# Transportation Fuels for Colorado's Future:


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

*Due to planned improvements in Colorado's electricity generation, electric vehicles will become more efficient and less polluting every year. By 2020 they will significantly outperform gasoline and CNG vehicles.*

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February, 2013

SWEEP
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**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.

The Colorado Transportation Blueprint provides a set of recommendations for transportation policymakers. The complete report is available for download on the SWEEP website at http://www.swenergy.org/programs/transportation/blueprint.htm. For more information contact Will Toor, wtoor@swenergy.org.

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# Executive Summary

This report compares the life-cycle energy consumption and emissions of greenhouse gases (GHG) and ozone precursors from three different light-duty vehicle fuels: gasoline, compressed natural gas (CNG) and electricity. Energy use and emissions are shown for 2013, when a vehicle has just been purchased, and for 2020, after the vehicle has been in operation for seven years. This time frame provides perspective on how changes in the state's electricity mix will impact the transportation sector. This comparison provides information for vehicle purchasers and policy makers wanting to make informed choices about investments in new vehicles and supporting infrastructure.

Policymakers in Colorado are considering a number of issues that may be informed by this analysis including proposals to regulate fugitive methane emissions from natural gas drilling; whether the state Department of Transportation should use Congestion Mitigation and Air Quality Funds to pay for natural gas fueling stations; whether to create an ongoing revenue stream to invest in electric vehicle charging stations; and the potential extension of tax credits for natural gas and electric vehicles.

## Energy Use

In 2013, electric vehicles are the most efficient at converting energy into miles traveled, outperforming gasoline vehicles by 11% and CNG vehicles by 8%. By 2020, electric vehicles are expected to be 30% more efficient than gasoline vehicles and 26% better than CNG vehicles.

## Greenhouse Gas Emissions

Assuming low methane leakage rates in natural gas production, CNG vehicles produce 7% less GHG emissions per mile than gasoline and electric vehicles in 2013. However, there is substantial controversy about actual life-cycle methane emissions, with recent observations from both the Denver-Julesburg Basin in Colorado and the Uinta Basin in Utah showing very high methane emissions from natural gas extraction. At higher emission rates, CNG vehicles' GHG emission advantage disappears. Because the electric utilities are moving towards greater use of renewable energy and replacing coal fired power plants with natural gas plants, electric vehicles are projected to emit the least amount of GHG by 2020, 35% less than gasoline vehicles and 28% less than CNG vehicles. Electric vehicle emissions are expected to continue to drop after 2020.

## Ozone Precursors

In 2013, CNG vehicles emit the least amount of nitrogen oxides ($NO_x$) per mile, 40% less than gasoline vehicles and 64% less than electric vehicles. Electric vehicles emit the least amount of volatile organic compounds (VOC) per mile, 88% less than gasoline vehicles and 54% less than CNG vehicles. By 2020, the electric vehicle will have the lowest $NO_x$ and VOC emissions of the three fuel types. $NO_x$ emissions for electric vehicles will be 69% lower than gasoline vehicles and 34% less than CNG vehicles. VOC emissions from electric vehicles will be 93% lower than gasoline vehicles and 74% less than CNG vehicles.

## Conclusion

In 2013, electricity and CNG each have the best performance in certain areas so it is difficult to quantify which is better overall. In 2020, however, due to changes in electrical generation (switching from coal to natural gas and renewables), electricity is clearly the most efficient and least emitting of the vehicle fuels.

Over the medium and long term, electricity provides the greatest energy efficiency and environmental benefits of the three fuel types. Furthermore, electricity as a transportation fuel will continue to improve its performance as long as the electric grid improves, reducing emissions without requiring future investment in new vehicles.

If Colorado's electricity supply continues its current trajectory after 2020, the performance gap between electricity and gasoline and CNG will continue to increase. If methane leakage rates from natural gas extraction are significantly higher than the base case in the models, then natural gas vehicles lose any performance advantage in greenhouse gas emissions, even in the short term.

From a public policy perspective, this analysis suggests that policy makers should focus on:

1) investments and policies to increase the penetration of electric vehicles into the light-duty vehicle fleet; and
2) efforts to better characterize and reduce methane emissions from natural gas extraction.

## Introduction

In 2011, the Southwest Energy Efficiency Project (SWEEP) developed an analysis for the Denver Regional Air Quality Council (RAQC) comparing emissions of light-duty vehicles fueled by gasoline, compressed natural gas (CNG) and electricity.[1] The air emissions analysis in this report compared direct emissions from the tailpipes of conventional gasoline and CNG vehicles with the increased emissions from power plants that will result from generating the additional electricity needed to power electric vehicles. The estimates of greenhouse gas (GHG) emissions in that analysis focused exclusively on carbon dioxide ($CO_2$) and omitted any estimate of methane emissions associated with the three fuel types.[2]

To better reflect the life-cycle energy use and emissions from these different fuel types, SWEEP has updated 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 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[4, 5]

In December 2012, new and more precise estimates of emissions of traditional air pollutants and $CO_2$ from light-duty vehicles became available from the emissions modeling conducted by researchers from the University of Colorado and the National Renewable Energy Laboratory. This modeling was done for the Colorado Electric Vehicle and Infrastructure Readiness Plan (CEVIRP) funded by the U.S. Department of Energy under the auspices of the Denver Clean Cities Program.[6] The CEVIRP includes an analysis of the emissions of conventional gasoline-fueled vehicles compared to plug-in

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[1] Yuhnke, B. and Salisbury, M. 2011. Ozone Precursors and GHG Emissions from Light-Duty Vehicles: Comparing Electricity and Natural Gas as Transportation Fuels. Available at www.swenergy.org.
[2] Methane ($CH_4$) comprises roughly 98% of natural gas, is a powerful GHG, and has a 100-year climate forcing effect approximately 25 times greater than $CO_2$ for each ton emitted
[3] Argonne National Laboratory. 2012. Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation. Retrieved from http://greet.es.anl.gov/
[4] An analysis using the vehicle cycle model was not included in the CEVIRP.
[5] 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.
[6] Colorado Electric Vehicle and Infrastructure Readiness Plan [CEVIRP]. 2012. http://denvercleancities.org/Colorado%20PEV%20Readiness%20Plan.pdf

electric vehicles (PEVs) in 2020 and shows PEVs with a cleaner emissions profile than gasoline vehicles (except for sulfur oxides). The modeling in the CEVIRP also included detailed estimates of the marginal electricity mix expected to be used by PEVs in 2020. However, this air emissions analysis did not include emissions from natural gas vehicles as this was beyond the scope of the CEVIRP.

To account for these new, more comprehensive and more reliable sources of data, and to include emissions data for natural gas vehicles in the comparison, SWEEP determined that the emissions comparison in SWEEP's earlier report should be updated to help inform decision makers of the energy, climate and air quality consequences of each fuel and vehicle option.

## Methodology

This report is partly based on the findings of the CEVIRP, specifically section XII, "Emissions Impact Study Findings" and Appendix 24, "Emissions Changes from Electric Vehicle Use in Colorado." Every effort was made to match the results of SWEEP's GREET analysis with that from the CEVIRP. One notable change from the CEVIRP is that SWEEP's analysis uses the average fuel efficiency of new light-duty gasoline vehicles (30.6 mpg) rather than the average fuel efficiency of existing light-duty vehicles (21.0 mpg). Because most CNG and electric vehicles will be newer vehicles, we believe that a new gasoline-fueled vehicle provides an appropriate comparison. For the purposes of modeling the fuel mix for additional electrical generation required for charging vehicles, SWEEP based its analysis on the scenario modeled in the CEVIRP report, assuming a high penetration of electric vehicles by 2020, with PEVs making up 22% of sales and 10% of the light-duty vehicle fleet. The charging of all these PEVs is estimated to result in an additional 1,530 gigawatt-hours of electricity generation in 2020. In the CEVIRP report, the PLEXOS dispatch model was used to determine the electricity mix that would meet this additional demand: 44% natural gas, 24% coal and 32% renewables.

SWEEP analyzed the energy consumption and emissions of these three vehicle fuels for vehicles in 2013 (when the vehicle would be purchased) and then, using the assumptions from the CEVIRP for 2020, analyzed the emissions these same vehicles would have if they were still operating in 2020.

## 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 studies have estimated that 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.[7] In addition, recent research by the National Oceanic and Atmospheric Administration (NOAA) in Colorado and Utah has shown leakage rates of 4% and 9% respectively, though 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.[8] The GREET model's default assumptions for methane leakage during extraction are 2.0% for conventional gas and 1.3% for shale gas;[9] these were used for the base analysis and then doubled to provide a range of values. Note that these doubled values are still well below NOAA's high end observations of leakage rates. 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.

In addition, we analyzed 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 absorbs much more infrared radiation than a molecule of carbon dioxide. However, methane remains in the atmosphere for only twelve years while a portion of the carbon dioxide emitted into the atmosphere remains for thousands of years.[10] Because of this, the global warming potential of methane compared to carbon dioxide depends upon the time scale of analysis; its climate forcing impact is lessened when considered over a 100-year time frame. With significant global temperature changes forecast between now and 2050,[11] using 100-year global warming potential

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[7] 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

[8] 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

[9] 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.*

[10] Environmental Protection Agency. 2012. Methane Emissions. Retrieved from http://epa.gov/climatechange/ghgemissions/gases/ch4.html

[11] 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

underestimates the importance of methane as a driver of climate change over the next few decades.

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.[12]

# Results

In each figure, the energy use and emission rates are broken down into four categories representing different stages of the life-cycles for fuels and vehicles:[13]

- *Vehicle Production* encompasses the emissions from the manufacturing and disposing of vehicles;
- *Feedstock* represents the extraction, transportation and storage of the fuel base;
- *Fuel* represents the "production, transportation, storage and distribution" of the fuel used in the vehicle;
- *Vehicle Operation* represents energy used and emissions from the vehicle when it is being driven.

## 2013 Scenario

In 2013, both the CNG and electric vehicles show slight improvements in energy efficiency compared to the gasoline vehicle, with the electric vehicle performing the best overall (see Figure 1).

For life-cycle greenhouse gas emissions (Figure 2), the CNG vehicle has the best performance, with the gasoline and electric vehicles essentially tied.

[12] 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

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

**Figure 1. Comparison of Energy Consumption, 2013**

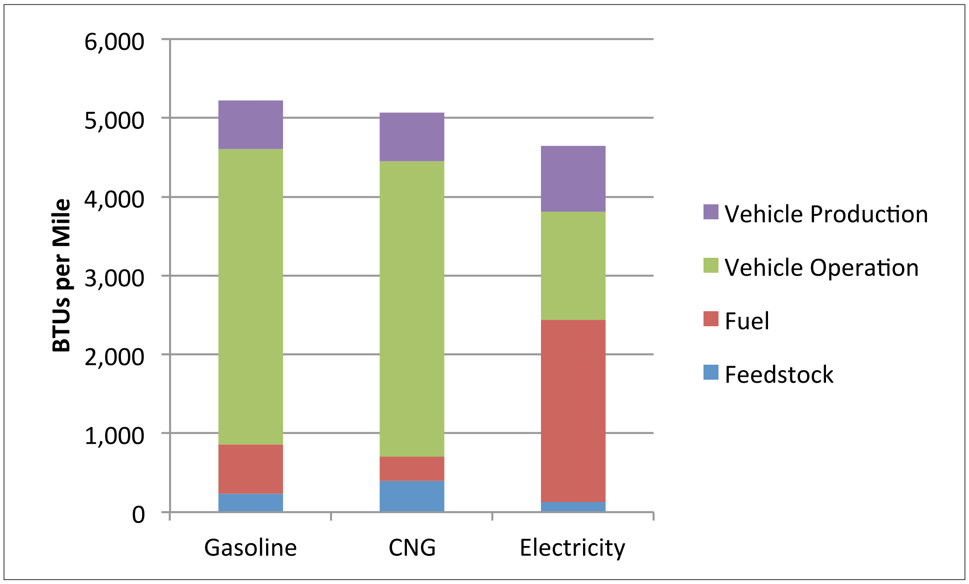
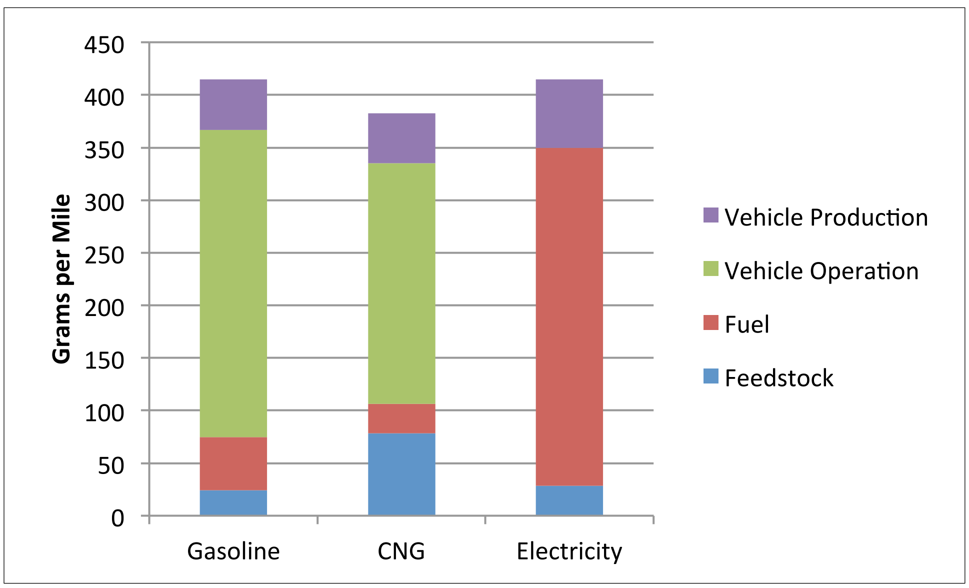



**Figure 2. Comparison of GHG Emissions, 2013**




If methane leakage rates are double the rates assumed in the GREET model, CNG loses almost all of its GHG emission benefit compared to gasoline and electricity, and all three 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 gasoline vehicle show the best result (due to its low use of natural gas), emissions for electric vehicles increase by 13%, and emissions for CNG vehicles increase by 30%, as shown in Figure 3 below.

**Figure 3. Comparison of GHG Emissions with Methane Sensitivity Analysis, 2013**[14]

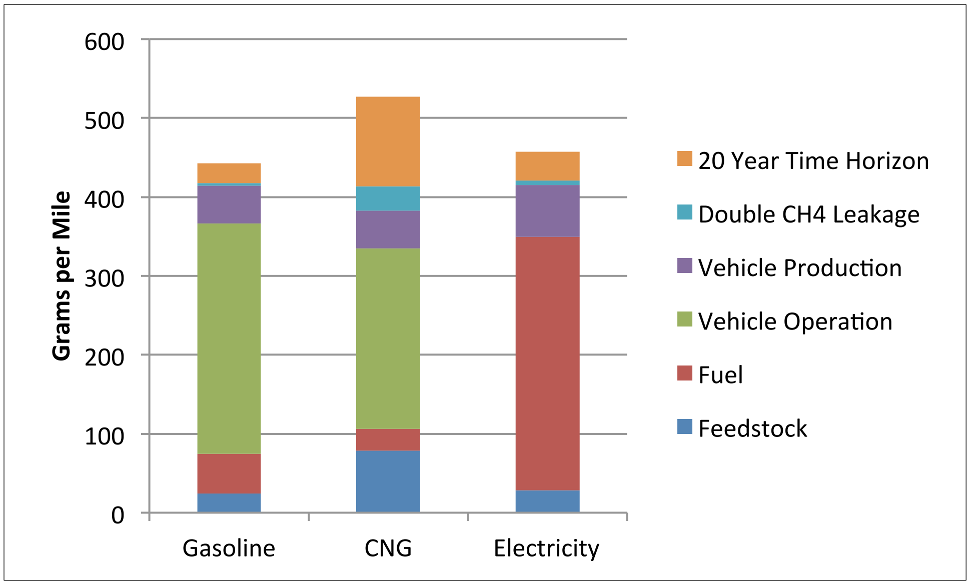



**Figure 4. Comparison of Ozone Precursor Emissions, 2013**

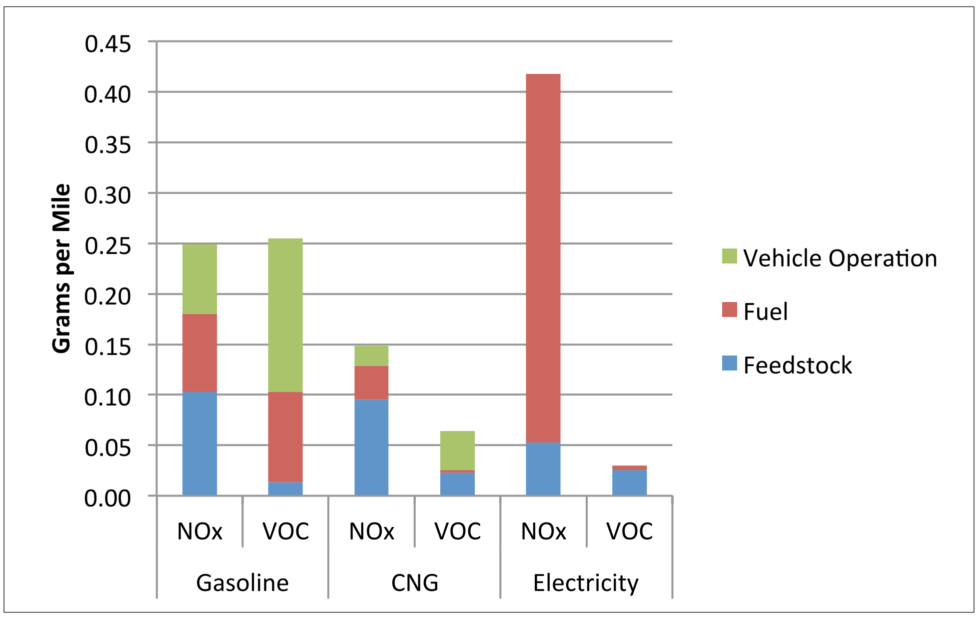



Figure 4 above shows that the CNG vehicle has the best result for nitrogen oxides ($NO_x$) and the electric vehicle has the best result for volatile organic compounds (VOC). Ground level ozone, which is the main component of smog, is formed by reactions

[14] The additional emissions from doubling methane leakage rates and shortening the time horizon are exclusive of each other and are not additive. Therefore in the CNG example, the doubling of leakage rates would add 30 grams per mile while the shortened time horizon would add 114 grams per mile, but each one would be separately added to the original CNG base of 382 grams per mile.

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. Upstream emissions (from the fuel and feedstock categories) which do not take place in the same general area where the vehicle will be driven could reasonably not be considered as contributing to the overall emission rates shown in Figure 4.

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 Colorado's energy system is beyond the scope of this report, it is not clear that the model would accurately represent the situation in Colorado. For example, there is significant oil and natural gas extraction activity surrounding the urban areas of Denver, Fort Collins and Grand Junction, while the national average (used as the default value in GREET) is that only 1% of natural gas and 2% of oil extraction takes place in urban areas. Applying these values to Colorado would greatly underestimate the urban area feedstock emissions from these fuels. In addition, a significant portion of the electricity that is generated in Colorado is generated from power plants located in urban areas. Therefore, while the total life-cycle emissions shown in Figure 4 may over-represent the importance of upstream emissions of the ozone precursors, this is the most accurate representation that can be made at this time.

The vehicle production stage is not shown in Figure 4 because it is unlikely that any of the resulting emissions would take place within the same area as the fuel life-cycle stages.

## 2020 Scenario

Comparing the 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.[15] 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

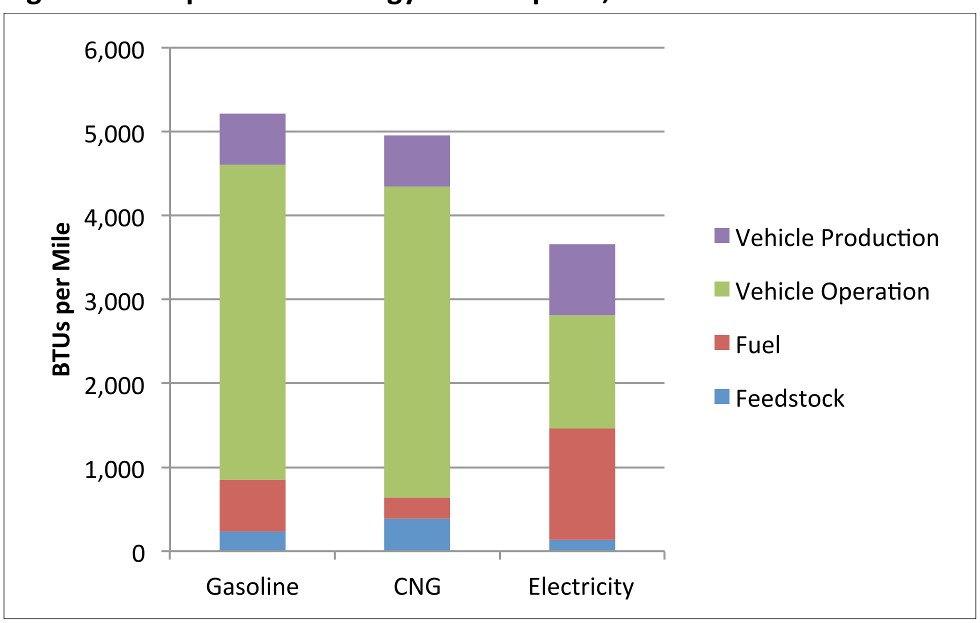
[15] The GREET model is designed to run only through 2020, so it is not possible to extend the comparison over the full operating life of the vehicle.

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.

However, 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[16] and the Renewable Portfolio Standard[17]) an electric vehicle purchased in 2013 will have significantly lower energy use and emission rates by 2020. The same is true for any electric vehicle operating in 2020, whether purchased in 2013 or later.

Concerning energy efficiency, vehicles in 2020 follow a similar pattern to 2013 (see Figure 5 below). Gasoline and CNG vehicles (with the same operating efficiencies of 30.6 mpg and 31.0 mpge respectively) experience modest decreases in energy consumption due to slightly lower consumption in the feedstock and fuel phases, while energy consumption for vehicle operation remains about the same. Electric vehicles, despite having the same efficiency (99 mpge), reduce their overall energy consumption by 21% due to expected improvements in the efficiency of electricity production.

**Figure 5. Comparison of Energy Consumption, 2020**

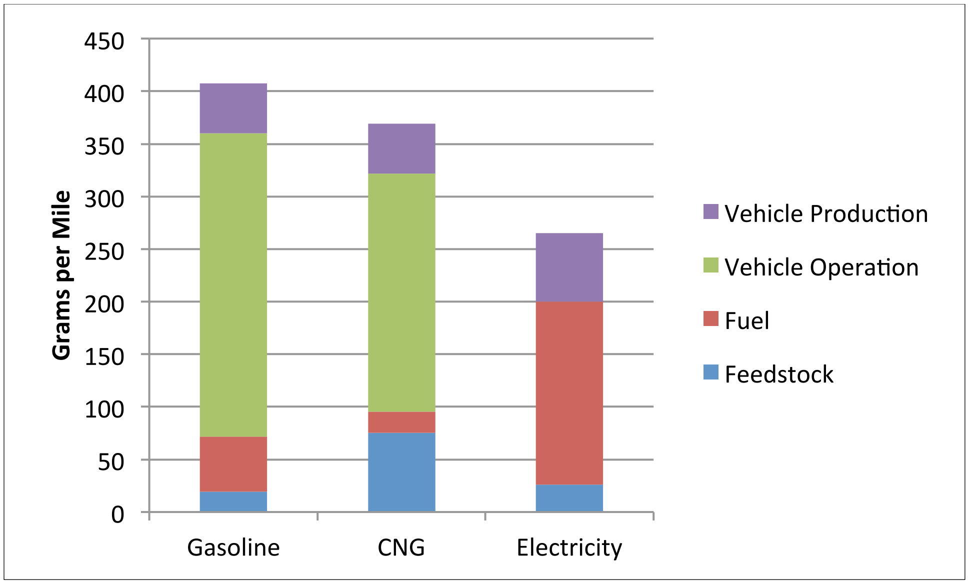



[16] Colorado House Bill 10-1365. Clean Air, Clean Jobs is expected to result in an 88% reduction in $NO_x$ emissions and a 28% reduction in $CO_2$ emissions from the electricity generating sector. Retrieved from http://rechargecolorado.org/images/uploads/pdfs/Colorado_Clean_Air_Clean_Jobs_Act_GEO_White0Paper.pdf

[17] Colorado's Renewable Portfolio Standard calls for 30% of investor-owned utility electricity generation to come from renewables and 10% of generation from cooperatives and municipal utilities to come from renewables.

Regarding greenhouse gas emissions, electric vehicles purchased in 2013 experience a significant decrease of 36% in emissions between 2013 and 2020, again due to the expected changes in electricity generation (see Figure 6). This shift makes the electric vehicle the lowest emitting of the three vehicle technologies, a major change from 2013 when the CNG vehicle was responsible for the least amount of greenhouse gas emissions (assuming low methane leakage rates).

**Figure 6. Comparison of GHG Emissions, 2020**




Regardless of the sensitivity analysis, electricity has the lowest GHG emissions (see Figure 7 below). For CNG, doubling methane leakage rates increases GHG emissions by 8% and shortening the analytical time frame increases GHG emissions by 30%.

Figure 8 illustrates a dramatic reduction in ozone precursor emissions for electric vehicles. By 2020, gasoline vehicles will have slightly reduced $NO_x$ emissions due to lower fuel phase emissions, while VOC emissions will remain the same. CNG vehicles will see a slight reduction in $NO_x$ emissions, also due to decreases in the fuel phase, and VOC emissions will remain essentially unchanged. Electric vehicles will see minor decreases in $NO_x$ and VOC emissions from the feedstock phase, but will see a very significant 89% decrease in $NO_x$ emissions from the fuel phase, due to the phase-out of coal fired power plants in the Denver metro area.

**Figure 7. Comparison of GHG Emissions with Methane Sensitivity Analysis, 2020**[18]

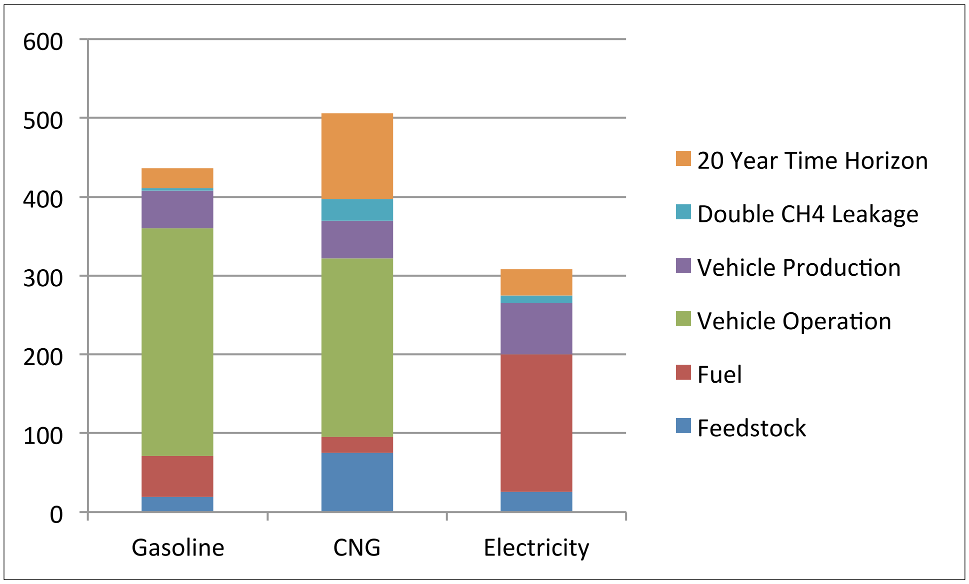
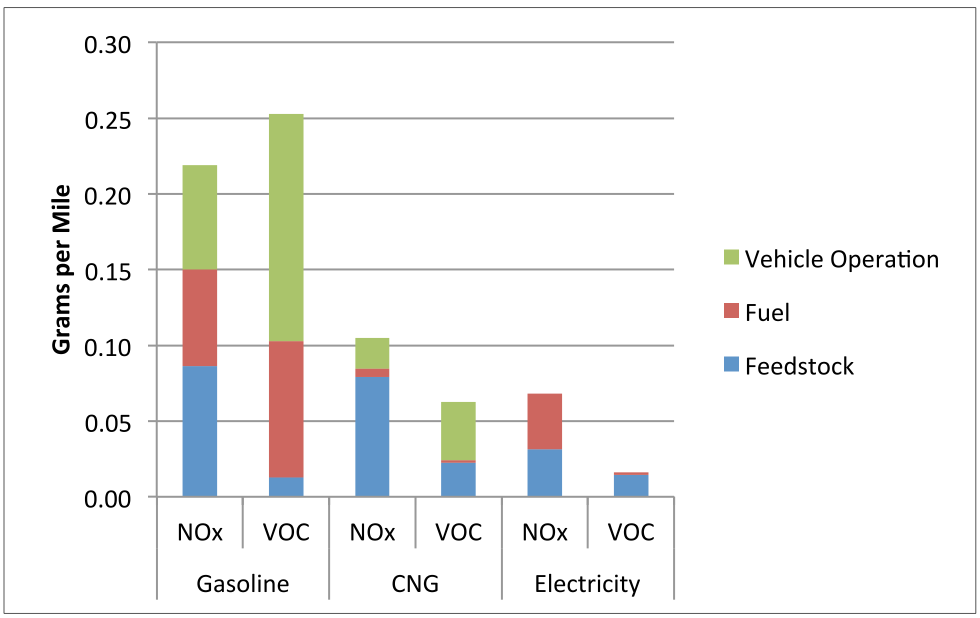



**Figure 8. Comparison of Ozone Precursor Emissions, 2020**




[18] The additional emissions from doubling methane leakage rates and shortening the time horizon are exclusive of each other and are not additive. Therefore, in the CNG example, the doubling of leakage rates would add 27 grams per mile and the shortened time horizon would add 109 grams per mile; each one would be separately added to the original CNG base of 369 grams per mile.

Ozone precursor emissions from transportation fuels will be critical information in 2020, because at that time Colorado 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 Colorado comply with the new standard, to a greater extent than would a shift to natural gas vehicles.

## Conclusion

In 2013, electricity and CNG each have the best performance in certain areas so it is difficult to quantify which is better overall. In 2020, however, due to changes in electrical generation (switching from coal to natural gas and renewables), electricity is clearly the most efficient and least emitting of the vehicle fuels.

Over the medium and long term, electricity provides the greatest energy efficiency and environmental benefits of the three fuel types. Furthermore, electricity as a transportation fuel will continue to improve its performance as long as the electric grid improves, reducing emissions without requiring future investment in new vehicles.

If Colorado's electricity supply continues its current trajectory after 2020, the performance gap between electricity and gasoline and CNG will continue to increase. If methane leakage rates from natural gas extraction are significantly higher than the base case in the models, then natural gas vehicles lose any performance advantage in greenhouse gas emissions, even in the short term.

Policymakers in Colorado are considering a number of issues that may be informed by this analysis including proposals to regulate fugitive methane emissions from natural gas drilling; whether the state Department of Transportation should use Congestion Mitigation and Air Quality Funds to pay for natural gas fueling stations; whether to create an ongoing revenue stream to invest in electric vehicle charging stations; and the potential extension of tax credits for natural gas and electric vehicles.

From a public policy perspective, this analysis suggests policy makers should focus on:

1) investments and policies to increase the penetration of electric vehicles into the light-duty vehicle fleet; and
2) efforts to better characterize and reduce methane emissions from natural gas extraction.

## Assumptions

### Light-duty Vehicle Efficiency

*(same for 2013 and 2020)*

- New gasoline vehicles have an average efficiency of 30.6 mpg.[19]
- Electric vehicles have an average efficiency of 99.0 mpge.[20]
- CNG vehicles have an average efficiency of 31.0 mpge.[21]

### Electricity Mix

*2013*

- Baseload & Incremental: 23.8% Natural Gas, 64.5% Coal, 11.6% renewables.[22] Due to the small number of electric vehicles charging in 2013 in Colorado they would not be expected to have any significant impact on the electricity mix so no incremental mix has been calculated. In addition, the type of dispatch modeling (as done in the CEVIRP report) is beyond the scope of this report.

*2020*

- Baseload: 12.1% natural gas, 57% coal, 30.9% renewables.[23]
- Incremental mix for electric vehicle: 44% natural gas, 24% coal, 32% renewables.[24]

### Tailpipe Criteria Pollutant Emissions

- CNG Vehicle: $NO_x$: 0.02, VOC: 0.038[25]
- Gasoline Vehicle: $NO_x$: 0.069, VOC: 0.150[26]
- Electric Vehicle: Zero tailpipe emissions

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[19] 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

[20] CEVIRP. 2012.

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

[22] 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

[23] CEVIRP. 2012.

[24] Ibid.

[25] Environmental Protection Agency. 2012. Green Vehicle Guide. Retrieved from http://www.epa.gov/greenvehicles/Index.do and GREET model.

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

## 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.

## Acronyms

BTU – British Thermal Unit
CEVIRP – Colorado Electric Vehicle and Infrastructure Readiness Plan
CNG – Compressed Natural Gas
$CH_4$ – Methane
$CO_2$ – Carbon Dioxide
GHG – Greenhouse Gas
GREET – Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
MPGe – Miles per Gallon Equivalent
NOAA – National Oceanic and Atmospheric Administration
$NO_x$ – Nitrogen Oxides
PEV – Plug-in Electric Vehicle
RAQC – Regional Air Quality Council
SWEEP – Southwest Energy Efficiency Project
VOC – Volatile Organic Compounds