Ozone Precursor and GHG Emissions from Light Duty Vehicles -- Comparing Electricity, Natural Gas and Biofuels as Transportation Fuels

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Alternatives to gasoline present significant opportunities for reducing ozone precursor emissions from the transportation sector, decreasing fuel use and GHG emissions, shifting fuels to domestic rather than foreign sources, creating jobs in Colorado, and retaining in the local economy resources that are now lost to importing fuels from other states and nations.

Compressed natural gas (CNG) and electric vehicles (EVs) currently offer all of these benefits compared to gasoline powered vehicles. A few CNG models are available now and plug-in hybrid electric and pure EVs will be in showrooms beginning in late 2010. Biofuels other than corn-based ethanol are not commercially available in sufficient supply to provide a significant displacement of gasoline in the near term.

Energy Efficiency, GHG Emissions and Ozone Air Pollution Impacts --

Internal combustion engines burning gasoline or natural gas are much less efficient than electric motors. A CNG vehicle will use 1000 cubic feet of natural gas to travel 230 miles, while the same amount of natural gas converted to electricity could power an electric vehicle for 545 miles.

Using natural gas to power a vehicle achieves only half the efficiency as using electricity as a transportation fuel. Converting the light duty fleet to natural gas by 2030 will reduce CO_2 emissions by about 24% compared to gasoline, but converting the fleet to electric vehicles will reduce CO_2 emissions by 39% even if electricity is generated using the current coal fuel mix.

Electric vehicles will achieve greater initial reductions in ozone precursors and CO_2, and offer the potential for continued ozone precursor and CO_2 reductions to offset the effects of VMT growth as the grid is decarbonized. Natural gas can be used most effectively to power the transportation sector by replacing coal in power plants to generate electricity for battery powered vehicles. Substituting natural gas for coal in the electric fuel mix will solve the Front Range ozone violations by reducing nitrogen oxides (NO_x) by 91%, virtually eliminate sulfur dioxide (SO_2) and mercury emissions emitted from power plants, and reduce power plant CO_2 emissions by 62%.

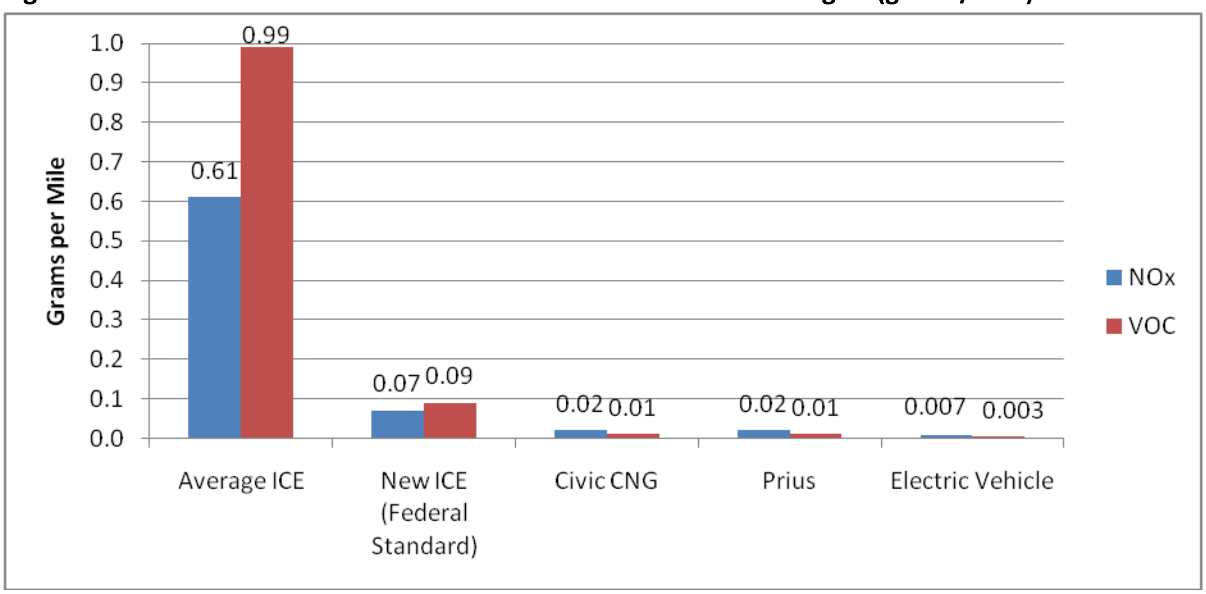
Table 1. Comparison of Energy Use by Vehicle Technology

	Annual Energy Use (MMBTUs)	% Energy Reduction vs New ICE	Annual CO2 Emissions (Tons)	% CO2 Reduction vs New ICE	Annual CO2 Emissions (Tons) in 2030	%Annual CO2 Reduction vs New ICE
New ICE	70.7		4.98		3.52	
Natural Gas Vehicle	53.7	24%	2.85	43%	2.66	24%
PHEV 10	25.2	64%	2.23	55%	2.04	42%
PHEV 40	17.7	75%	2.41	51%	1.93	45%
BEV	10.2	85%	2.59	48%	1.82	48%

Comparing Ozone Precursor Emissions from Natural Gas and Electric Vehicles.

Emissions data for NOx and VOCs emitted by natural gas (NG) and plug-in electric hybrid vehicles (PHEV) when operating on the gasoline engine are not widely available because of the lack of commercially available models. Emissions data for the production model of the CNG Honda Civic and the Toyota Prius hybrid show identical emission rates for NOx (0.2 gr/mi) and VOC (0.1 gr/mi). Both vehicles emit much less than the EPA standard for new gasoline vehicles (0.7 gr/mi NOx and 0.9 gr/mi VOC). Replacing traditional gasoline engines with these vehicles will achieve significant reductions in ozone precursors even when PHEVs are operated on their gasoline power source.

Figure 1. Criteria Pollutant Emissions for Different Vehicle Technologies (grams/mile)



EPA does not currently recognize any emission reduction credit for States that adopt strategies designed to replace gasoline ICE vehicles with natural gas or electric vehicles. EPA recognizes that electric vehicles emit zero NOx and VOCs when operating on the battery, but has not developed any criteria for states to use in estimating the amount of VMT during a day when a PHEV will be operating on the battery. In its assessment of strategies available to reduce GHG emissions from the transportation sector,[1] EPA estimates that PHEV and pure EVs together will travel 66% of daily VMT on battery power generated from the grid. Using this assumption, an electric vehicle fleet will emit 66% less NOx and VOCs than a comparable natural gas powered vehicle fleet.

For electric vehicles, ozone precursor emissions are eliminated at the tailpipe, but are shifted to the power plant if the power is generated with fossil fuels. For power generated from coal in Colorado, NOx emissions per mile travelled increase compared to tailpipe emissions from a gasoline vehicle. VOC emissions decrease. However, depending on the location of the generating station, pollutants attributable to increased demand from electric vehicles may be removed from the nonattainment area, will be released above the mixing layer of the atmosphere rather than at ground level and will not mix with emissions from ground level sources for significant portions of the day, and will mostly be emitted at night during vehicle charging when ozone formation does not occur.

If natural gas replaces coal to generate the power for electric vehicles, NOx emissions can be reduced as much as 90% compared to gasoline. If the power is generated from renewable sources, both power plant and vehicle emissions of NOx and VOC, as well as SO2 and mercury, are eliminated.

Comparing GHG Emissions from Natural Gas and Electric Vehicles.

CNG vehicles will reduce CO2 emissions compared to gasoline, but emissions reductions will not continue after the gasoline fleet is replaced. GHG emissions will return to 2005 levels by 2050 because of VMT growth. Electric powered vehicles offer the opportunity to offset much of the increased energy demand from VMT growth, and to achieve sustainable, long-term reductions in CO2 that achieve the 80% target identified by Governor Ritter in the Colorado Climate Action Plan and the International Panel on Climate Change. The greatest advantage of electric vehicles is that they do not require the combustion of fossil carbon. GHG emissions linked to vehicles will drop as the carbon sources of power generated for the electric grid are replaced with renewable sources. The GHG emissions from PHEVs when using liquid fuels for the on-board power source will also drop as cellulosic biofuels are substituted for gasoline. Electric vehicles also require less energy because electric motors are inherently more efficient.

The figure and table below compares the CO2 emissions resulting from several fuel scenarios:

Gasoline scenario (blue bars) – assumes gasoline vehicles meet the current fuel economy standards of 35.5 mpg by 2016 but no further improvements are made. Fuel economy improvements are overwhelmed by population growth and increased per capita VMT leading to increased fuel use and CO2 emissions.

Natural Gas scenario (red bars) – assumes entire light duty fleet converted to natural gas by 2030. CO2 is reduced 24% compared to gasoline, but after 2030 these reductions are overwhelmed by

[1] EPA Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios. February 10, 2010. Available at: http://www.epa.gov/oms/climate/GHGtransportation-analysis03-18-2010.pdf

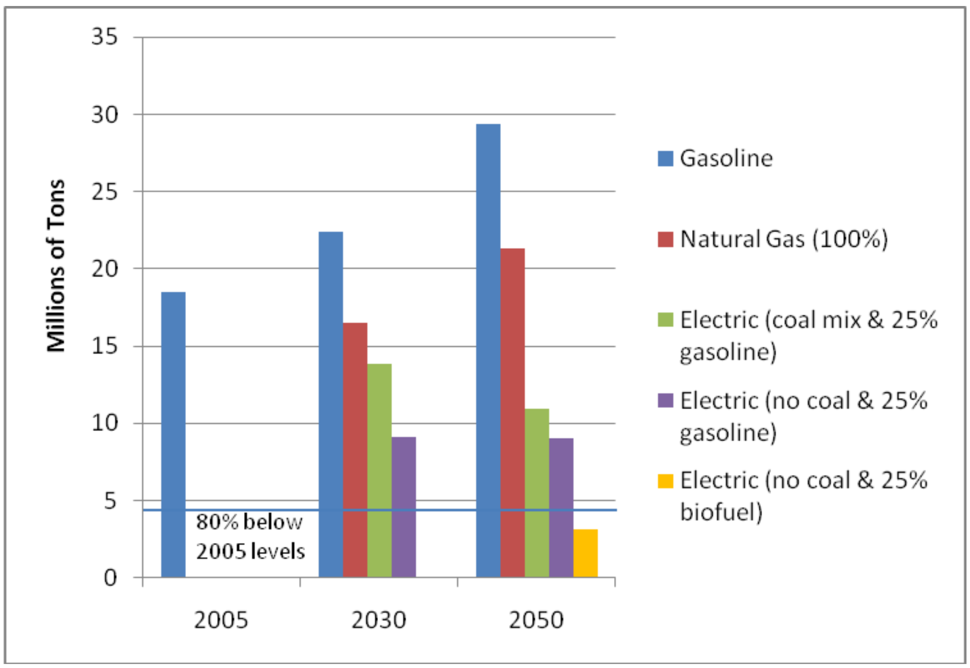
population growth and increased VMT per capita. CO2 emissions rise to 2005 levels by 2040, and 15% above 2005 levels by 2050.

Electric vehicle scenario 1 (green bars) -- 75% of VMT is powered by electricity from the grid, with the remaining 25% fueled by gasoline. Electric generation has reduced its CO2 emissions by 20% by 2030 and 80% by 2050 with coal being partially displaced by natural gas, wind and solar.

Electric Vehicle scenario 2 (purple bars) – assumes same % VMT powered by electricity as the first electric vehicle scenario, but natural gas replaces all coal in generating electricity for the grid.

Electric Vehicle scenario 3 (orange bar) -- same as the second electric vehicle scenario except the 25% of VMT fueled by gasoline (fossil carbon) has been replaced by cellulosic biofuels with 80% less fossil carbon content than gasoline.

Figure 2. CO2 Emissions from Light Duty Vehicles in Colorado (2005-2050)



Infrastructure Needs and Costs for Each Fuel Scenario.

A convenient and accessible refueling infrastructure is essential for consumers to invest in owning alternative fueled vehicles. Without the potential for broad consumer demand, manufacturers have no incentive to offer a wide variety of natural gas or electric vehicles.

A significant barrier to the penetration of natural gas and electric vehicles into the light duty market is the lack of public refueling infrastructure. A potential advantage is the ability to refuel while the vehicle is at home and not in use. A majority (55% nationwide) of homes already have some kind of natural gas connection, and virtually all homes have access to the grid. Adding a home refueling station for natural gas is estimated to cost $4,500. Upgrading an existing home electric service (220 V) to allow for reasonable charging times (4-6 hours) is estimated to cost $2,000 to $2,500.

A dedicated public natural gas refueling station is estimated to cost $500,000 while a fast charging electric recharging station (15 minute charge) would cost between $200,000 and $400,000. Supplying refueling infrastructure for the Denver metropolitan area would cost $105 million for natural gas refueling and between $42 million and $84 million for electric refueling.

The availability of a moderate cost residential refueling option is the primary reason why manufacturers are bringing electric vehicles to market. Beginning in late 2010, more than 12 manufacturers are planning the introduction of new electric vehicles. See Attachment 1. No comparable commitment has been announced by manufacturers to produce natural gas vehicles.

Fuel Supply Issues –

The supply of gasoline may not be reliably available or affordable once global demand exceeds global production. Many energy market analysts expect this shortfall in supply to occur before 2015. Because the U.S. imports 60% of daily oil consumption, the U.S. economy and travelers dependent on gasoline vehicles are vulnerable to serious price shocks when this occurs.

The conversion of the light duty vehicle fleet to a domestically produced fuel source will require at least 20 years. Domestic supplies of natural gas are expected to remain reliably available through 2050 if the national light duty fleet were converted to natural gas by 2030. But supply may not be sufficient to both fuel the national light duty vehicle fleet and convert a large portion of electric power generation from coal to natural gas. A choice may be necessary between using natural gas to replace coal in power generation or to replace petroleum fuels in the transportation sector. If dedicated to transportation uses, diminishing supply of natural gas after 2050 may require that the national transportation system be converted again to another fuel by 2050.

Electric vehicles operate on a fuel source that will always be available, and generated in Colorado from domestic sources of energy, including wind, solar, geothermal and natural gas.

Biolfuels (e.g., ethanol) are currently made from food crops that will be needed before 2020 to meet the food demand of a growing population. Cellulosic biofuels that do not rely on food crops are not expected to be available in commercial quantities before 2020. Once commercially available, the volume of cellulosic biofuels is not expected to be sufficient to displace more than a fraction of current gasoline use, but could be expected to satisfy the remaining demand for liquid fuels if 75% of VMT were powered with electricity.

Fuel Costs.

Fuel cost is an important factor in determining public acceptance of an alternative fuel. Both natural gas and electricity offer significant advantages in fuel cost at today’s prices. In the future, as reductions in petroleum production and increased demand contribute to global fuel shortages, market factors will make natural gas and electricity much more attractive as motor fuels.

Table 2. CO2 Emissions and Fuel Costs Under Different Fuel Scenarios

	2005	2030				2050			
		Alternative Fuel	Gasoline	Total	Fuel Cost, billions	Alternative Fuel	Gasoline	Total	Fuel Cost, billions
Gasoline	18,464		22,429	22,429	$9.5		29,351	29,351	$14.8
Natural Gas (100%)		16,522		16,522	$4.1	21,300		21,300	$6.1
Electric (coal mix & 25% gasoline)		8,960	4,883	13,843	$5.1	3,622	7,338	10,960	$8.9
Electric (no coal & 25% gasoline)		4,220	4,883	9,103	$5.1	1,706	7,338	9,044	$8.9
Electric (no coal & 25% biofuel)						3,174		3,174	$8.9

Assumptions underlying Table: Fuel Economy standards will remain 35.5 mpg after 2016. A CNG vehicle will travel 230 miles using 1000 cf of natural gas. A PHEV 10 or 40 will travel 10 or 40 miles on electricity before converting to a liquid fuel. Electricity generated in Colorado will use 20% less fossil carbon by 2030, and 80% less by 2050, compared to 2005 levels. DOE projected fuel prices in 2030 (2008$): gasoline: $3.75/gallon; electricity: $0.10/kwh; natural gas: $1.40/100 cubic feet.

<u>Glossary of Abbreviations</u>

BEV – Battery Electric Vehicle that operates only on electric power
CNG – Compressed Natural Gas
CO2 – Carbon Dioxide which accounts for over 96% of GHG emissions from the transportation sector.
ICE – Internal Combustion Engine
IPCC – Intergovernmental Panel on Climate Change
MMBTU – Million BTUs
NOx – Nitrogen Dioxide, the pollutant emitted from ICEs that contributes most to atmospheric ozone
PHEV – Plug in Hybrid Electric Vehicle
SO2 – Sulfur Dioxide, the pollutant emitted from burning coal that contributes most to the Brown Cloud
VMT – Vehicle Miles Traveled

Attachment 1. Planned EV and PHEV Releases with Target Dates for Sale in US Market

Make/Model	EV or PHEV	Battery Size (kwh)	Electric Range (miles)	Target Intro in US	Estimated Price
Audi A1 Sportback	PHEV	20		2011	
BMW ActiveE	EV	125	100	Field trial in 2011	
BYD E6	EV	75-200	Up to 200	2010	
BYD F3DM	PHEV		60	2010	$22,000
Coda Sedan	EV		90-120	2010	$45,000
Daimler Smart ED	EV		90+	2012	
Fisker Karma	PHEV		50	2010	$87,900
Ford Escape	PHEV	10	40	2012	
Ford Focus	EV		100	2011	
Chevy Volt	PHEV	16	40		$41,000
Hyundai Blue Will	PHEV		38	2012	
Hyundai i10	EV		100	2012	
Mitsubishi iMiEV	PHEV	16	50	2010 (limited)	$47,500
Fiat Micro-Vett e500	EV		75	2012	
Nissan Leaf	EV	24	100	2010 (limited)	$32,780
Tesla Model S	EV		150-300	2011	$57,400
Tesla Roadster	EV		220	2010	$109,000
Think City	EV		80	2010	
Toyota Prius	PHEV		10-18	2010- 2012	$27,550
Volkswagen Twin Drive	PHEV		30	2013	
Volvo V70	PHEV		31	2012	