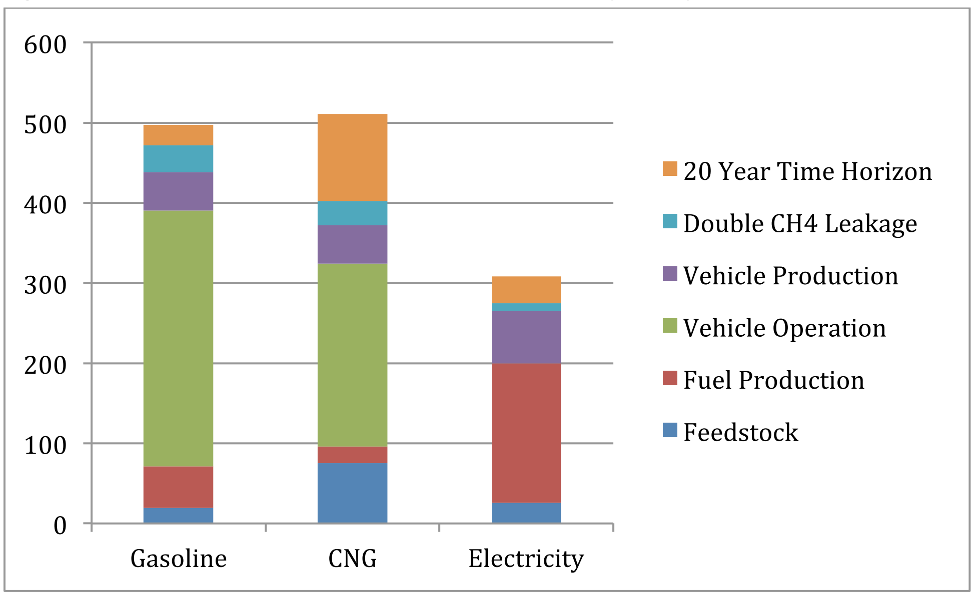


Figure 20. GHG Emissions with Methane Sensitivity Analysis, 2013 Vehicles in 2020 – Colorado



New Vehicles in 2020

Comparing new vehicles in 2020 gives the same results, with electric vehicles having the best performance in every category, although increased efficiency of gasoline and CNG vehicles reduces the advantage 2013 vehicles had in 2020.

Figure 21. Energy Consumption, New Vehicles in 2020 – Colorado

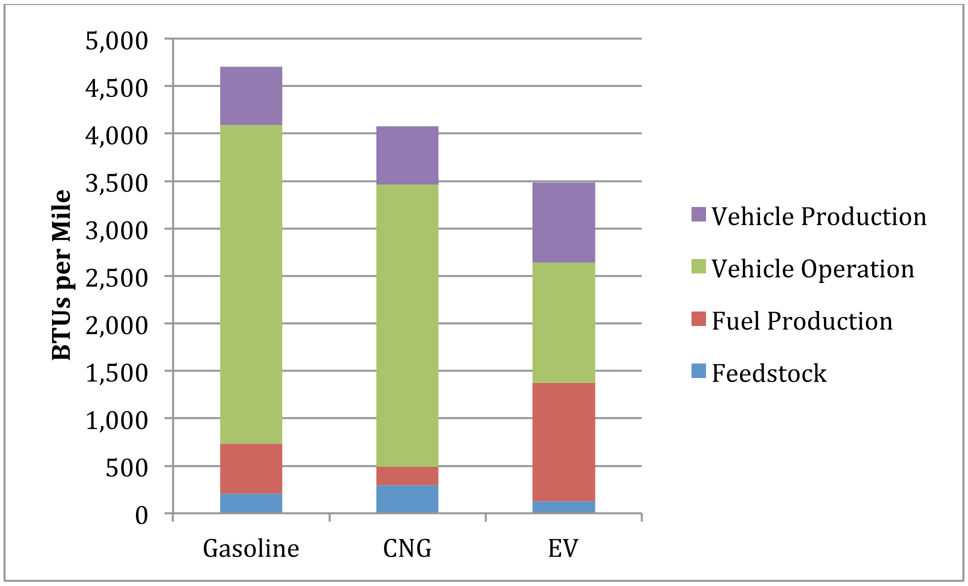


Figure 22. Comparison of Ozone Precursor Emissions, New Vehicles in 2020 – Colorado

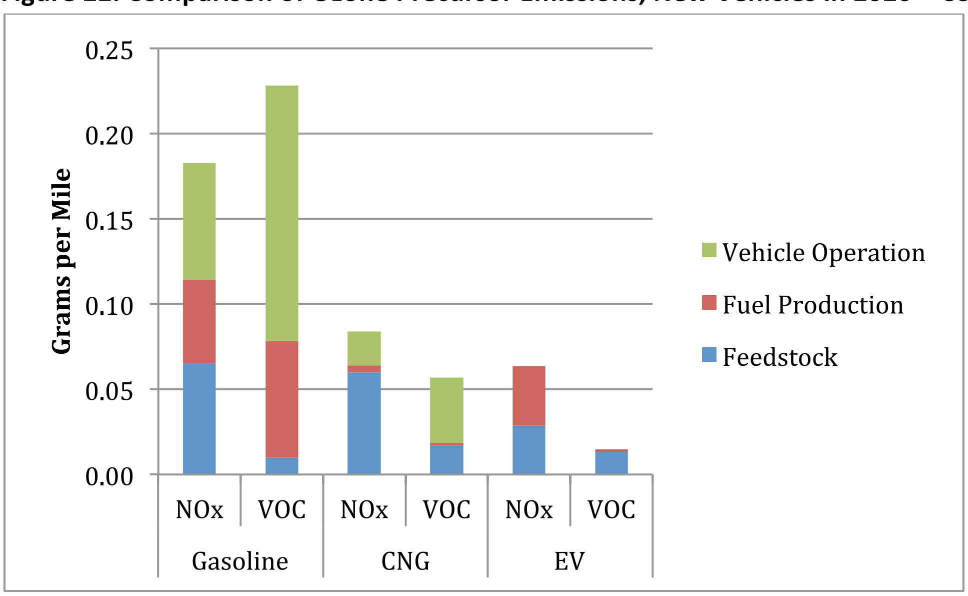


Figure 23. GHG Emissions, New Vehicles in 2020 – Colorado

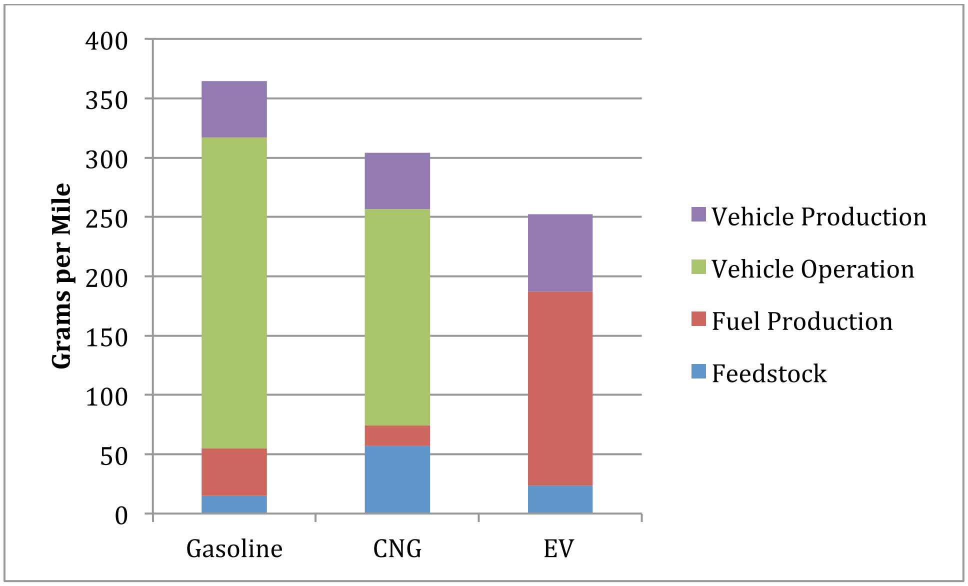
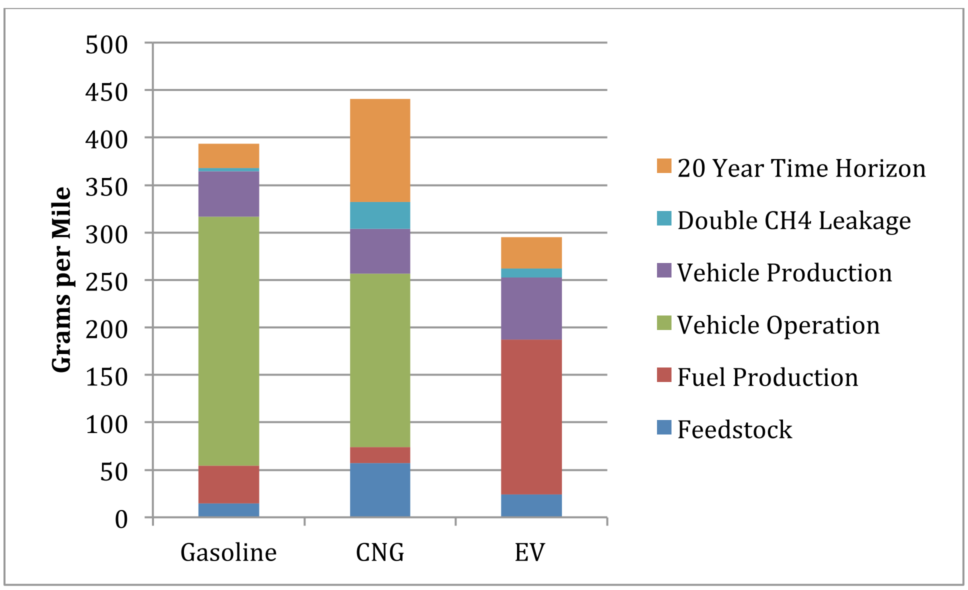


Figure 23. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2020 – Colorado



Nevada

New Vehicles in 2013

In 2013, electric vehicles are the most efficient vehicle type in Nevada. With the same amount of energy that an EV would use to travel 100 miles, a CNG vehicle can travel 84 miles and the gasoline vehicle only 76 miles. Regarding ozone precursors, CNG vehicles emit the lowest level of NO_x and electric vehicles emit the least amount of VOCs. Gasoline vehicles have the highest level of NO_x and VOC emissions.

Table 3. Best Performing Vehicles in Nevada

Parameter	New vehicles in 2013	2013 vehicles in 2020	New vehicles in 2020
Fuel consumption	EV	EV	EV
GHG *(base analysis)*	EV	EV	EV
GHG *(doubled CH_4 leakage rates)*	EV	EV	EV
GHG *(20 year time horizon)*	EV	EV	EV
NO_x	CNG	EV	CNG
VOC	EV	EV	EV

Figure 25. Comparison of Energy Consumption, New Vehicles in 2013 – Nevada

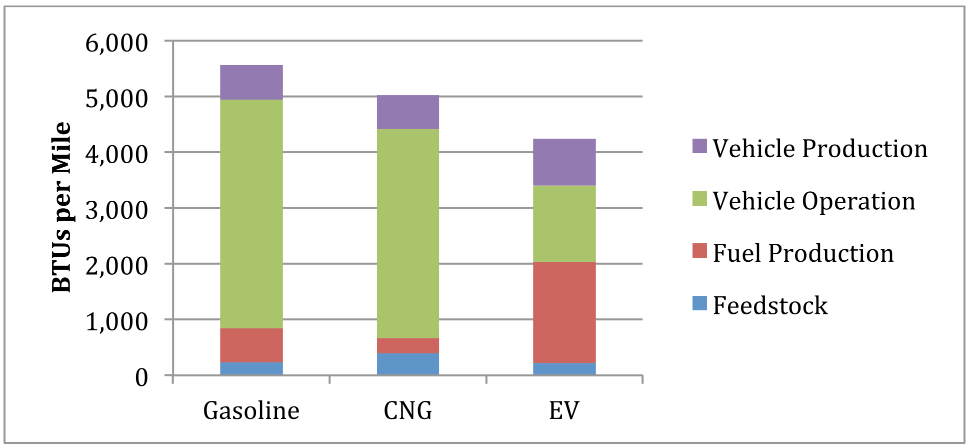
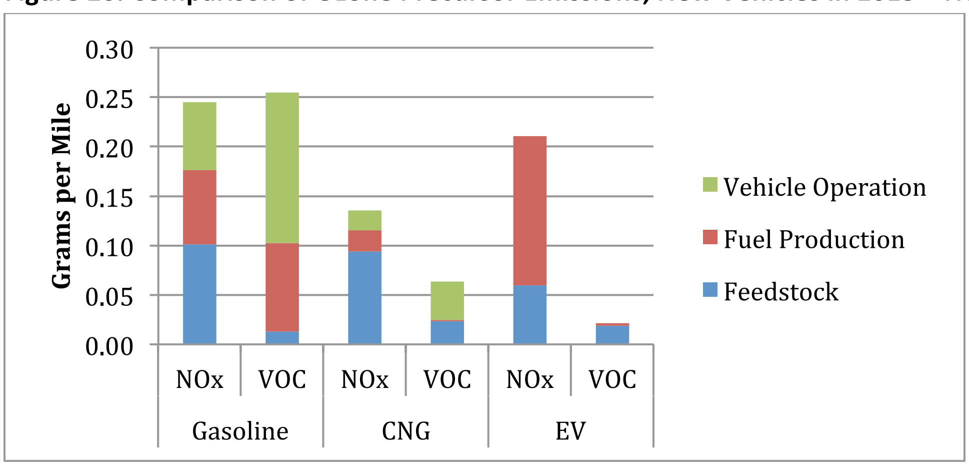


Figure 26. Comparison of Ozone Precursor Emissions, New Vehicles in 2013 – Nevada



EVs emit the least amount of greenhouse gases and gasoline vehicles emit the most greenhouse gases. If methane emission rates are doubled, the ranking of the vehicles stays the same but CNG vehicles lose most of their advantage over gasoline vehicles. If greenhouse gas emissions are considered on a 20-year timeframe, CNG vehicles emit the highest level of emissions and EVs maintain their advantage over the other vehicles.

Figure 27. GHG Emissions, New Vehicles in 2013 – Nevada

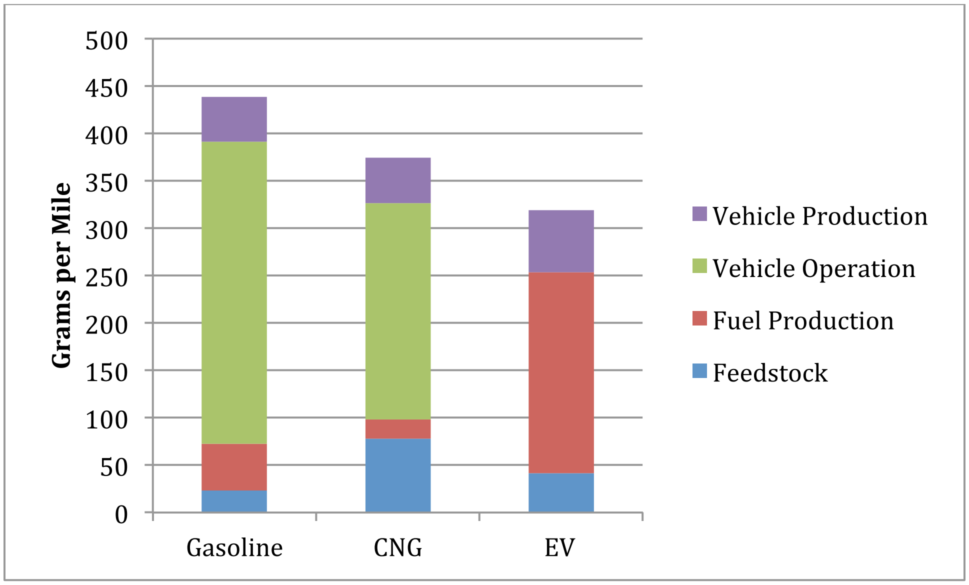
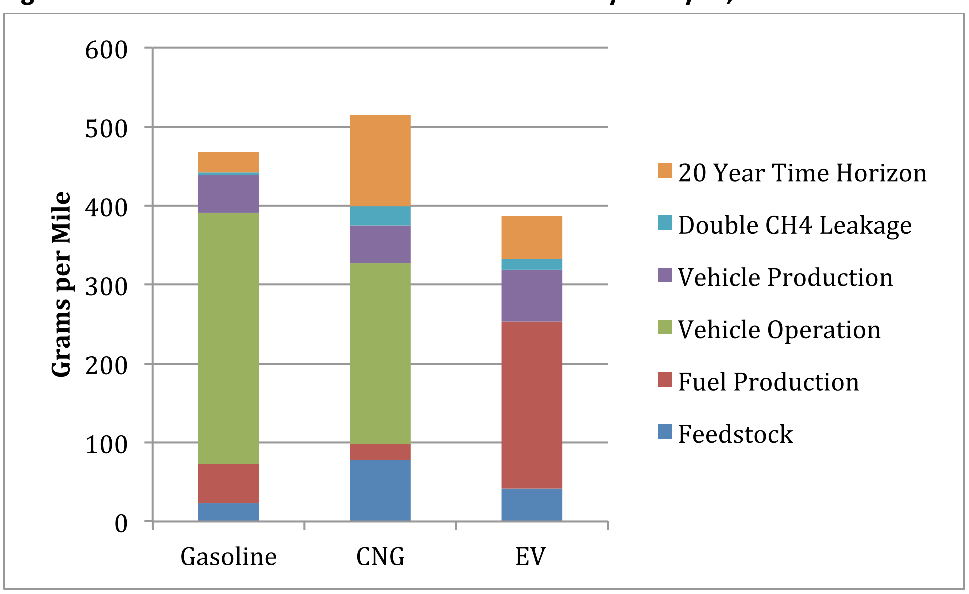


Figure 28. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2013 – Nevada



2013 Vehicles in 2020[30]

For 2013 vehicles operating in 2020, due to the shift from coal to increasing use of renewable electricity sources, EVs have increased their efficiency advantage, with CNG and gasoline vehicles now traveling only 81 and 73 miles respectively with the same amount of energy an EV would use to travel 100 miles. Likewise, the greenhouse gas emissions advantage has increased with GHG emissions from EVs decreasing by 10% compared to 2013 levels, while emissions from gasoline and CNG vehicles decrease by less than one percent. As in 2013, doubling the leakage rates for methane increases CNG emissions and removes most of its advantage over gasoline vehicles. Using a 20-year time horizon for greenhouse gas emissions, CNG vehicles are the highest emitters. In 2020, EVs become the lowest emitting vehicles for NO_x and remain the lowest emitting for VOCs. Gasoline vehicles have the highest level of both NO_x and VOC emissions.

Figure 29. Energy Consumption, 2013 Vehicles in 2020 – Nevada

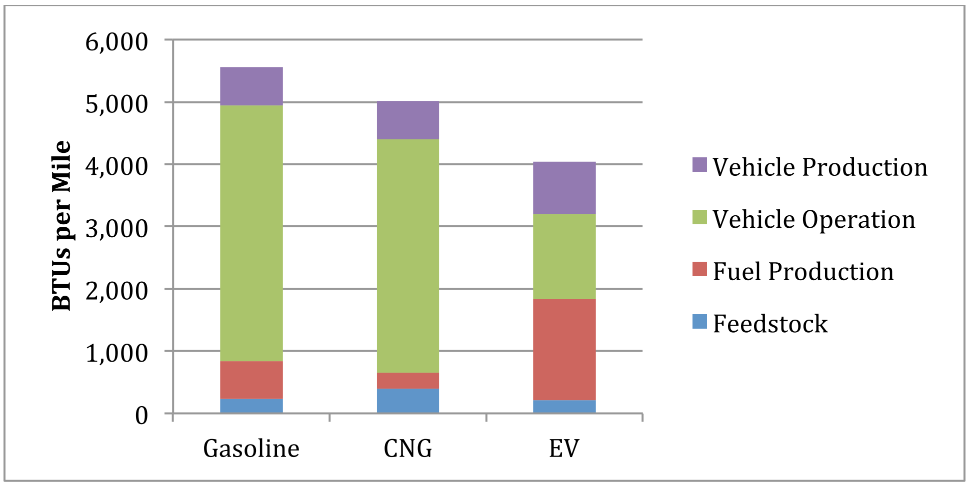
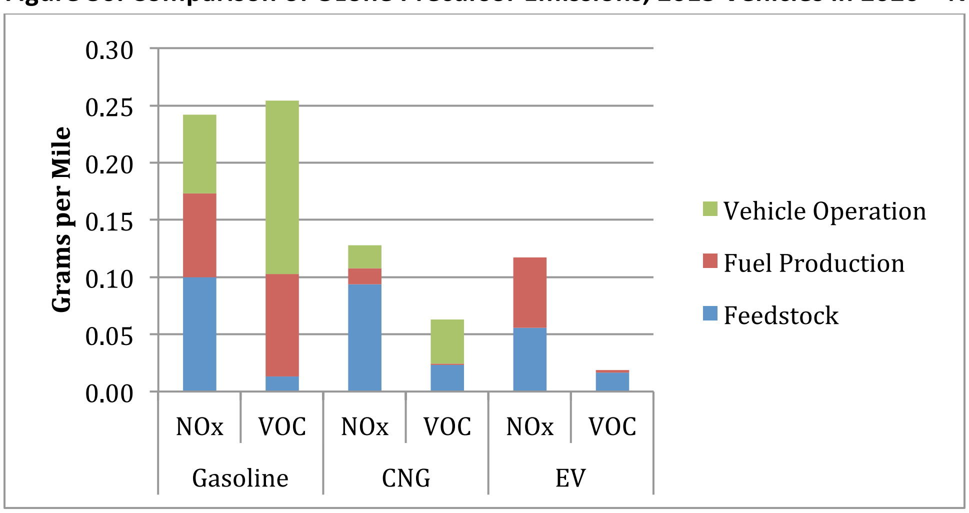


Figure 30. Comparison of Ozone Precursor Emissions, 2013 Vehicles in 2020 – Nevada



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30 After this analysis was completed, legislation was passed in 2013 in Nevada (SB 123) which will close the State's remaining coal fired plants by 2019. Therefore the electricity profile for Nevada will contain even less coal than forecast and this analysis likely underestimates the potential benefits of electric vehicles in Nevada.

Figure 31. GHG Emissions, 2013 Vehicles in 2020 – Nevada

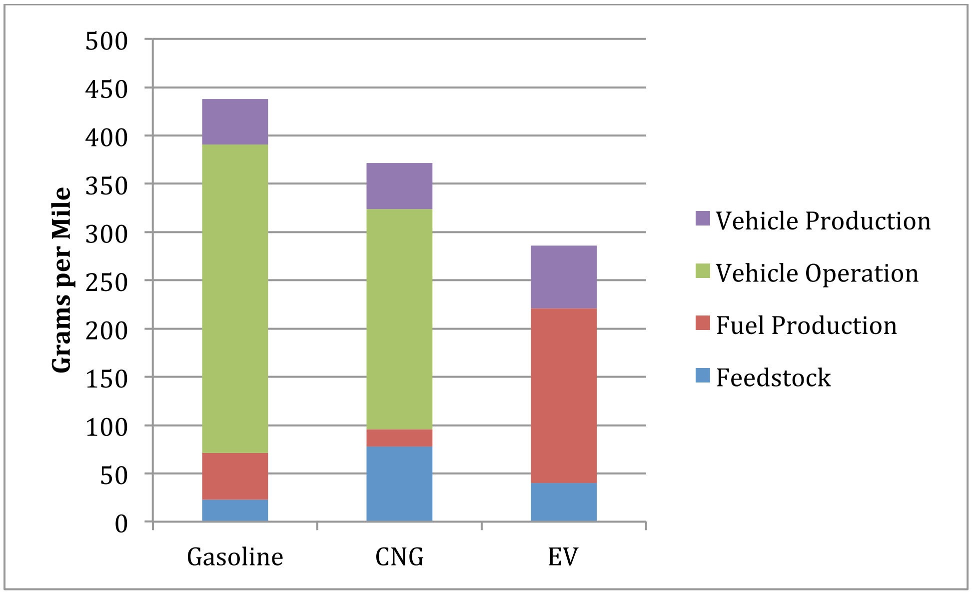
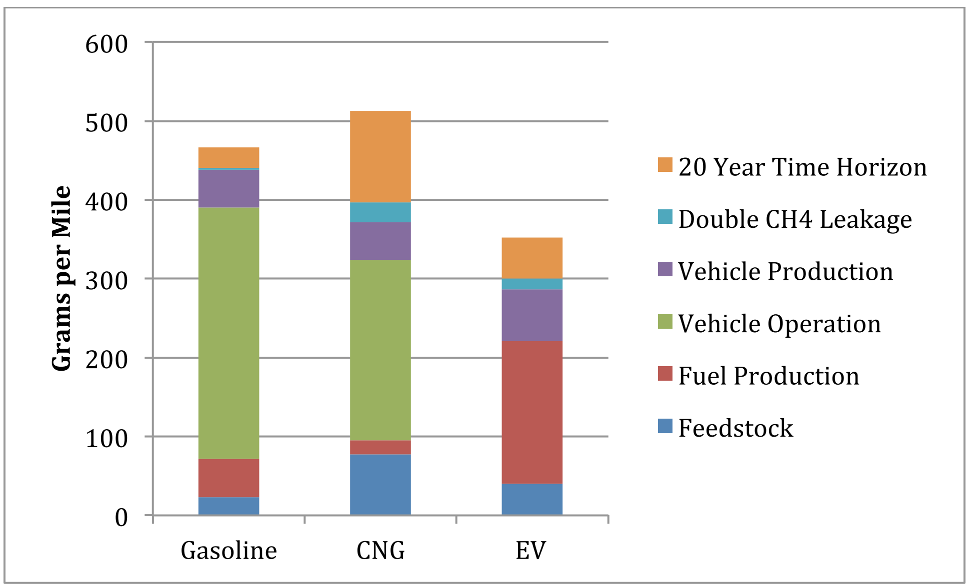


Figure 32. GHG Emissions with Methane Sensitivity Analysis, 2013 Vehicles in 2020 – Nevada



New Vehicles in 2020

For new vehicles in 2020, EVs remain the most energy efficient and the lowest emitting for greenhouse gases. Greater efficiency improvements in gasoline and CNG vehicles compared to EVs means that the advantage for electric vehicles has narrowed compared to 2013 vehicles operating in 2020. New CNG vehicles have the lowest NO_x emissions in 2020.

Figure 33. Energy Consumption, New Vehicles in 2020 – Nevada

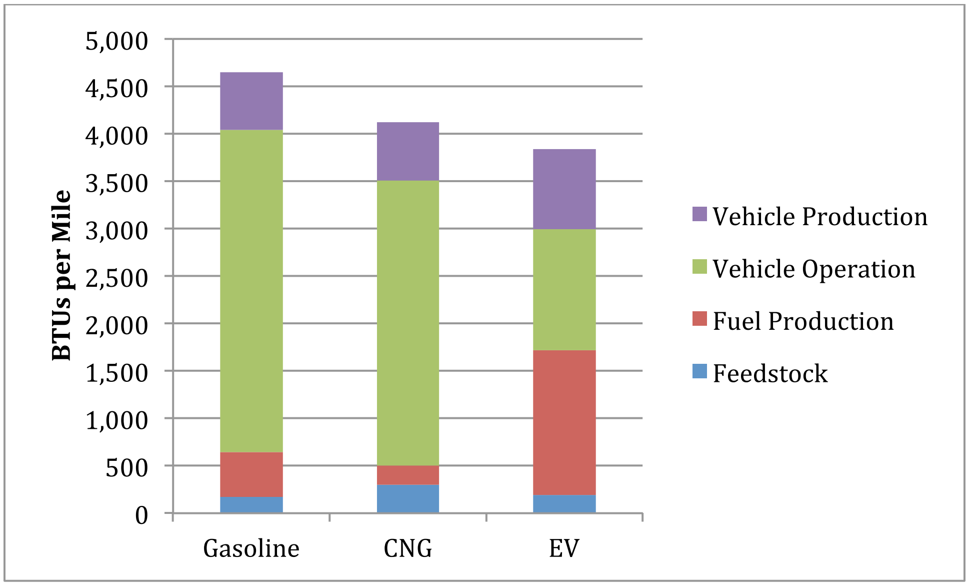


Figure 34. Ozone Precursor Emissions, New Vehicles in 2020 – Nevada

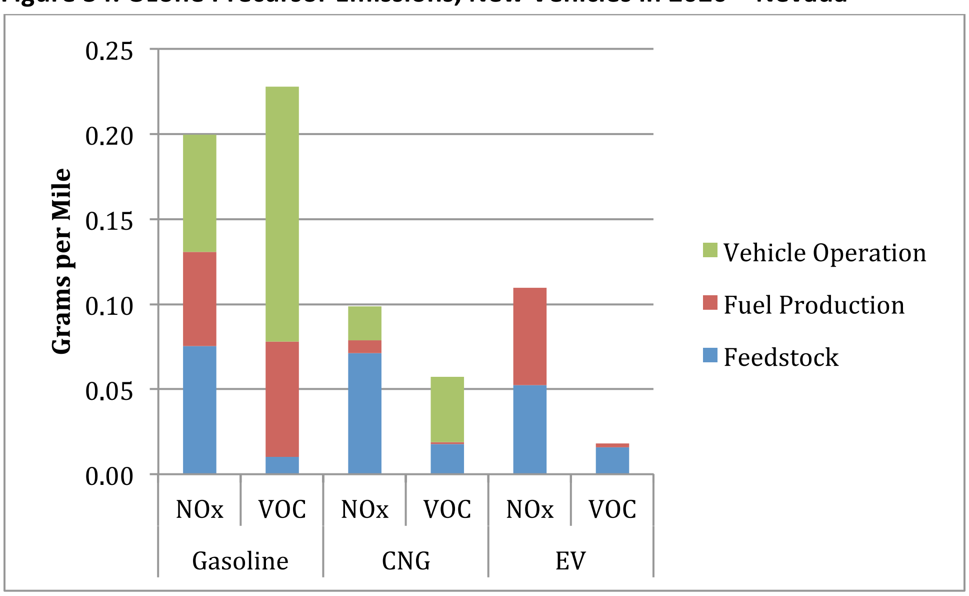


Figure 35. GHG Emissions, New Vehicles in 2020 – Nevada

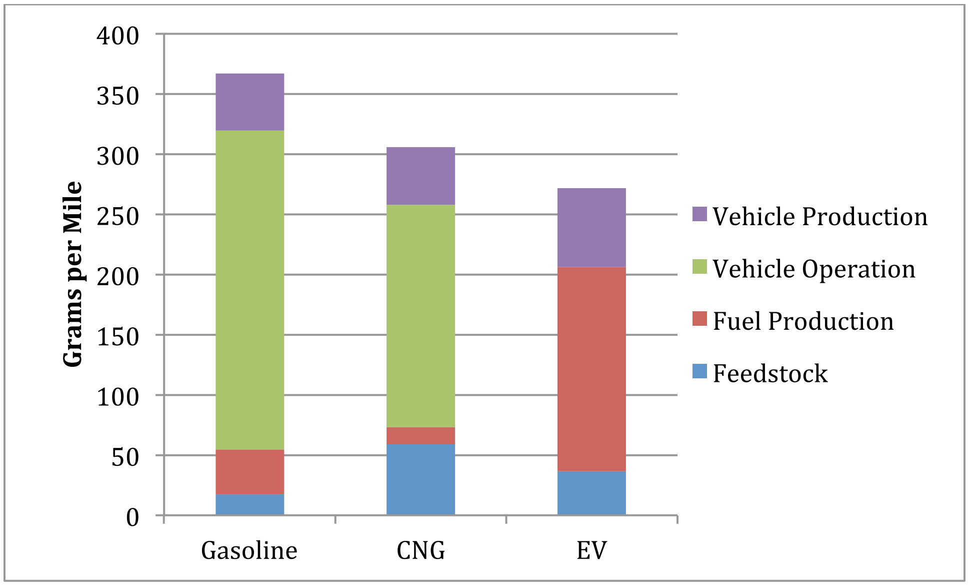
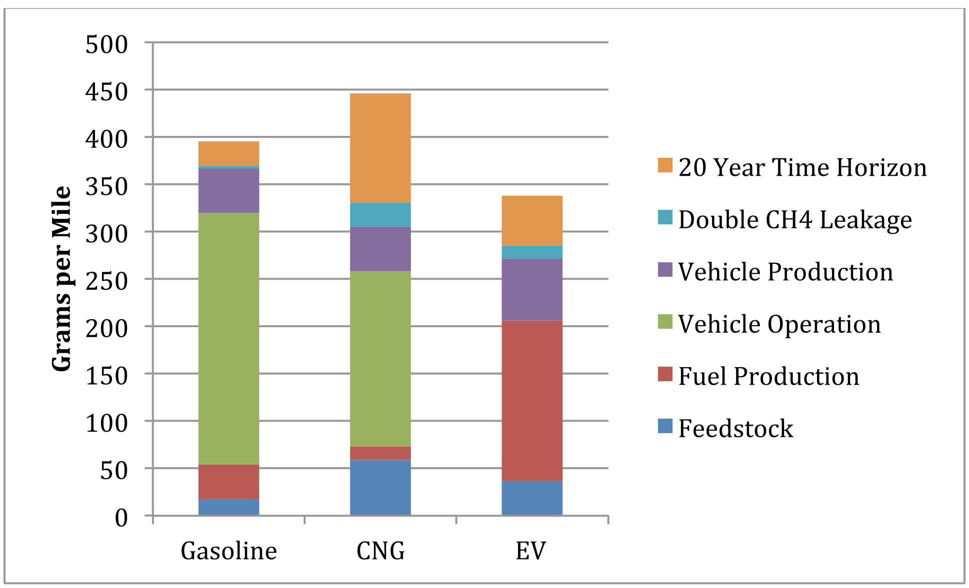


Figure 36. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2020 – Nevada



New Mexico

New Vehicles in 2013

In 2013, electric vehicles have a small advantage in energy consumption compared to gasoline and CNG vehicles. With the same amount of energy that an electric uses to travel 100 miles, a CNG vehicle can travel 93 miles and a gasoline vehicle only 85 miles. For ozone precursor emissions, CNG vehicles emit the lowest level of NO_x and EVs emit a very high level of NO_x due to high reliance on coal for electricity generation in the state. EVs emit the lowest level of VOCs and gasoline vehicles the highest level.

Table 4. Best Performing Vehicles in NM

Parameter	New vehicles in 2013	2013 vehicles in 2020	New vehicles in 2020
Fuel consumption	EV	EV	CNG
GHG *(base analysis)*	CNG	EV	CNG
GHG *(doubled CH_4 leakage rates)*	CNG	EV	CNG
GHG *(20 year time horizon)*	EV	EV	EV
NO_x	CNG	EV	CNG
VOC	EV	EV	EV

Figure 37. Energy Consumption, New Vehicles in 2013 – New Mexico

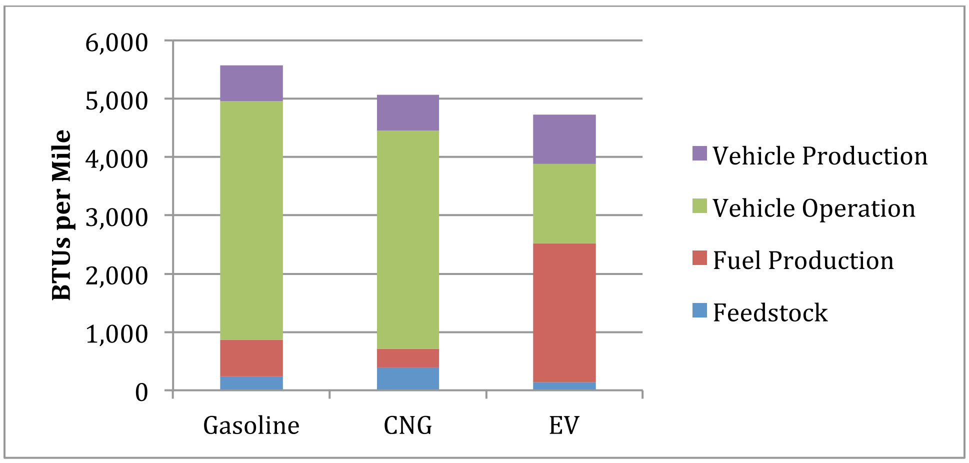
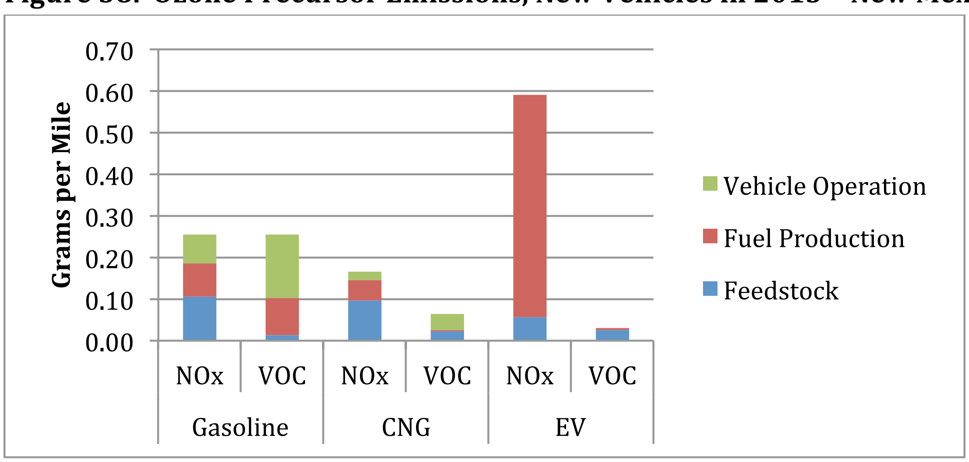


Figure 38. Ozone Precursor Emissions, New Vehicles in 2013 – New Mexico



CNG vehicles have the lowest level of greenhouse gas emissions of the three vehicle types. If methane leakage rates are doubled, CNG vehicles lose some of their advantage but remain the lowest emitting vehicle. Using a 20-year time horizon for emissions, EVs are the lowest emitting and CNG vehicles the highest emitting over their lifetimes.

Figure 39. GHG Emissions, New Vehicles in 2013 – New Mexico

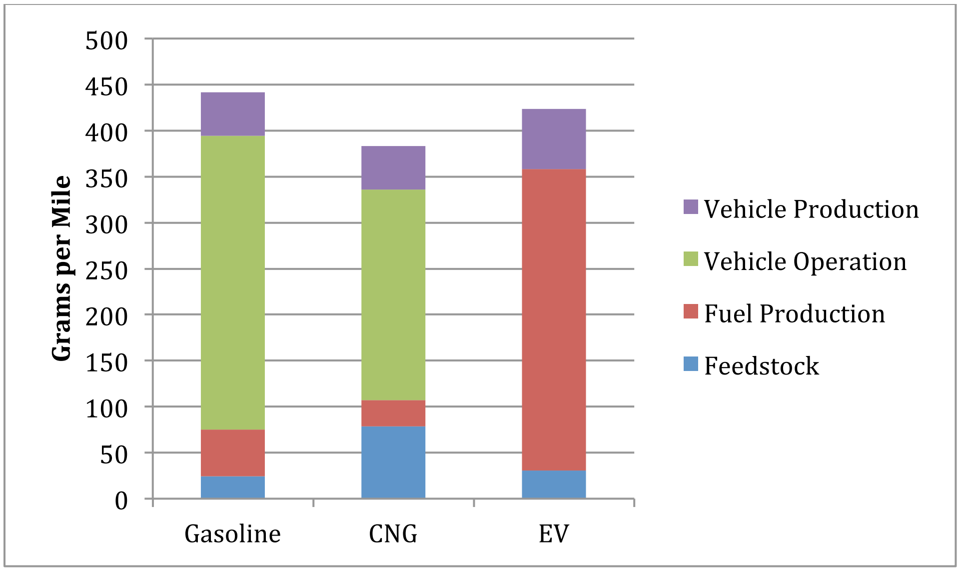
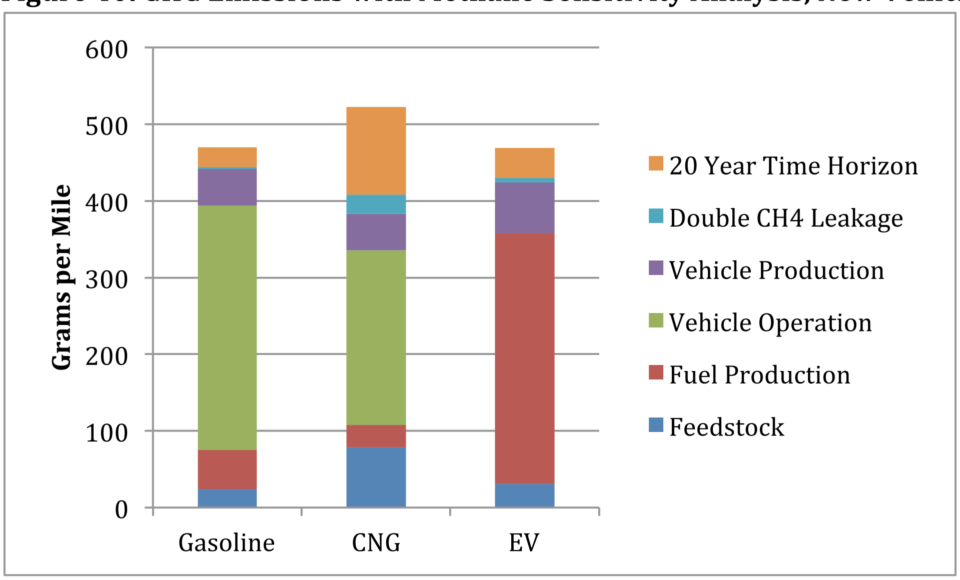


Figure 40. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2013 – NM



2013 Vehicles in 2020

By 2020, New Mexico will have replaced large amounts of coal for electricity generation with natural gas and renewables, thereby improving both efficiency and emissions for electric vehicles. For 2013 vehicles operating in 2020, EVs increase their advantage in energy consumption, reducing energy consumption by seven percent while gasoline and CNG vehicles see decreases of less than one percent. The amount of energy to power 100 miles of travel with an EV will now power a CNG vehicle 88 miles and a gasoline vehicle only 79 miles. For the ozone precursor pollutants, gasoline vehicles will have the highest level of NO_x and VOC emissions. EVs have significantly reduced (by 80%) levels of NO_x emissions since 2013, and now have slightly lower emissions than CNG vehicles. Electric vehicles are still the lowest emitting vehicle type regarding VOC emissions.

Figure 41. Energy Consumption, 2013 Vehicles in 2020 – New Mexico

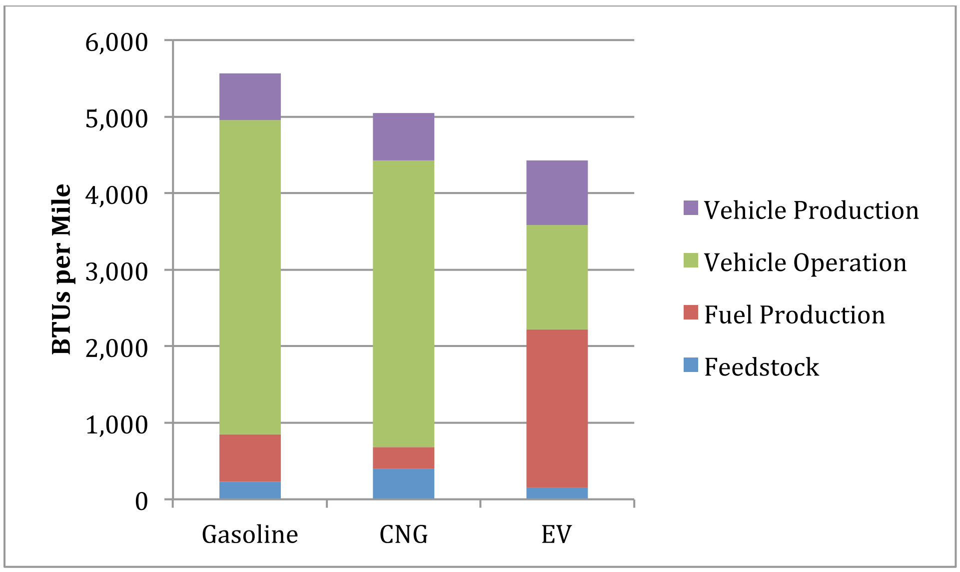
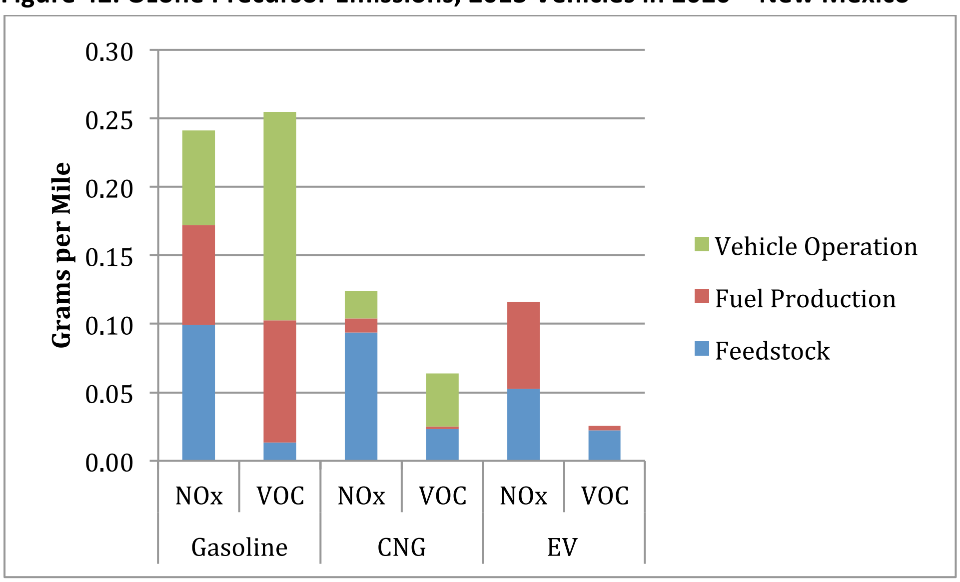


Figure 42. Ozone Precursor Emissions, 2013 Vehicles in 2020 – New Mexico



EVs will have the lowest level of GHG emissions, with a small advantage over CNG vehicles. If methane emission rates are doubled, EVs are still the lowest emitting and have a greater advantage over CNG vehicles. Considering a 20-year time horizon for GHG emissions makes CNG vehicles the highest emitting vehicle type for greenhouse gases.

Figure 43. GHG Emissions, 2013 Vehicles in 2020 – New Mexico

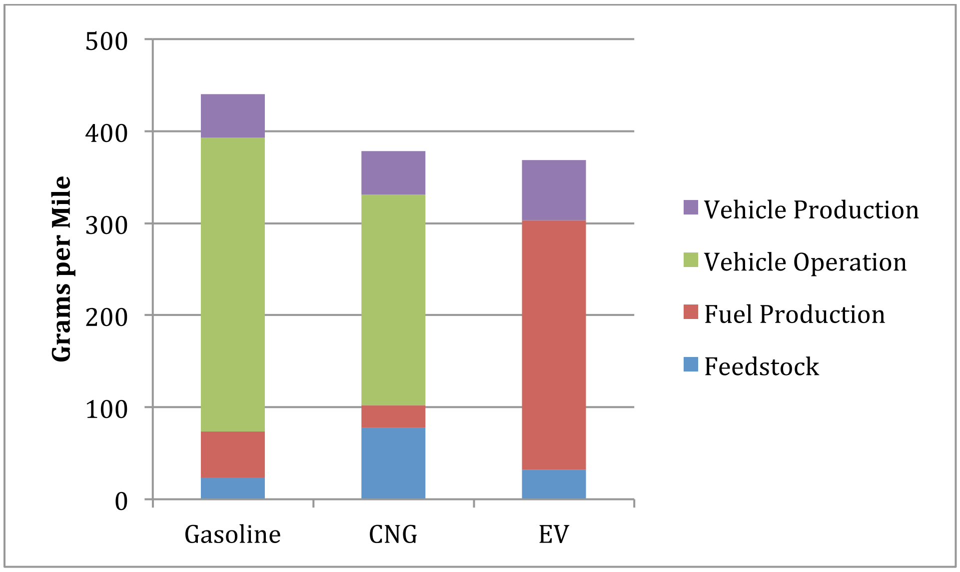
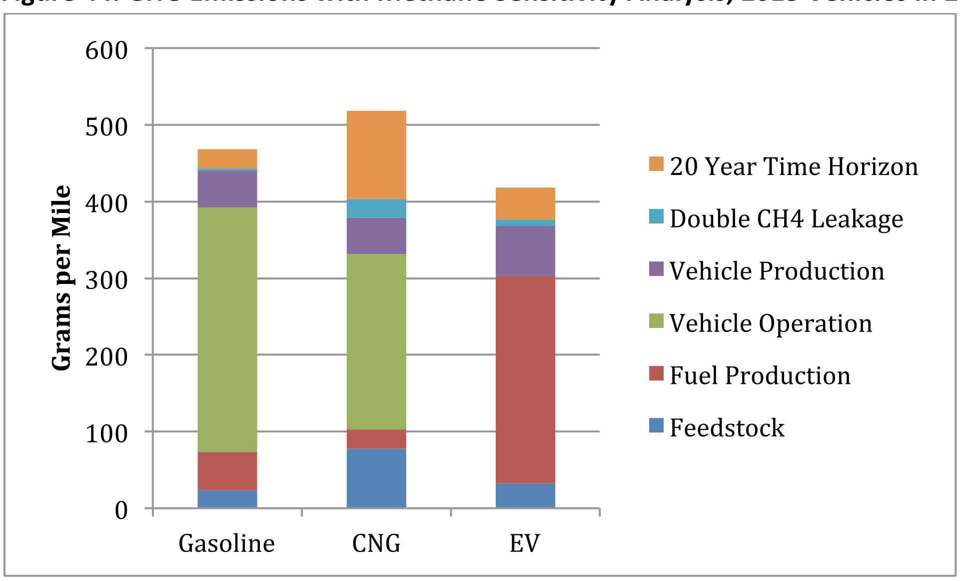


Figure 44. GHG Emissions with Methane Sensitivity Analysis, 2013 Vehicles in 2020 – NM



New Vehicles in 2020

When new vehicles are compared in 2020, CNG vehicles become the most efficient vehicle type, with EVs traveling 99 miles and gasoline vehicles traveling 89 miles on the same amount of energy that powers a CNG vehicle for 100 miles. Likewise, CNG vehicles become the lowest emitting vehicle type for lifecycle greenhouse gas emissions, while gasoline vehicles are still the highest emitting. The CNG vehicle remains the lowest emitting vehicle if methane leakage rates are doubled, but becomes the highest emitting vehicle if a 20-year time horizon for GHG emissions is considered. Regarding ozone precursors, CNG vehicles have the lowest level of NO_x emissions, EVs the lowest level of VOC emissions, and gasoline vehicles the highest levels for both pollutants.

Figure 45. Energy Consumption, New Vehicles in 2020 – New Mexico

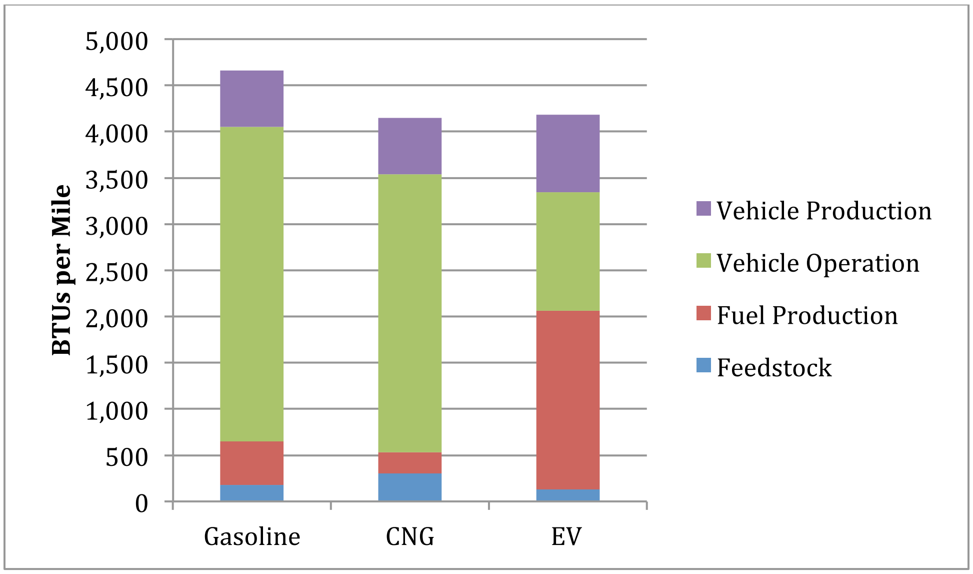


Figure 46. Ozone Precursor Emissions, New Vehicles in 2020 – New Mexico

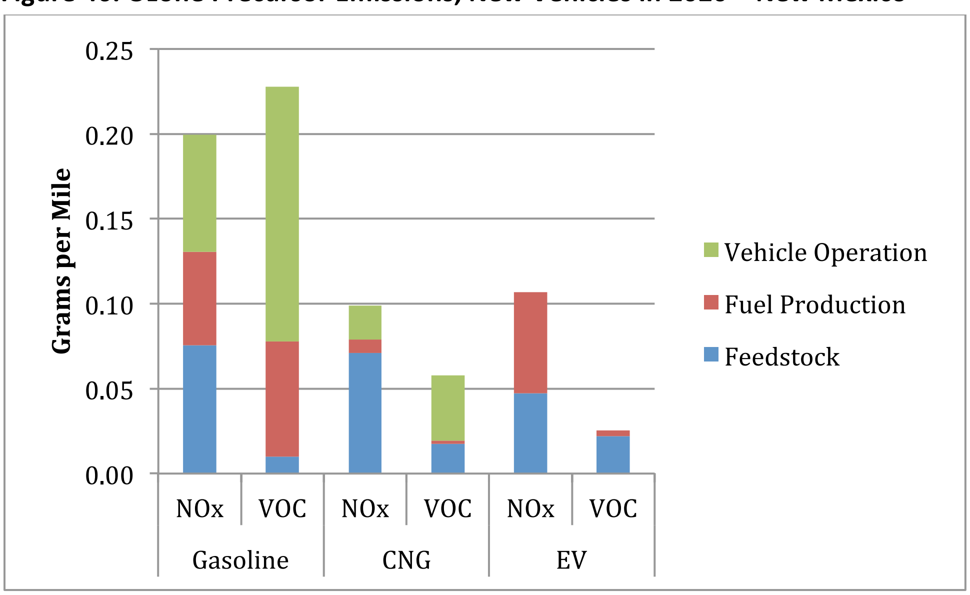


Figure 47. GHG Emissions, New Vehicles in 2020 – New Mexico

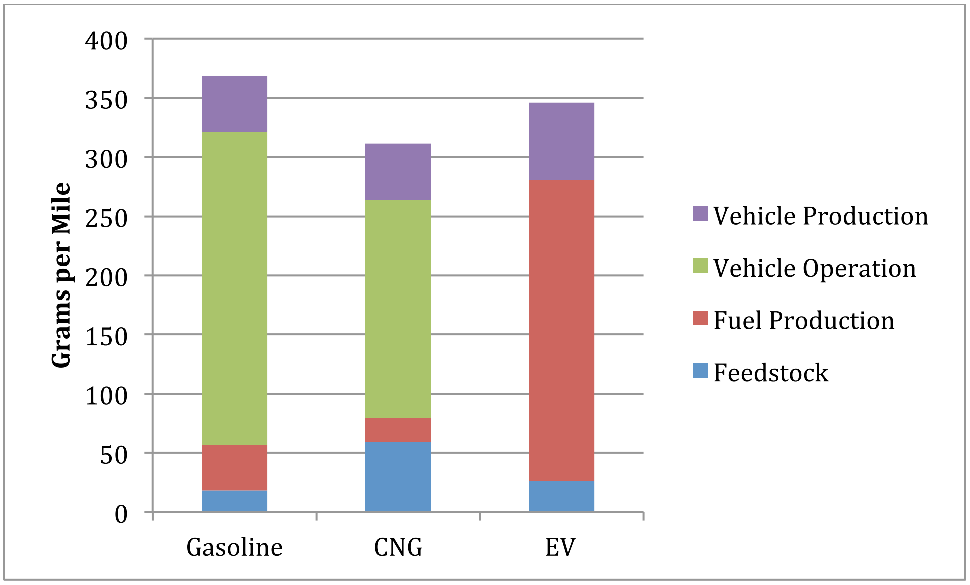
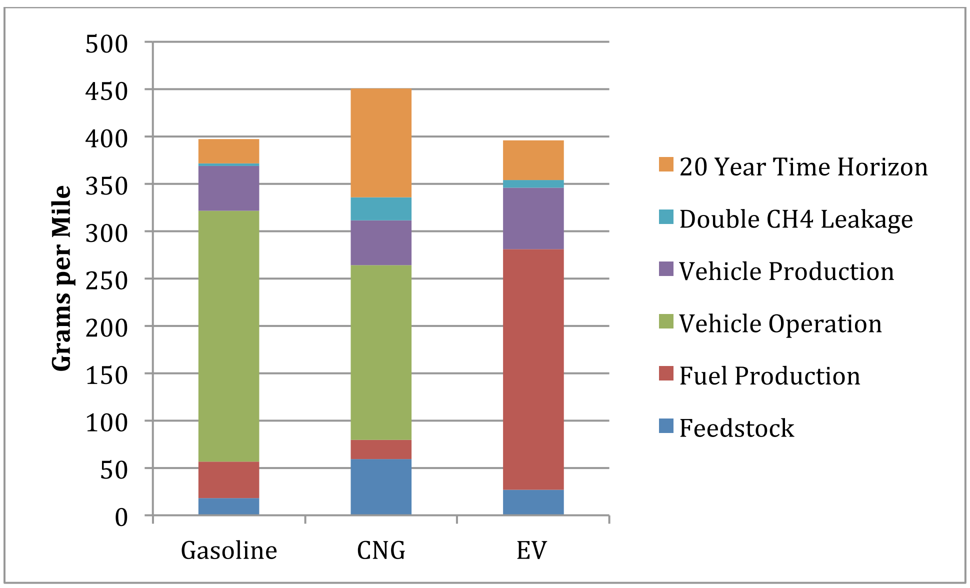


Figure 48. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2020 – New Mexico



Utah

New Vehicles in 2013

In 2013, electric vehicles are the most efficient vehicle at converting energy to miles traveled in Utah. Using the same amount of energy that powers an EV for 100 miles, a CNG vehicle can travel 96 miles and a gasoline vehicle only 88 miles. Regarding ozone precursors, CNG vehicles emit the least amount of NO_x and EVs the most. EVs emit the least amount of VOCs and gasoline vehicles emit the most.

Table 5. Best Performing Vehicles in Utah

Parameter	New vehicles in 2013	2013 vehicles in 2020	New vehicles in 2020
Fuel consumption	EV	EV	CNG
GHG *(base analysis)*	CNG	CNG	CNG
GHG *(doubled CH_4 leakage rates)*	CNG	EV	CNG
GHG *(20 year time horizon)*	Gasoline	EV	Gasoline
NO_x	CNG	EV	CNG
VOC	EV	EV	EV

Figure 49. Energy Consumption, New Vehicles in 2013 – Utah

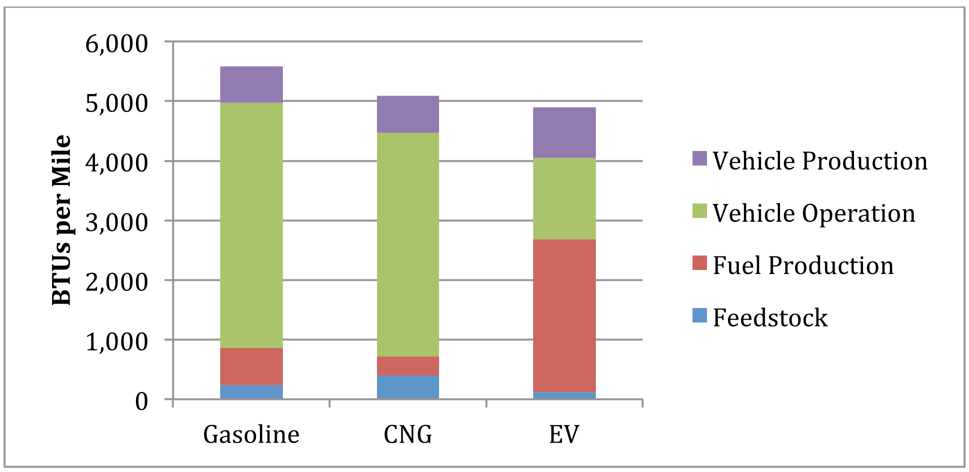
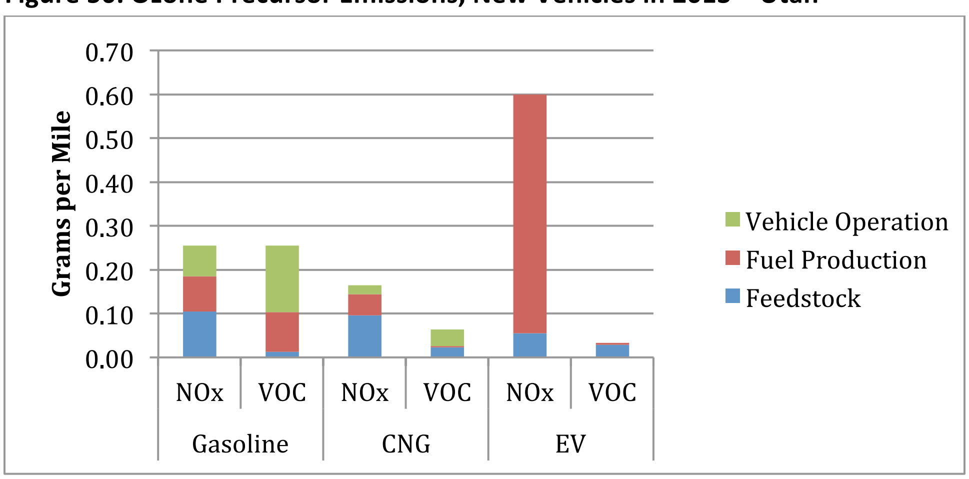


Figure 50. Ozone Precursor Emissions, New Vehicles in 2013 – Utah



CNG vehicles emit the lowest level of greenhouse gases and EVs the highest. If methane emission rates are doubled, CNG vehicles remain the lowest emitting; however, if we consider a 20-year time horizon, CNG vehicles become the highest emitting by a small margin.

Figure 51. GHG Emissions, New Vehicles in 2013 – Utah

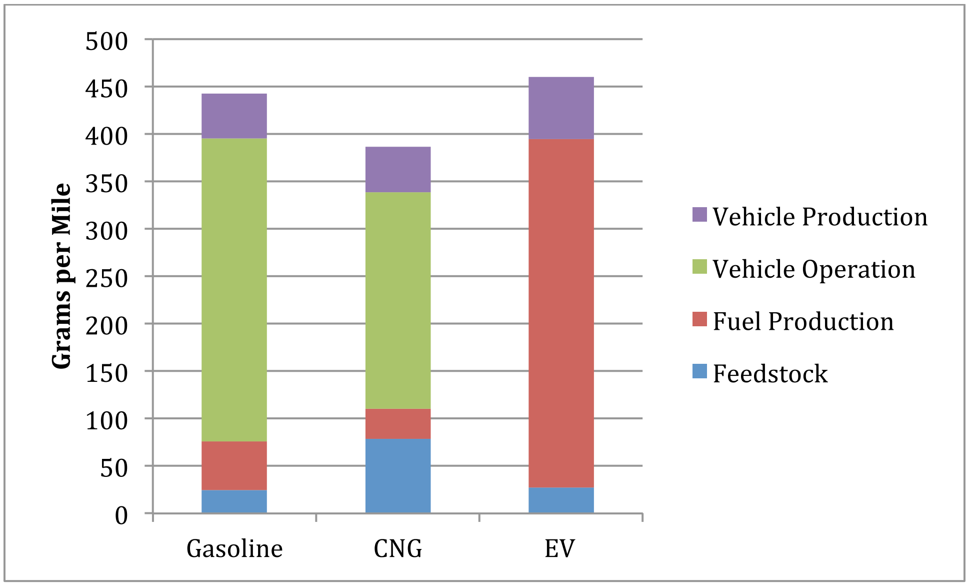
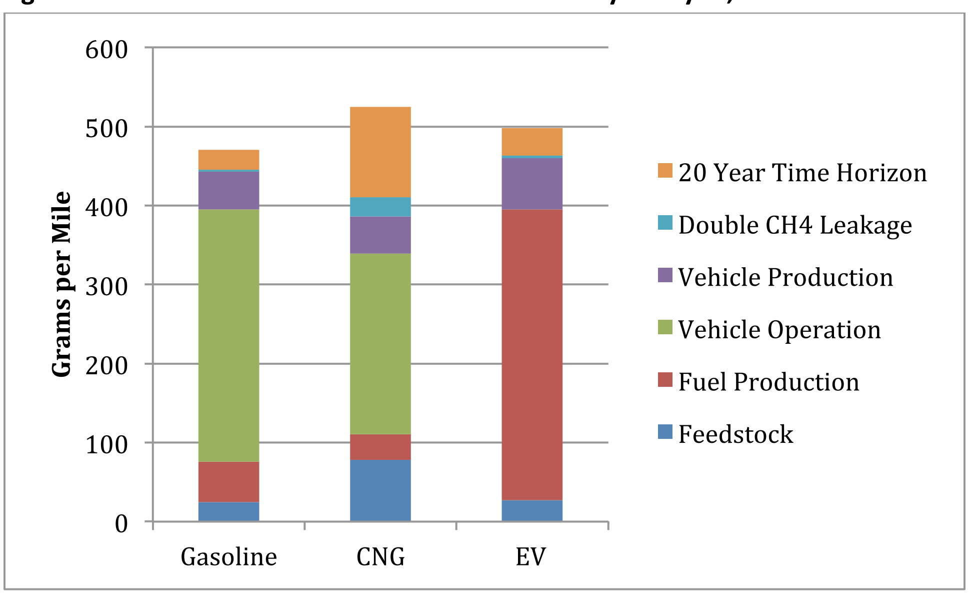


Figure 52. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2013 – Utah



2013 Vehicles in 2020

By 2020, the electric grid in Utah has improved by reducing the percentage of coal generation from 80% to 55% and replacing that with a mix of natural gas and renewables. For 2013 vehicles operating in 2020, the efficiency advantage of EVs has improved slightly due to improvements in the electric grid. A CNG vehicle would now travel 90 miles and a gasoline vehicle only 82 miles using the same amount of energy that would power an EV for 100 miles. CNG vehicles remain the lowest emitting vehicle type regarding greenhouse gas emissions, while gasoline vehicles now emit the highest levels. If rates of methane leakage are doubled, EVs become the lowest emitting vehicle by a small margin. If considering a 20-year time horizon for GHG emissions, CNG vehicles become the highest emitters and EVs the lowest. For ozone precursors, CNG and EVs have the same levels of NO_x emissions. EVs still have the lowest VOC emissions, with gasoline vehicles being by far the highest emitting for both pollutants.

Figure 53. Energy Consumption, 2013 Vehicles in 2020 – Utah

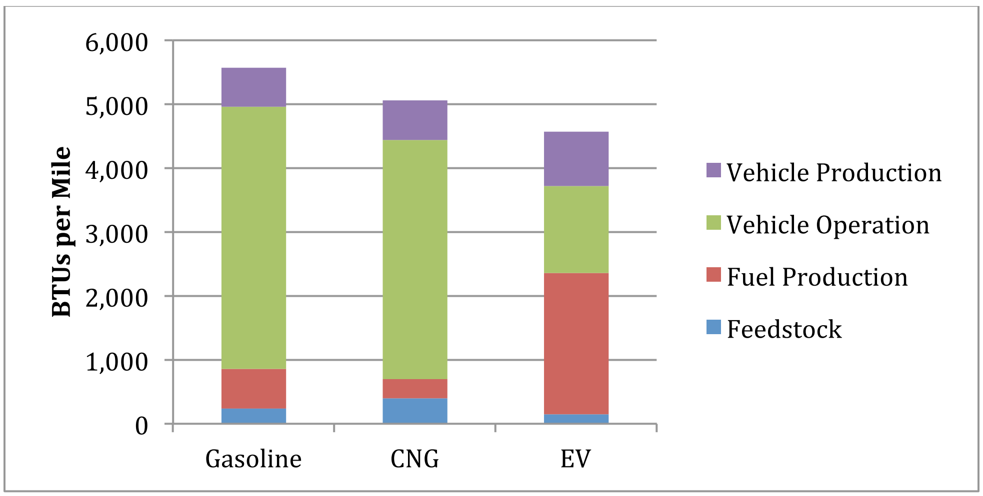


Figure 54. Comparison of Ozone Precursor Emissions, 2013 Vehicles in 2020 – Utah

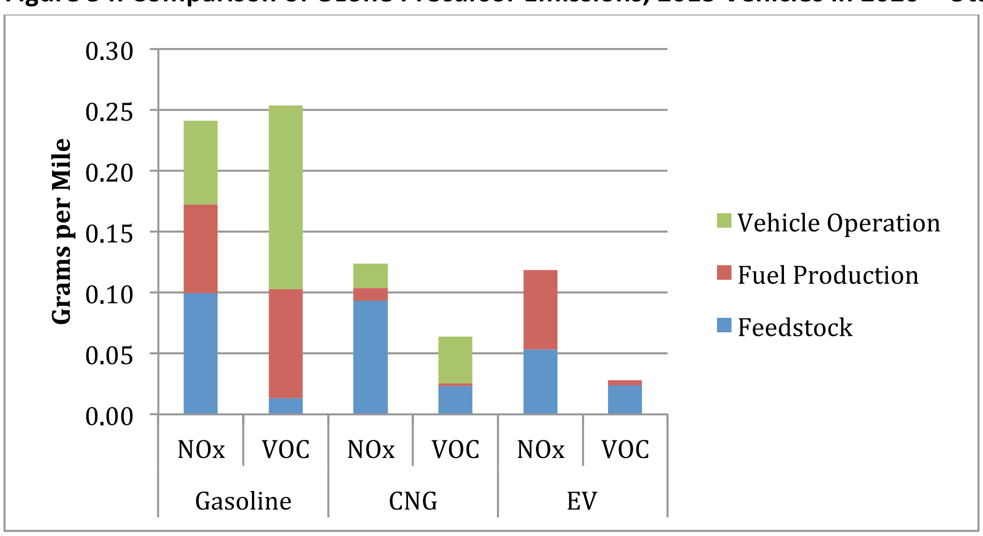


Figure 55. GHG Emissions, 2013 Vehicles in 2020 – Utah

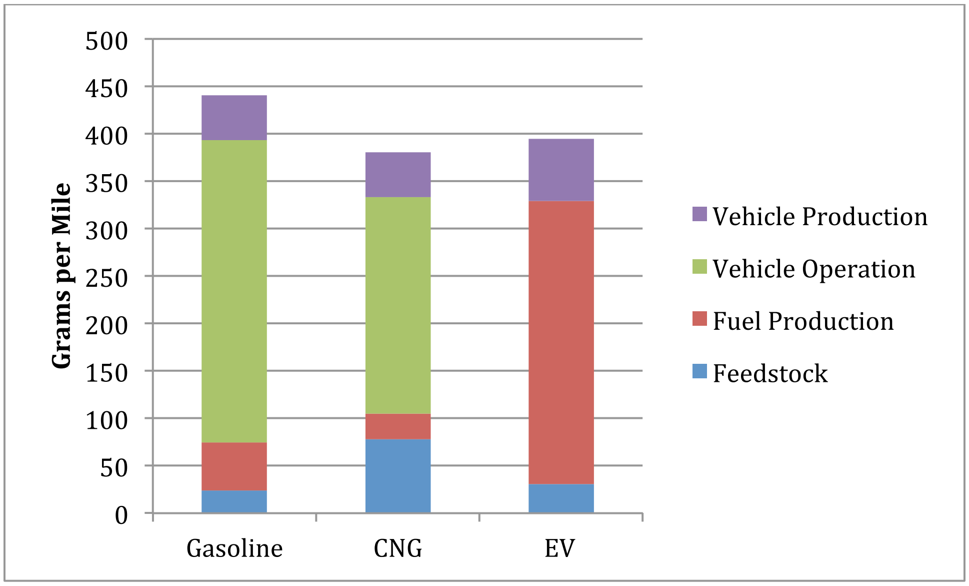
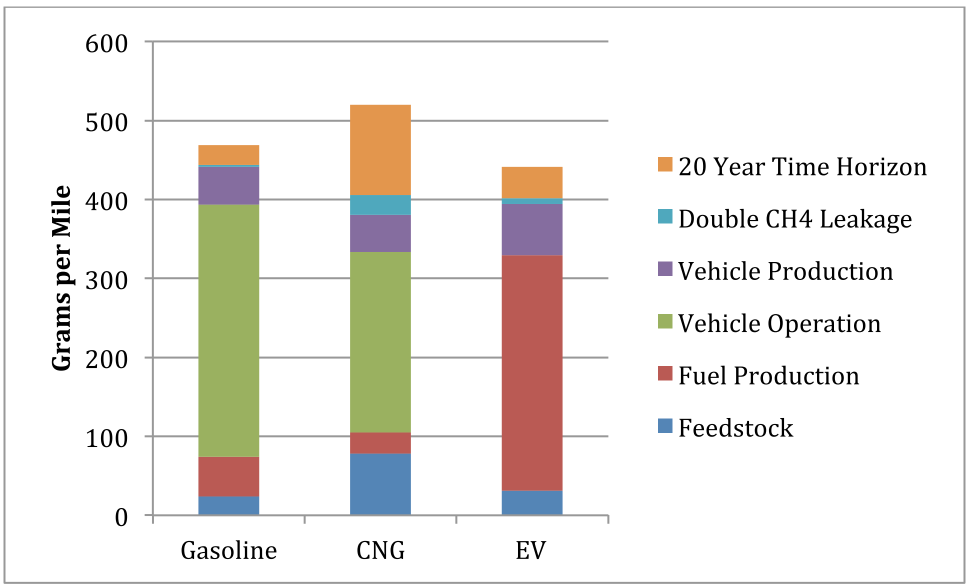


Figure 56. GHG Emissions with Methane Sensitivity Analysis, 2013 Vehicles in 2020 – Utah



New Vehicles in 2020

Comparing new vehicles in 2020, CNG vehicles become the most efficient, with an EV traveling 96 miles and a gasoline vehicle 89 miles using the same amount of energy a CNG vehicle uses to travel 100 miles. Regarding lifecycle greenhouse gas emissions, CNG vehicles remain the lowest emitting vehicle type while EVs become the highest emitting. If a 20-year time horizon for emissions is considered, CNG vehicles become the highest emitting vehicle type. For ozone precursors, CNG vehicles are the lowest emitter of NO_x and electric vehicles remain the lowest emitter of VOCs, while gasoline vehicles remain the highest emitter of both pollutants.

Figure 57. Energy Consumption, New Vehicles in 2020 – Utah

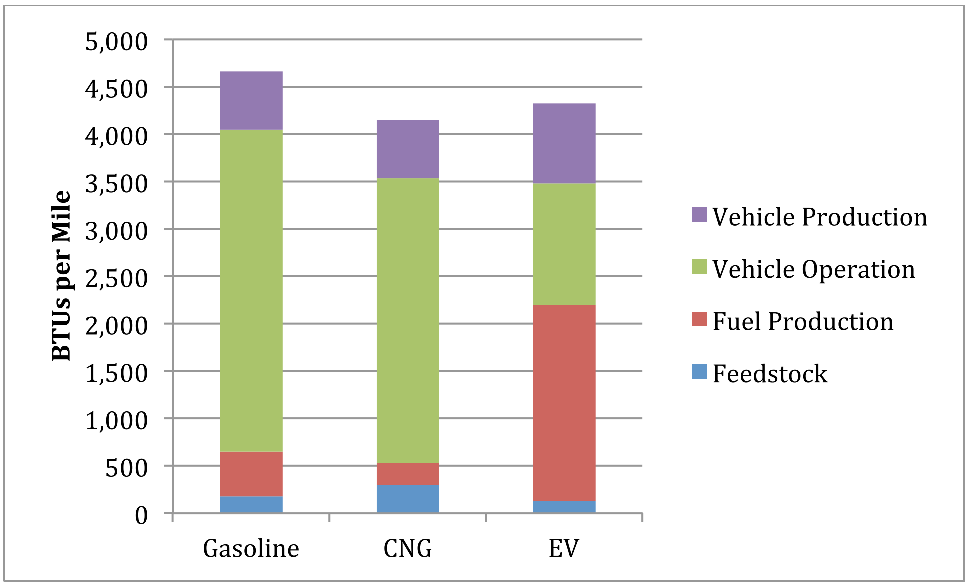


Figure 58. Ozone Precursor Emissions, New Vehicles in 2020 – Utah

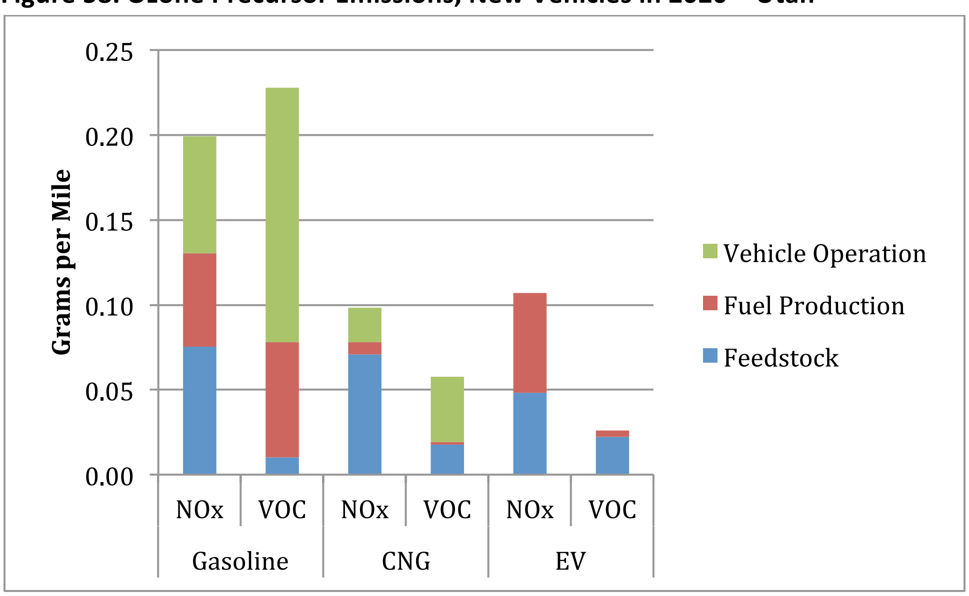


Figure 59. GHG Emissions, New Vehicles in 2020 – Utah

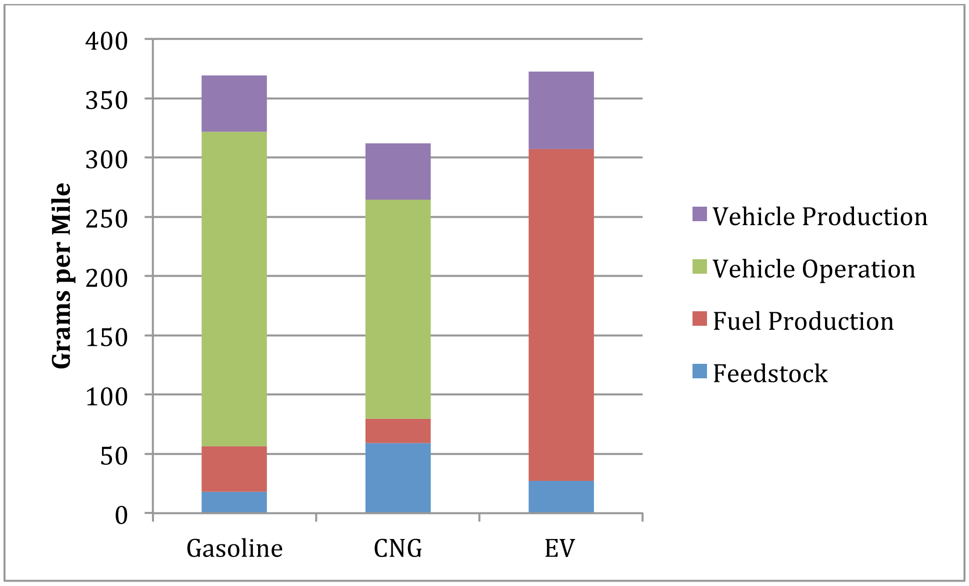
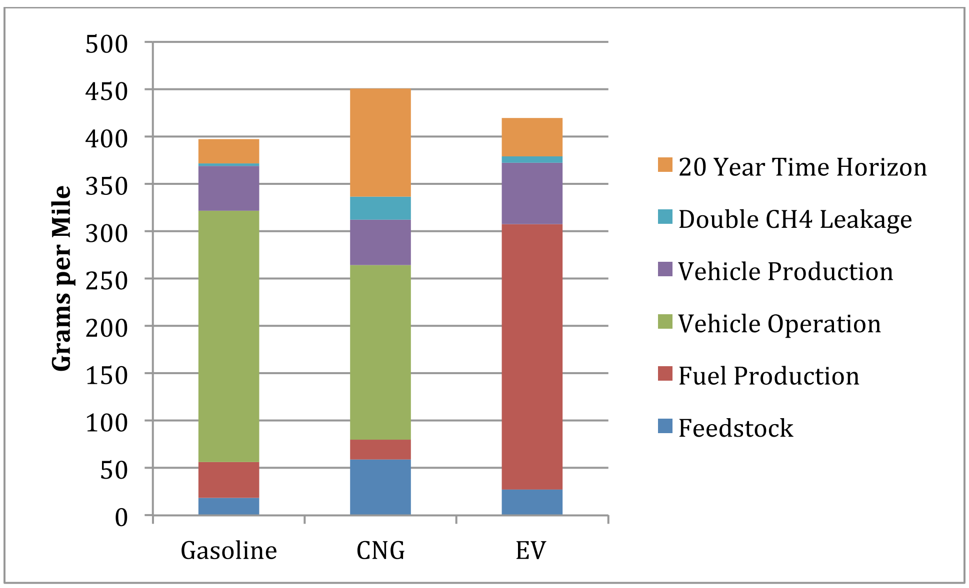


Figure 60. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2020 – Utah



Wyoming

New Vehicles in 2013

In 2013, electric vehicles are the most efficient vehicle at converting energy to miles traveled in Wyoming. Using the same amount of energy that would power an EV for 100 miles, a CNG vehicle can travel 96 miles and a gasoline vehicle only 87 miles. Regarding ozone precursors, CNG vehicles emit the least amount of NO_x and electric vehicles by far the most. Electric vehicles emit the least amount of VOCs and gasoline vehicles emit the most.

Table 6. Best Performing Vehicles in Wyoming

Parameter	New vehicles in 2013	2013 vehicles in 2020	New vehicles in 2020
Fuel consumption	EV	EV	CNG
GHG *(base analysis)*	CNG	CNG	CNG
GHG *(doubled CH_4 leakage rates)*	CNG	CNG	CNG
GHG *(20 year time horizon)*	Gasoline	EV	Gasoline
NO_x	CNG	EV	EV
VOC	EV	EV	EV

Figure 61. Energy Consumption, New Vehicles in 2013 – Wyoming

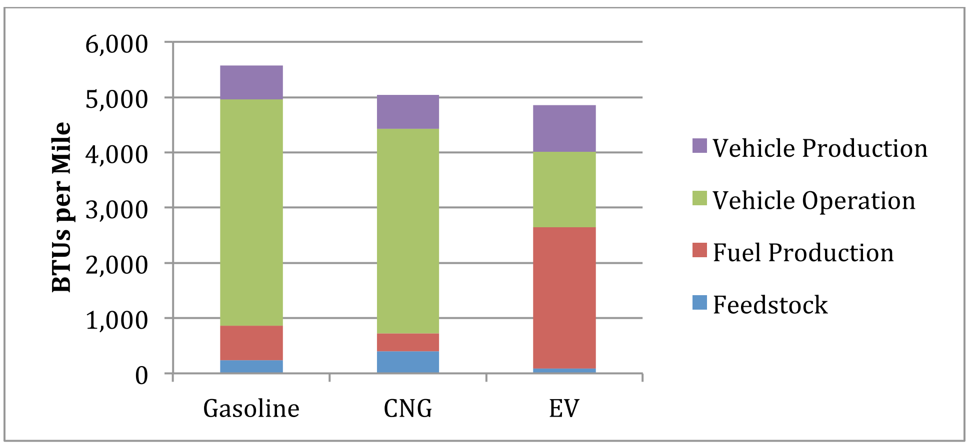
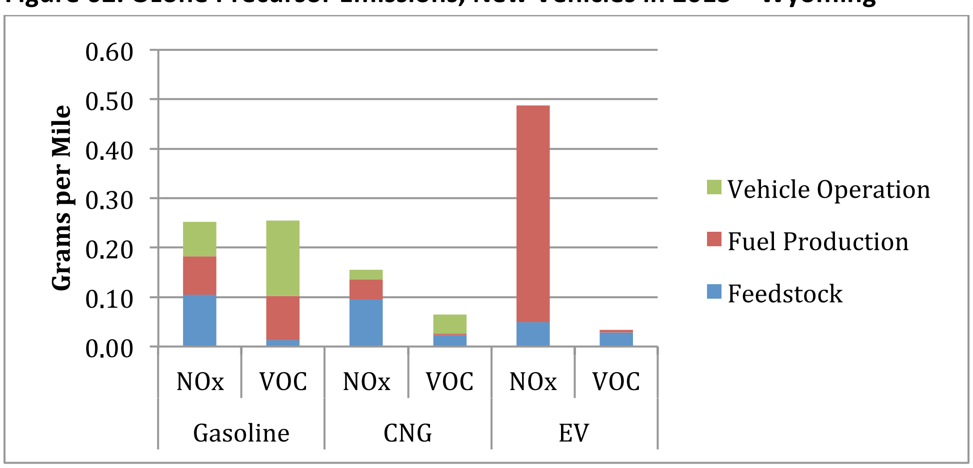


Figure 62. Ozone Precursor Emissions, New Vehicles in 2013 – Wyoming



CNG vehicles emit the lowest level of greenhouse gases and EVs the most. If methane emission rates are doubled, CNG vehicles remain the lowest emitting; however if a 20-year time horizon is used to evaluate GHG emissions, CNG vehicles become the highest emitting and gasoline vehicles generate the lowest emissions.

Figure 63. GHG Emissions, New Vehicles in 2013 – Wyoming

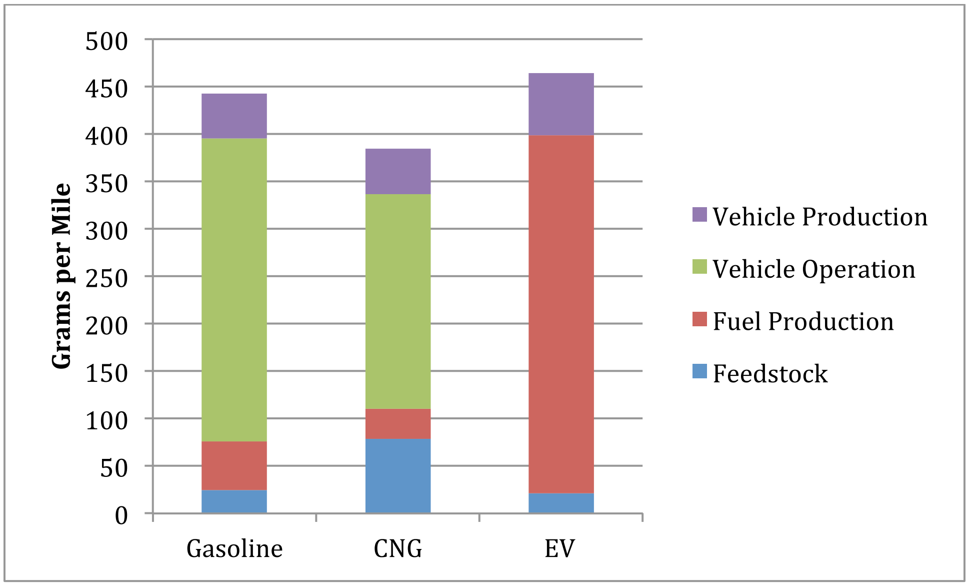
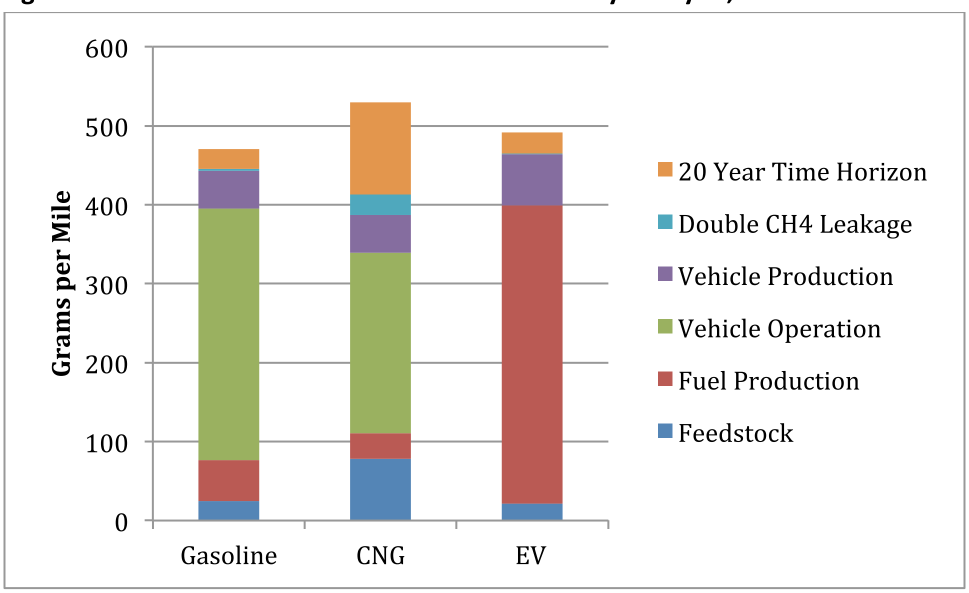


Figure 64. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2013 – WY



2013 Vehicles in 2020

By 2020, the efficiency advantage of EVs has improved slightly due to improvements in the electric grid, where renewables and natural gas have replaced a small amount of coal for electricity generation. A 2013 CNG vehicle operating in 2020 will travel 91 miles and a gasoline vehicle only 83 miles on the same amount of energy that powers an EV for 100 miles. CNG vehicles remain the lowest emitting vehicle type regarding GHG emissions, while gasoline vehicles now emit the highest level of greenhouse gases. If methane leakage rates are doubled, CNG vehicles, by a small margin, remain the lowest emitting vehicle type. If considering a 20-year time horizon for GHG emissions, CNG vehicles become the highest emitters and EVs the lowest by a small margin over gasoline vehicles. For ozone precursors, EVs have the lowest NO_x and VOC emissions, while gasoline vehicles are by far the highest emitting.

Figure 65. Energy Consumption, 2013 Vehicles in 2020 – Wyoming

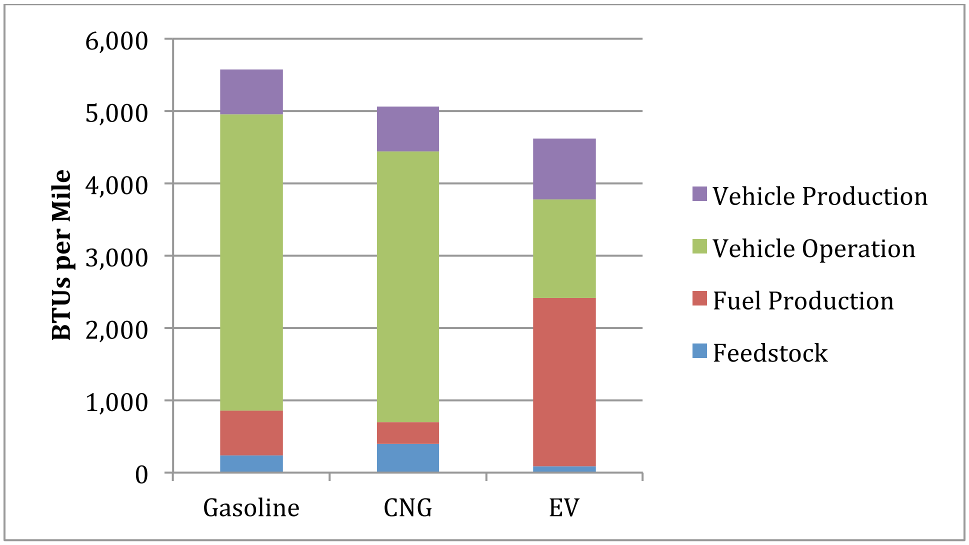


Figure 66. Ozone Precursor Emissions, 2013 Vehicles in 2020 – Wyoming

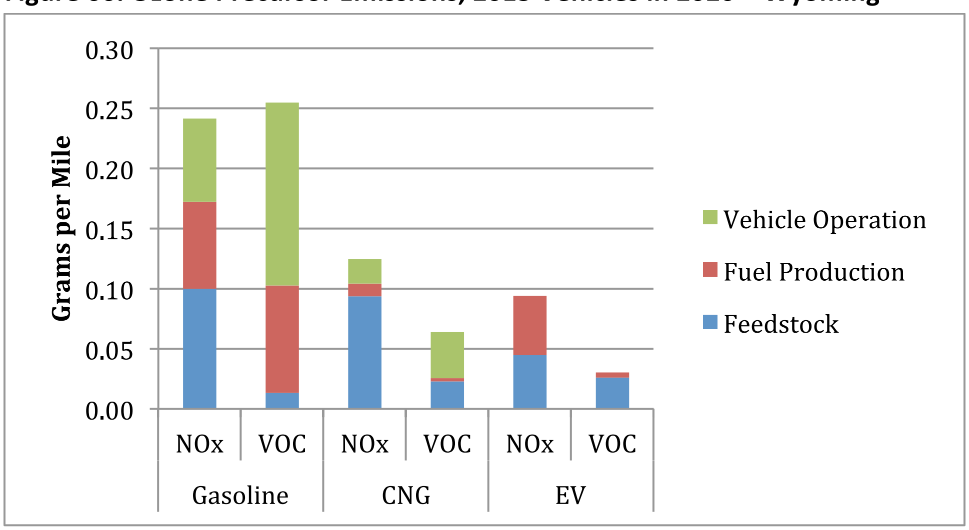


Figure 67. GHG Emissions, 2013 Vehicles in 2020 – Wyoming

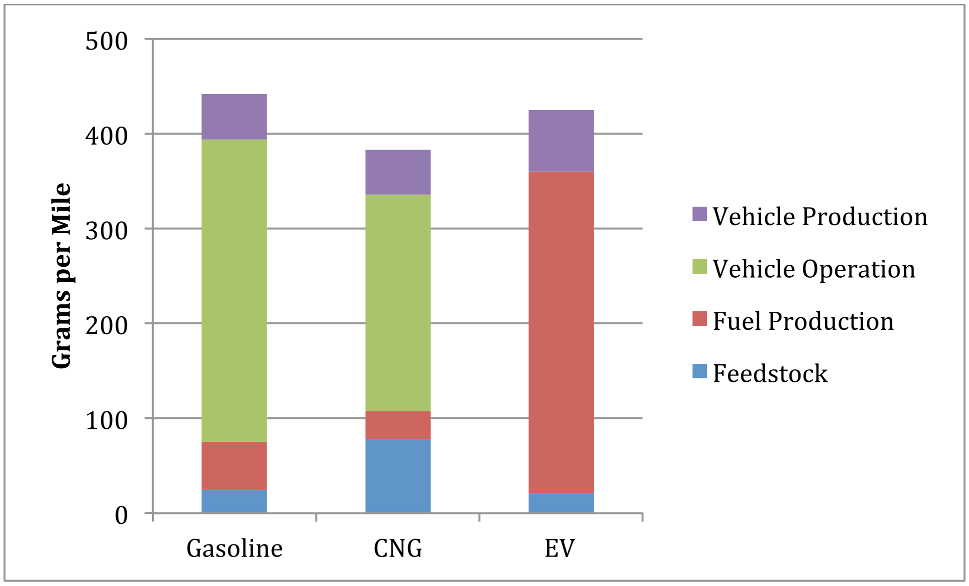
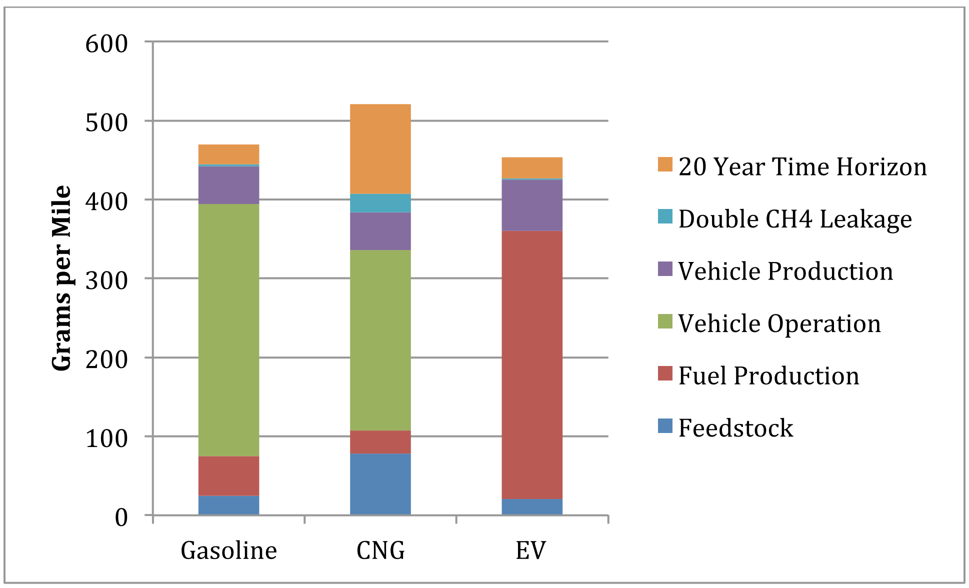


Figure 68. GHG Emissions with Methane Sensitivity Analysis, 2013 Vehicles in 2020 – WY



New Vehicles in 2020

For new vehicles in 2020, CNG vehicles are now the most efficient vehicle type in Wyoming, with an EV traveling 95 miles and a gasoline vehicle traveling 89 miles using the same amount of energy that a CNG vehicle uses to travel 100 miles. CNG vehicles remain the lowest emitting vehicle type regarding greenhouse gas emissions; EVs have the highest level of GHG emissions, even if methane leakage rates are doubled. If GHG emissions are considered on a 20-year time horizon, gasoline vehicles become the lowest emitting vehicle, while EVs and CNG vehicles have similar levels of emissions. For ozone precursors, EVs are the lowest emitting for NO_x and VOCs, while gasoline vehicles are the highest emitting for both pollutants.

Figure 69. Energy Consumption, New Vehicles in 2020 – Wyoming

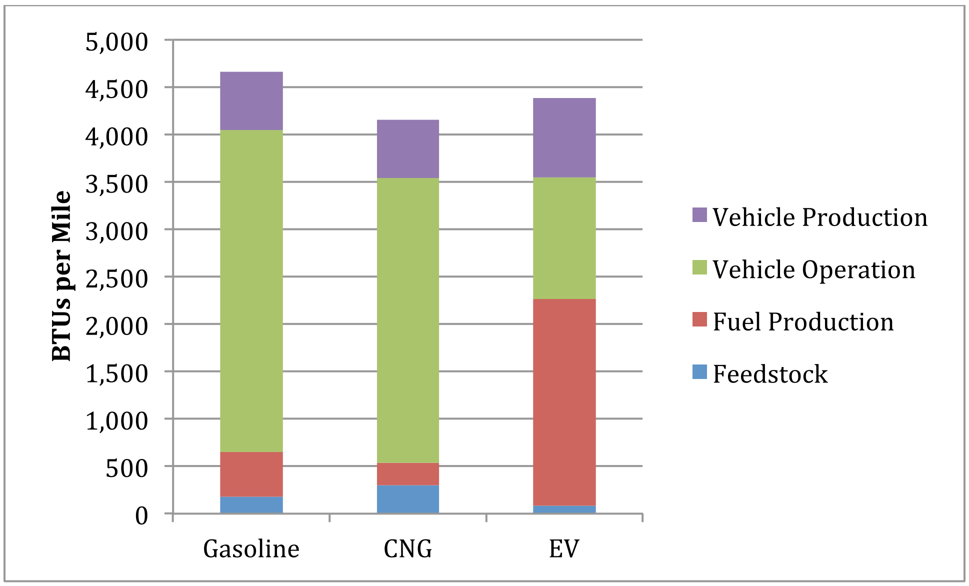


Figure 72. Ozone Precursor Emissions, New Vehicles in 2020 – Wyoming

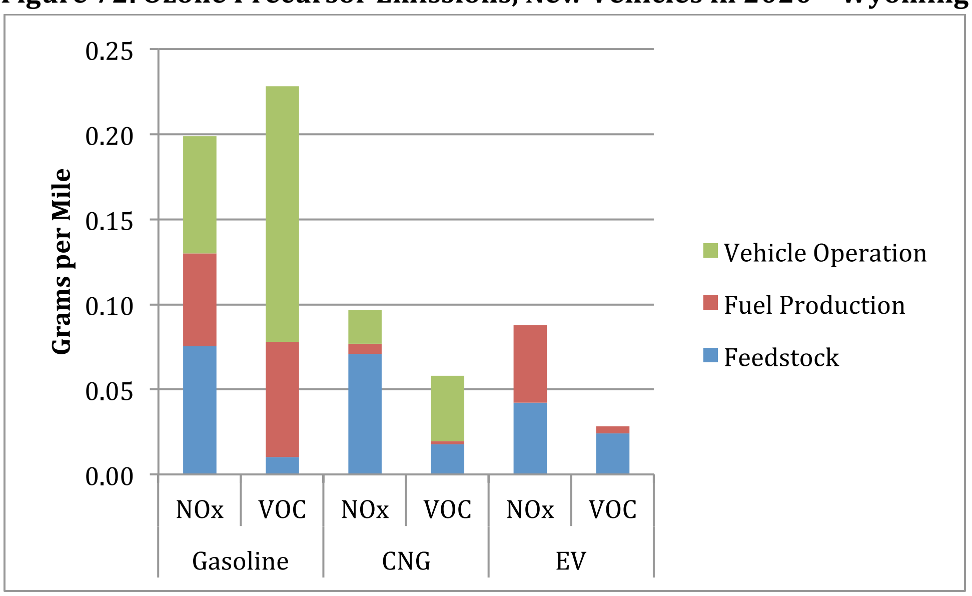


Figure 71. GHG Emissions, New Vehicles in 2020 – Wyoming

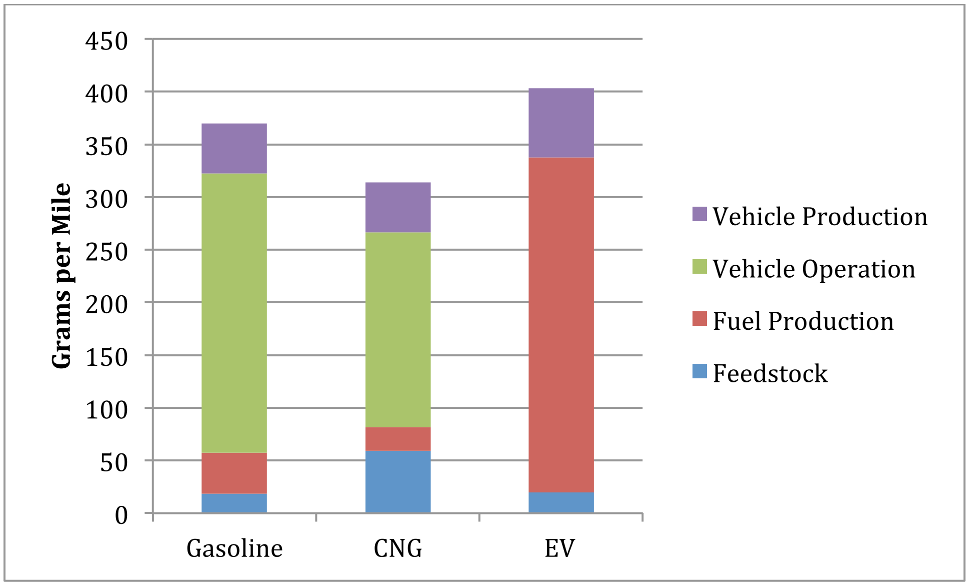
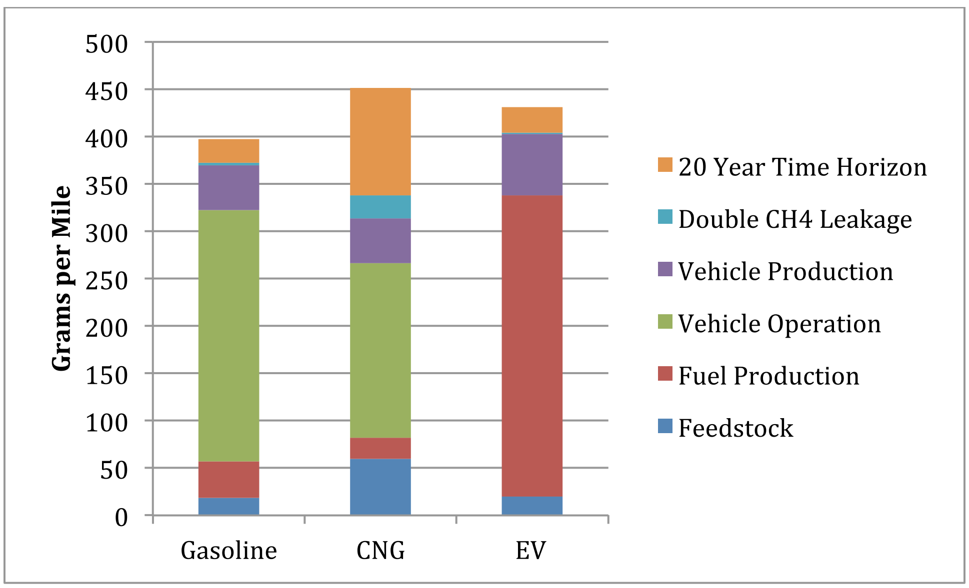


Figure 72. GHG Emissions with Methane Sensitivity Analysis, New Vehicles in 2020 – WY



Conclusion

The potential benefits of electric vehicles compared to gasoline and CNG vehicles are highly dependent on the sources of electricity that fuel the vehicles. EVs are more efficient than gasoline vehicles in every scenario and more efficient than CNG vehicles in most scenarios in most states. This clear efficiency advantage makes EVs a clear choice for those interested in conserving energy resources, improving energy security and reducing energy costs.

In all six states, electric and CNG vehicles offer significant benefits by 2020 in reduced emissions of ozone precursors compared to gasoline vehicles. By 2020, EVs in Arizona, Colorado and Wyoming provide a greater reduction in NO_x emissions compared to CNG vehicles; in Nevada, New Mexico and Utah NO_x emissions are relatively similar by 2020. In all states, EVs have the lowest level of VOC emissions. Policies to increase the use of EVs may be an important component of strategies to reduce urban air pollution and improve public health in all of the southwestern states. This is also important for states that will be required to show compliance by 2020 with an expected new ground-level ozone standard from the EPA.

Emissions of greenhouse gases vary widely between states. Our analysis shows significant GHG reductions from EVs in Arizona, Colorado, and Nevada compared to gasoline and CNG vehicles, suggesting that policies designed to increase the use of EVs in these states could be an important strategy to reduce greenhouse gas emissions and mitigate the impacts of climate change.

In Wyoming, New Mexico and Utah, however, it is not as easy to draw broad conclusions about the best vehicle technology for reducing greenhouse gas emissions, although electric vehicles tend to have lower emissions than gasoline vehicles and CNG vehicles tend to have lower emissions than electric vehicles. In these states, in order to have a positive climate benefit, policies to increase use of EVs should be coupled with additional efforts to shift electricity generation from coal to natural gas and renewables. There may also be opportunities to encourage customers to acquire EVs and solar photovoltaic systems together, allowing the vehicles to be at least partially charged by electricity with very low levels of GHG emissions.

Policymakers, fleet managers, new car buyers and any other interested parties should use the information from this report to make a more informed decision about what type of vehicle best fits their needs and goals.

Appendix A: Assumptions

Light-duty Vehicle Efficiency

2013

- New gasoline passenger vehicles have an average efficiency of 28 mpg.[31]
- Electric vehicles have an average efficiency of 99.0 mpge.[32]
- CNG vehicles have an average efficiency of 31.0 mpge.[33]

2020

- New gasoline passenger vehicles have an average efficiency of 33.8 mpg[34]
- A new electric vehicle has an average efficiency of 105.5 mpge[35]
- A new CNG vehicle has an average efficiency of 38.2 mpge[36]

Electricity Mix[37]

State	2013				2020			
	Coal	Natural Gas	Nuclear	Renewables	Coal	Natural Gas	Nuclear	Renewables
Arizona	35.6%	26.8%	28.3%	9.2%	29.2%	29.3%	27.3%	14.2%
Colorado	64.5%	23.8%	0.0%	11.6%	42.9%	31.2%	0.0%	25.9%
Colorado EV Mix[38]	64.5%	23.8%	0.0%	11.6%	24.0%	44.0%	0.0%	32.0%
New Mexico	64.2%	28.0%	0.0%	7.6%	45.9%	38.7%	0.0%	15.1%
Nevada	19.5%	66.4%	0.0%	14.0%	12.0%	66.8%	0.0%	21.1%
Utah	79.6%	14.9%	0.0%	5.3%	55.1%	32.6%	0.0%	12.2%
Wyoming	87.9%	1.5%	0.0%	10.4%	76.9%	5.7%	0.0%	17.2%

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31 Energy Information Administration. 2012. Annual Energy Outlook 2012. Table 41: Light-Duty Vehicle Miles per Gallon by Technology Type, Reference Case. Retrieved from http://www.eia.gov/forecasts/aeo/data.cfm

32 CEVIRP. 2012.

33 Fueleconomy.gov. Retrieved from http://www.fueleconomy.gov/feg/Find.do?action=sbs&id=32336

34 This is determined by taking the estimated CAFE number of 45.7 mpg for passenger vehicles in 2020 and applying the EPA's shortfall factor to convert CAFE numbers to on road efficiency. Environmental Protection Agency. 2013. EPA/NHTSA Final Rulemaking to Establish 2017 and Later Model Years Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards. Final Rule. Retrieved from: http://www.epa.gov/otaq/climate/regs-light-duty.htm#new1

35 By 2020, EIA predicts a 6.6% improvement in the efficiency electric vehicles which would result in a fuel economy of 105.5 mpge. Energy Information Administration. 2013. Annual Energy Outlook, Reference Case. Table 41. Light-Duty Miles per Gallon by Technology Type. Retrieved from: http://www.eia.gov/forecasts/aeo/data.cfm#transdemsec

36 Between, 2013 and 2020, EIA estimates that the fuel economy of CNG vehicles will increase by 23%. A 23% increase in CNG efficiency would give new CNG vehicles a fuel economy of 38.2 mpg in 2020. Energy Information Administration. 2013. Annual Energy Outlook, Reference Case. Table 41. Light-Duty Miles per Gallon by Technology Type. Retrieved from: http://www.eia.gov/forecasts/aeo/data.cfm#transdemsec

37 Geller, H. The $20 Billion Bonanza: Best Practice Utility Energy Efficiency Programs and Their Benefits for the Southwest. Retrieved from http://swenergy.org/programs/utilities/20BBonanza.htm

38 Colorado Electric Vehicle and Infrastructure Readiness Plan [CEVIRP]. 2012. Appendix 24. Retrieved from http://denvercleancities.org/Colorado%20PEV%20Readiness%20Plan.pdf

Vehicle Production

- All three vehicle types will have a lifetime of 160,000 miles. Electric vehicles will require one replacement battery during the vehicle's lifetime.
- Alternative results from GREET Vehicle-Cycle Model: If no battery replacement was required during the vehicle's lifetime, BTUs per mile would be reduced by 24 and GHG emissions per mile would be reduced by 2 grams. If an electric vehicle with one battery replacement was assumed to travel 40,000 additional miles, the BTUs per mile would be reduced by 154 and GHG emissions per mile would be reduced by 12 grams.

Tailpipe Criteria Pollutant Emissions

- CNG Vehicle: NO_x: 0.02, VOC: 0.038[39]
- Gasoline Vehicle: NO_x: 0.069, VOC: 0.150[40]
- Electric Vehicle: Zero tailpipe emissions
- Note that we do not assume that the EPA adopts Tier III emissions standards, which have been proposed but not yet adopted.[41] If these standards are adopted, new gasoline vehicles after 2017 will have significantly reduced emissions of NO_x and VOCs.

NO_x Emissions Rates for Coal Power Plants[42]

State	2013	2020
Arizona	1.164	0.133
Colorado	1.255	0.119
New Mexico	1.859	0.161
Nevada	1.156	0.142
Utah	1.559	0.156
Wyoming	1.164	0.154

[39] Environmental Protection Agency. 2012. Green Vehicle Guide. Retrieved from http://www.epa.gov/greenvehicles/Index.do and GREET model.
[40] Argonne National Laboratory. Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation. Retrieved from http://greet.es.anl.gov/
[41] Environmental Protection Agency. 2013. EPA Proposes Tier 3 Motor Vehicle Emission and Fuel Standards. Retrieved from http://www.epa.gov/otaq/documents/tier3/420f13016a.pdf
[42] Geller, H. The $20 Billion Bonanza: Best Practice Utility Energy Efficiency Programs and Their Benefits for the Southwest. Retrieved from http://swenergy.org/programs/utilities/20BBonanza.htm The NOx emissions rates underlying the study were obtained via email communication between the author and David White of Synapse Energy Economics.

Appendix B: Acronyms

BTU – British Thermal Unit

CEVIRP – Colorado Electric Vehicle and Infrastructure Readiness Plan

CNG – Compressed Natural Gas

CH_4 – Methane

CO_2 – Carbon Dioxide

EPA – Environmental Protection Agency

EV – Electric Vehicle

GHG – Greenhouse Gas

GREET – Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation

MPG – Miles per Gallon

MPGe – Miles per Gallon Equivalent

NOAA – National Oceanic and Atmospheric Administration

NO_x – Nitrogen Oxides

PEV – Plug-in Electric Vehicle

SWEEP – Southwest Energy Efficiency Project

VOC – Volatile Organic Compounds