COLORADO NATURAL GAS VEHICLE MARKET IMPLEMENTATION STUDY

For the Colorado Energy Office
Prepared by Antares Group, Inc.
Contact: Tim Rooney, Project Manager
Phone: 303-619-8509
Email: trooney@antaresgroupinc.com

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Disclaimer:

This report was prepared by Antares Group, Inc., for the Colorado Energy Office to provide an external assessment of the market for natural gas vehicles in Colorado. The report provides a snapshot of the market and policy environment as of June 2013. The views and opinions expressed herein do not necessarily state or reflect those of the Colorado Energy Office. The Colorado Energy Office would like to thank the Antares Group, Inc., for researching, assembling, and preparing this report.

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1 Executive Summary

The State of Colorado has identified the use of cleaner transportation fuels as a priority to promote energy security, environmental stewardship, job creation, and low consumer costs. As part of that effort, the State has specifically identified natural gas as a viable, low-cost alternative to gasoline and diesel. The nation's energy future is improved with the use of natural gas because it is more affordable, better for the environment, and reduces dependence on foreign oil. Natural gas is abundant in Colorado, with 8% of the proven reserves in the U.S[1]. As of February 2013, approximately 120,000 Natural Gas Vehicles (NGVs) are used across the nation, yet only 697 are in Colorado[2]. The adoption of NGVs is currently limited by the lack of fueling infrastructure, and potential developers are very hesitant to build natural gas fueling stations without more of these vehicles on the road.

The Colorado Energy Office (CEO) is seeking to develop an NGV implementation plan for the State. This study provides information that will assist CEO with cultivating that plan. The study summarizes:

- The economic and environmental impacts of NGV deployment in Colorado;
- Deployment strategies that maximize the environmental, economic, and energy security advantages of NGVs;
- Effective incentives and policies that promote the use of compressed natural gas (CNG) and liquefied natural gas (LNG) as transportation fuels; and
- A timeline, next steps, and an estimate of public sector resources required to increase NGV adoption.

The benefits of a sustainable NGV market in Colorado are broad reaching and include positive impacts on the environment and Colorado's economy, including:

- Energy Security
  - Fuel Price Volatility - Transportation fuel prices can be highly volatile, as-evidenced by the rapid rise and fall in crude oil prices in 2008/09. Although still volatile, natural gas prices have experienced relatively smaller price fluctuations and for the past 3-4 years natural gas prices have been significantly lower than diesel and gasoline on a $/Gasoline Gallon Equivalent (GGE) and $/Diesel Gallon Equivalent (DGE) basis. A favorable price differential is forecasted through at least 2025.
  - State Energy Imports – Colorado currently produces over three times[3] more natural gas than it consumes. In contrast, the state is a net importer of petroleum products. According to EIA, the State spends approximately $7 billion on gasoline alone.
- Environmental Implications
  - The potential for NGVs to reduce green house gas (GHG) emissions relative to conventional gasoline and diesel fueled vehicles is a key benefit. An Argonne National Laboratory study suggests that CNG vehicles can offer a 20-29% improvement in GHG emissions over diesel and gasoline vehicles, respectively.
  - Significantly lower emissions are also achievable in other criteria pollutants.

[1] http://www.eia.gov/dnav/ng/ng_enr_sum_a_EPG0_R11_BCF_a.htm

[2] Colorado DMV database of registered vehicles

[3] EIA 2011 Consumption Data

- Economic
  - NGVs provide economic value in many ways. A primary benefit is the direct value to the adopters in terms of reducing long term fuel costs, while allowing them to hedge against future energy prices through long term pricing agreements.
  - According to EIA data, for both CNG and LNG only 1/3 of the cost paid at the pump is for the natural gas commodity while 70% or more is the commodity cost of gasoline and diesel at the pump. This provides for lower price volatility and implies an opportunity for savings as infrastructure construction costs are driven down.
  - The natural gas futures market offers an opportunity to lock in commodity costs for periods ranging from a month to 10 years. This offers the opportunity for long-term, stable pricing that is essential for managing budgets.
  - The State of Colorado can replace imported petroleum with natural gas produced in-state, thus supporting the state's economic drivers. The extent of the economic impact will depend on relative tax rates on different fuels.

With the case for natural gas presented, research was then conducted to assess how other states have instituted effective NGV policies and incentives so that Colorado can learn from other successes and best use available resources. After an analysis of states such as Oklahoma, Texas, Pennsylvania and Indiana, a handful of key themes emerged:

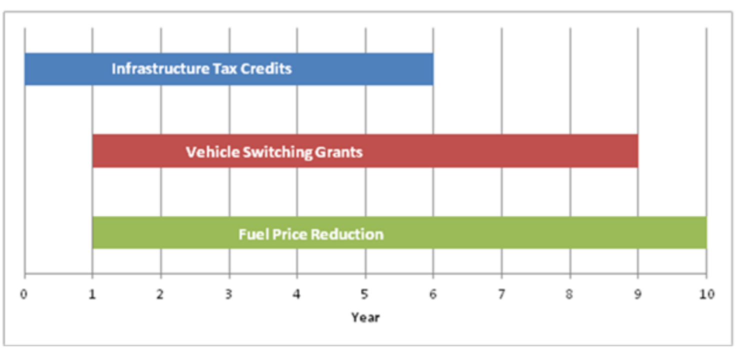
- Most states use a mix of financial and non-financial tools.
- Calculated and specific targeting of resources allows for effective industry motivation. A key example is targeting refuse or delivery fleets.
- Notable financial commitment is required to adequately stimulate the industry.
- Collaboration of all parties – state, fleet, and fueling – is essential to effective policy, incentives, and critical mass.
- Private industry, such as fueling partners, can be expected to provide varying levels of their own incentives if given the liberty and upside to do so.

Therefore, this report suggests a threefold, integrated approach to stimulate adoption of NGVs in Colorado:

- Tax credits to offset the construction of publically accessible natural gas fueling infrastructure
- Tax credits and grant programs to offset the incremental cost and conversion costs for NGVs
- Fuel supply incentives per GGE or DGE of natural gas.

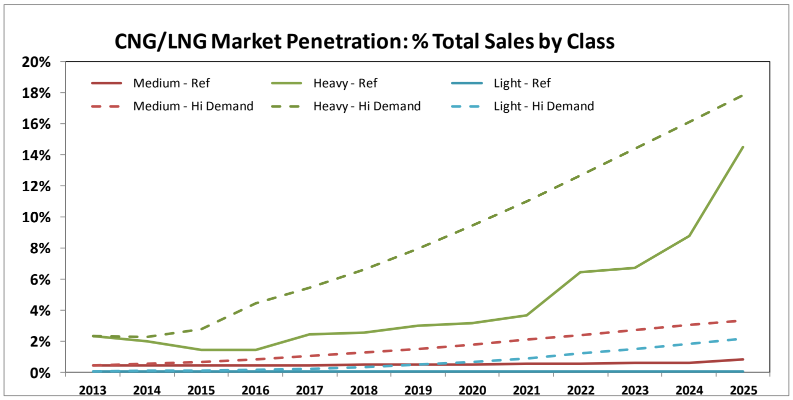
The Exhibit below illustrates a suggested phasing of these programs so that they bolster the efforts of one another without creating an undue or unnecessary financial strain on the funding sources. The report also suggests a pace of funding that reduces the total allocated funding over time.

Exhibit ES-1: Incentive Phasing Program



Included in this report is a preliminary analysis of market penetration for the State. Exhibit ES-2, below, illustrates two scenarios for NGV adoption. Data for these scenarios are based on forecasts by EIA and independent projection.

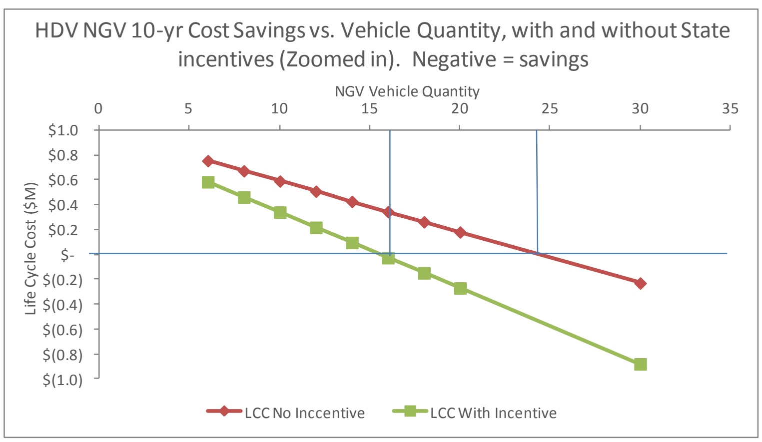
Exhibit ES-2: Colorado CNG/LNG Vehicle Market Penetration Curves – All Vehicle Classes



The analysis suggests that NGV program support be cognizant of the particular contribution to be made by fleets of heavy and medium duty vehicles. These fleets are particularly attractive due to a combination of fleet quantities, locations, vehicle ages, and vehicle characteristics. While medium and heavy duty vehicles become the focus of the analysis and estimations, light duty vehicles are not to be excluded. With proper consideration and planning, any and all infrastructure developed to satisfy the medium and heavy duty fleets could very easily service the needs of light duty vehicles.

Assuming a 50% incentive toward the incremental cost[4] of a natural gas vehicle, a notable reduction in upfront commitments can be made while improving the return on investment. Further analysis and incentive scenarios are explored in the report.

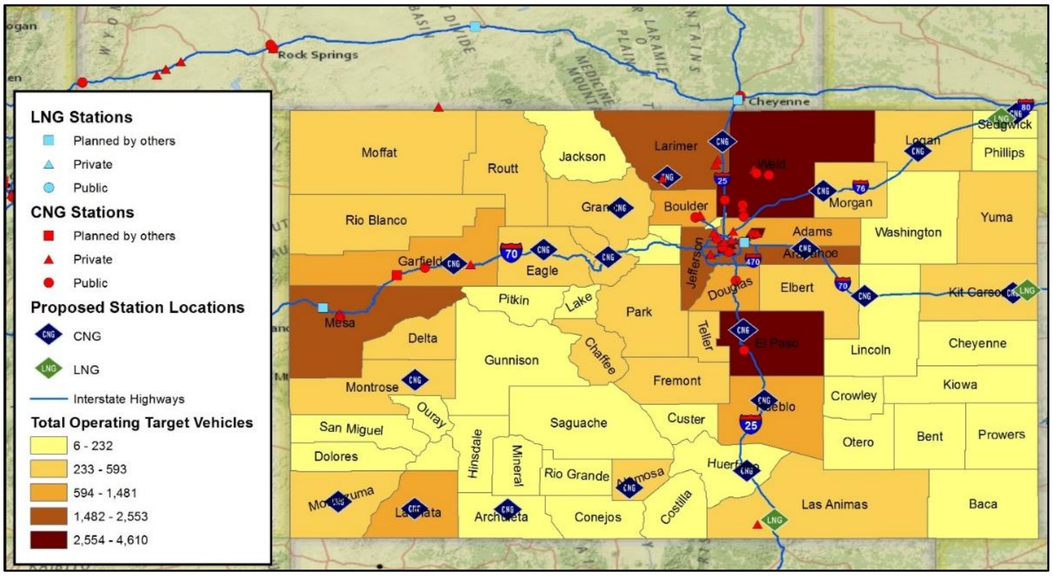
Exhibit ES-3: HDV 10-yr savings vs. vehicle quantity, w/ & w/o 50% state IC incentive (accounts for cost of on-site fueling)



This report also includes a spatial analysis to evaluate a variety of factors including population by county, vehicle registration by class and by county, registered NGVs by county, public/private current/planned CNG and LNG stations, major interstate corridors, and neighboring cities from other states. The results of this analysis reveal key geographic opportunities for investment in fleet adoption and retrofits and additional geographic targets for station development. Exhibit ES-4 illustratesexamples of good geographic targets.

[4] Incremental cost is defined as (Cost of natural gas vehicle) – (cost of equivalent gasoline or diesel-powered version), or the cost of conversion from gasoline or diesel power to natural gas power.

Exhibit ES-4: Map of Proposed Locations for CNG & LNG Fueling Stations



It is suggested that next steps for facilitating CO NGV market expansion center around validation of demand and establishing collaboration opportunities among fleets, fuel providers, utilities, the Colorado Energy Office, and other key organizations. It is advisable that interim benchmarks be established to help phase the growth of CO NGV infrastructure and best utilize all available resources. One suggestion for such an activity is a fleet-targeting study that identifies fleets for which technology, duty cycle, financial capacity, and concept buy-in already exist. This could be one fleet or many, with a goal of achieving a critical mass that justifies infrastructure development. Once developed, this infrastructure could then be use to catalyze adoption by neighboring fleets.

Collaboration is a key success factor for NGV adoption in Colorado. Fleets, fuel providers, station owners, the Colorado Energy Office, local municipalities, and other stakeholders must work as a team to overcome the short-term technical, logistical, and financial hurdles that hinder realizing the long-term upside. For example, several fleets within close proximity to one another could fuel at the same fueling station, enabling that station to be built sooner and be built bigger, and require less financial assistance to become profitable for the owner. The CEO could serve as a facilitator, helping to bring these parties to the table and get conversations started.

Technologies such as propane/Autogas could also prove to fill gaps in areas such as light-duty vehicle fleets. Given the parallels in sourcing, economic advantages, and environmental benefits, bolstered by its relatively low infrastructure and conversion cost, propane/Autogas has become a very popular fuel for fleets such as law enforcement, taxies, and paratransit.

Currently, Colorado has approximately 65,000 medium and heavy-duty vehicles, 58% of which are over the generally accepted “useful life” of 8 years old. If 10% of the outside useful live vehicles (3,760) were replaced by NGVs of equivalent specifications and use over the course of the next 5 years, 13 Million DGE/yr of petroleum could be reduced. Exhibit ES-5 provides a simplified look at what is possible in each of the vehicle classes.

Exhibit ES-5: Petroleum Reduction Opportunities by Weight Class

Vehicle Weight Class	# of vehicles registered	> 10 yrs old	GGE of natural gas used if 10% are replaced with NGVs
Light	4,200,000	59%	129 Million
Medium	44,200	63%	6 Million
Heavy	20,600	47%	7 Million

2 Market Projections

This Chapter describes the model developed to forecast potential market penetration for NGVs under two different scenarios. While this chapter focuses on methods and input information, Chapter 3 describes the model results in context of NGV benefits.

2.1 ASSUMPTIONS REGARDING MARKET PROJECTIONS

Market expansion models are based on a variety of approaches, but for this effort, ANTARES has used two different approaches to estimating the future Colorado NGV market: a Reference Case and a High Demand Case. Some general points about the model are as follows:

- The results of the model are primarily driven by projected incremental demand for NGVs purchased in the 2013 to 2025 time frame. According to DMV registration data, there were 697 NGVs with active registrations in Colorado through the first quarter of 2013. The vast majority (86%) were Light Duty Vehicles (LDVs). Heavy duty vehicles (HDVs) made up 12% (87 vehicles), nearly all of which were registered in the last 5 years. The model does not consider these factors since the investment in infrastructure and vehicles has already been made for the existing fleet of NGVs. However, the model does forecast (based on vehicle life and other data) the ongoing contribution of these vehicles to new natural gas demand, offsets to out-of-state petroleum purchases and emission offsets.
- New NGV vehicle sales are driven by forecasts of market penetration of NGVs in their respective classes as a percent of total new vehicles in those classes.
- The analysis relies heavily on industry averages and weighting factors which have been derived from third party sources.
- Data collected from the Colorado Department of Motor Vehicles (DMV) was used to identify current market penetration of NGVs in the state and served as the starting point for market penetration projections.
- Vehicles were grouped into three classes: Light Duty Vehicles (LDV), Medium Duty Vehicles (MDV) and Heavy Duty vehicles (HDV). The definitions for these categories are consistent with the definitions provided by the Federal Highway Administration:
    - LDVs – gross vehicle weight less than 10,000 lb (Class 1-2)
    - MDVs – gross vehicle weight 10,001-26,000 lb (Class 3 – 6)
    - HDVs – gross vehicle weight >26,0001 lb (Class 7-8)

REFERENCE CASE

EIA projections of market growth for CNG vehicles nationwide[5] were used as the basis for a reference case. In the 2013 Annual Energy Outlook, EIA provides a variety of projections for Light Duty, Medium Duty and Heavy Duty Vehicles by technology type. Most important to this analysis are the projections made for annual unit sales by fuel type in each of the above classes, including NGVs. The data provided in EIA's projections was used in the reference case for the following purposes:

- Estimating future sales of vehicles in each class from 2013 to 2025;
- Estimating rate of adoption of CNG vehicles over the same time frame;
- In combination with the Colorado DMV data, the EIA data was used to evaluate Colorado's share of the national market for the three classes of vehicles; and
- Colorado DMV registration data was used as a proxy for annual sales in normalizing starting values for market penetration calculations.

[5] EIA does provide some breakouts for LDVs at a regional level. However, these breakouts are not published for MDVs or HDVs and after additional analysis, it appeared that the regional estimates were simple breakouts of the national data and no detailed analysis was being conducted at the regional level. Therefore, national data was used for all vehicle classes.

In the reference case, the shape of the EIA market penetration curve was used to estimate future NGV sales. EIA's curve for predicting future NGV sales is very flat, especially for LDVs. After reviewing a variety of sources[6], it was determined that EIA's projected market penetration for this segment is conservative. A recent report by Pike Research suggests that Fleet sales of NGVs for North America (including Canada) could have short term growth rates of more than 10 percent per year. Insufficient data was available for this report to use this information as an alternative to EIA, but the authors felt that this information also helped justify the higher penetration curves estimated in the HighDemand case described below. In contrast to the differences in projections for LDVs, all sources reviewed appear to agree that the highest market penetration is likely to occur for heavy duty vehicles.

HIGH DEMAND CASE

In the Annual Energy Outlook 2012 edition, EIA conducted an analysis specifically aimed at the MDV and HDV market segments. Entitled, "Heavy Duty Vehicles Natural Gas Potential Case," the EIA analysis examined the potential market penetration for CNG/LNG vehicles assuming that infrastructure is expanded to support this growth.[7] The "High Demand" case shown in the following tables (Exhibit 4) uses the penetration curve developed by EIA for that scenario. However, starting values for the market are corrected for Colorado based on 2012 Colorado DMV vehicle registration data.

A different approach was taken for forecasting the LDV market for the High Demand Case since EIA did not conduct a similar analysis for this segment. As an alternate to EIA's penetration curve, ANTARES developed a higher penetration scenario based on an S-curve market penetration model. This type of model imagines market penetration to occur slowly at first, then rapidly during a transition phase between early adoption and market acceptance. Future penetration is slowed as the market reaches maturity. The difficulty in using this type of model is that the precise shape of the curve is difficult to predict in advance. Often, analogs are used to make educated guesses about the shape, especially early in deployment.

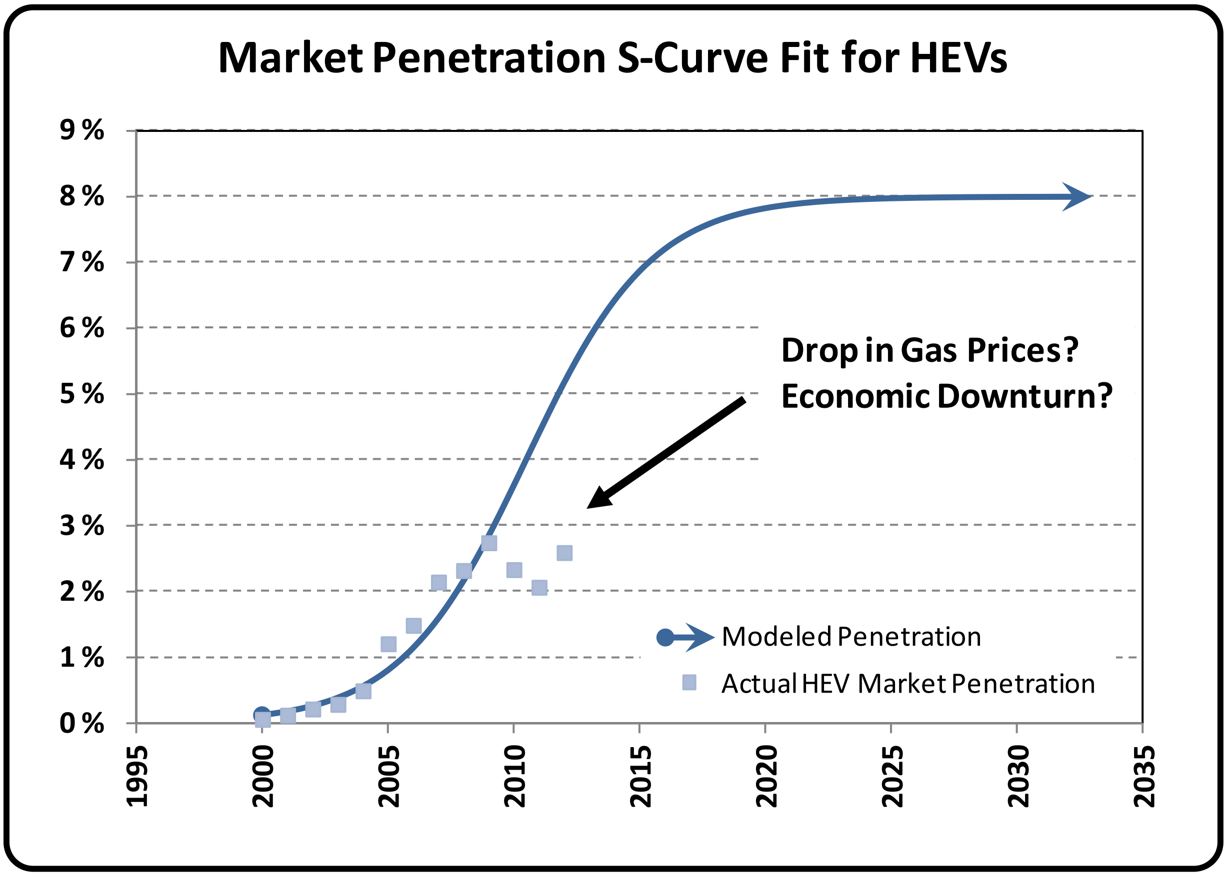
In a recent report published by the American Natural Gas Alliance, *"U.S. and Canadian Natural Gas Vehicle Market Analysis: Comparative Analysis,"* the suggested analog is the Hybrid Electric Vehicle (HEVs) market. While not a precise analog, the HEV market is mature enough that an S-Curve can at least be postulated. To develop the S-Curve, ANTARES collected historical sales data for HEVs and compared those to sales for the entire LDV market segment to calculate annual market penetration. This methodology is similar to the methodology use by TIAX LLC in an extensive report[8] completed for America's Natural Gas Alliance. As the exact parameters for that study were not provided in the report, ANTARES updated the data set and generated a similar curve based on data that was available. Interestingly enough, sales for that segment fell off starting late in the previous decade. There are a variety of potential causes including the US economic recession and falling gas prices. For reference, average gasoline prices in the 2008/2009 time frame dropped by half (Exhibit 6) from their prior peak values up to that point. At minimum, one would expect this to have a chilling effect on the HEV market as high petroleum prices are significant motivator for alternative fuel use. Gasoline prices have since rebounded and sales of HEVs appear to be doing the same. The example penetration curve is shown in Exhibit 1.

[6] This includes, "Driving on Natural Gas: Fuel Price and Demand Scenarios For Natural Gas Vehicles to 2025", April 2013, American Clean Skies Foundation 2013 and "EXECUTIVE SUMMARY: Light Duty Natural Gas Vehicles Natural Gas Passenger Cars and Light Duty Pickup Trucks, SUVs, Vans, and Light Commercial Vehicles: Global Market Analysis and Forecasts," Pike Research, 2012

[7] Excerpt from AEO2012, "The AEO2012 HD NGV Potential case permits expansion of the HDV market to allow a gradual increase in the share of HDV owners who would consider purchasing an NGV if justified by the fuel economics over a payback distribution with a weighted average of 3 years. The gradual increase in the maximum natural gas market share reflects the fact that a national natural gas refueling program would require time to build out. The natural gas refueling infrastructure is expanded in the HD NGV Potential case simply by assumption; it is not clear how (or whether) specific barriers to natural gas refueling infrastructure investment can be overcome."

[8] U.S. and Canadian Natural Gas Vehicle Market Analysis: Comparative Analysis, 2011, Tiax LLC

Exhibit 1: S-Curve Model for LDV High Demand Scenario



2.2 MARKET PENETRATION RESULTS

A graph showing the penetration curves for all of the classes and the two scenarios modeled for Colorado is provided in Exhibit 2. Exhibit 3 displays this data with only the Light and Medium-Duty vehicles shown since the scales of penetration are somewhat different. On a percentage basis, market penetration in the high demand cases is significantly higher than the reference case.

Exhibit 2: Colorado CNG/LNG Vehicle Market Penetration Curves – All Vehicle Classes

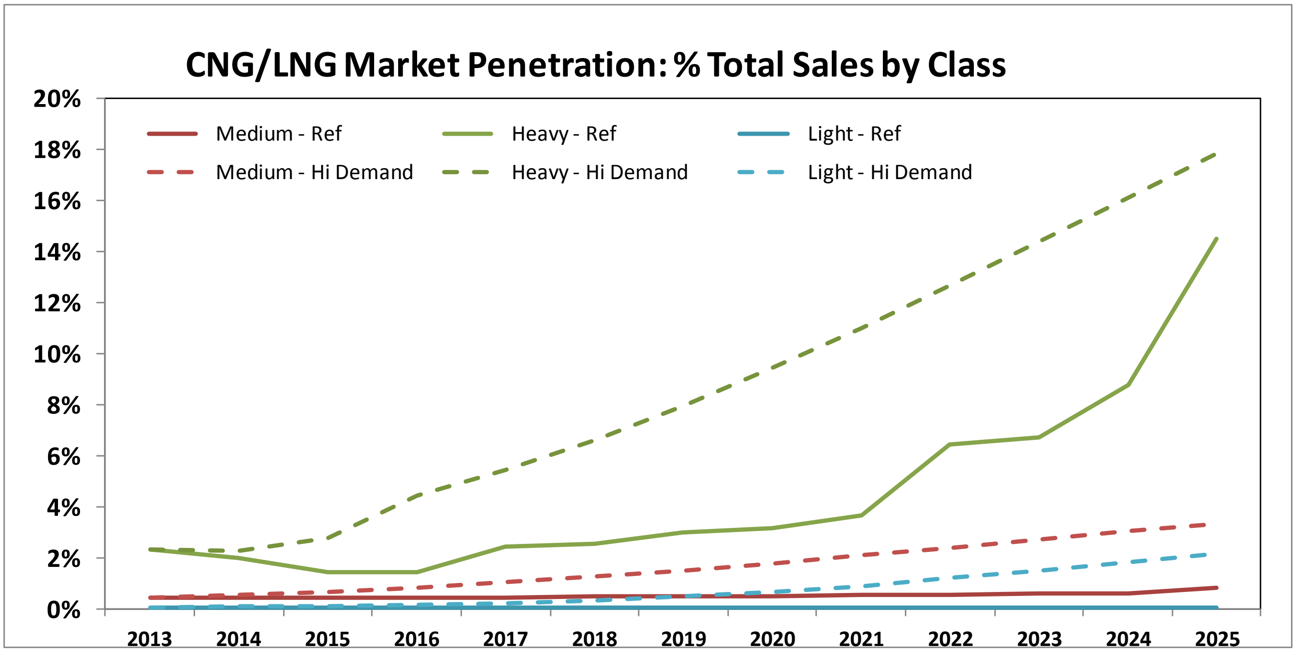
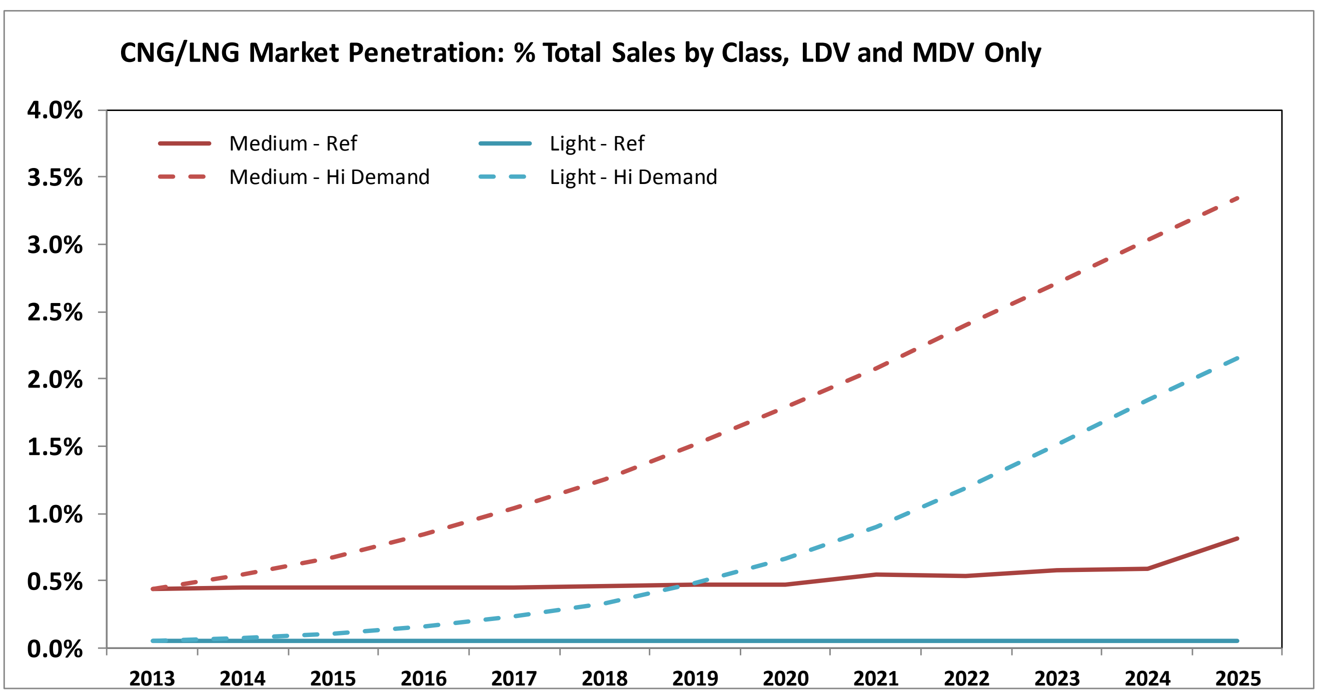


Exhibit 3: Colorado CNG/LNG Vehicle Market Penetration Curves – Light and Medium Duty Vehicles Only



The following tables provide the results of the market penetration calculations. These include fuel use, and new vehicle forecasts.

Exhibit 4: Projected Colorado Vehicle Penetration and Final Market Share, by Class

	2013 - 2018	2019 - 2025	Total	2025 Mk't %
Reference				
Light Duty	669	799	1,468	0.05%
Medium Duty	48	81	129	0.81%
Heavy Duty	200	867	1,067	14.48%
Total	*917*	*1,747*	*2,664*	
Hi Demand				
Light Duty	2,231	21,006	23,237	2.2%
Medium Duty	89	340	429	3.3%
Heavy Duty	399	1,666	2,065	17.8%
Total	*2,719*	*23,012*	*25,731*	

Exhibit 5: Estimated Demand for Natural Gas, by Class (MGGE)

	2013 - 2018	2019 - 2025	Total
Reference			
Light Duty	1.45	4.97	6.42
Medium Duty	0.43	1.66	2.09
Heavy Duty	5.56	29.22	34.78
Total	*7.44*	*35.85*	*43.29*
Hi Demand			
Light Duty	3.44	53.47	56.91
Medium Duty	0.67	4.97	5.64
Heavy Duty	9.23	69.57	78.81
Total	*13.34*	*128.02*	*141.35*

It is worth reiterating that the EIA reference forecast appears conservative with respect to the LDV and MDV segments. Based on the existing DMV data, the penetration rates going forward are not significantly different from current sales volumes. As such, the case is probably best described as status quo.

In contrast, the alternate case predicts significantly more penetration in these sectors. The MDV market penetration is still somewhat limited, but that appears to reflect EIA's belief that the most significant opportunity lies in the HDV segment. Even in the reference case, market penetration by 2025 is significant for this segment.

3 NGV Benefits to Colorado

The benefits of a sustainable NGV market in Colorado are broad reaching. This chapter provides a review of environmental and economic benefits and is informed, in part, on the market penetration model and results developed in Chapter 2.

3.1 Energy Security

Energy security refers to the affordability and uninterrupted supply of energy sources to end users. The utilization of NGVs in the State of Colorado will have positive impacts on the State's energy security. These impacts will include a reduction in fuel price volatility, decreased dependence on foreign oil, and a reduction in the amount of transportation fuels imported into the State of Colorado. The subsequent discussion describes these impacts.

3.1.1 Fuel Price Volatility

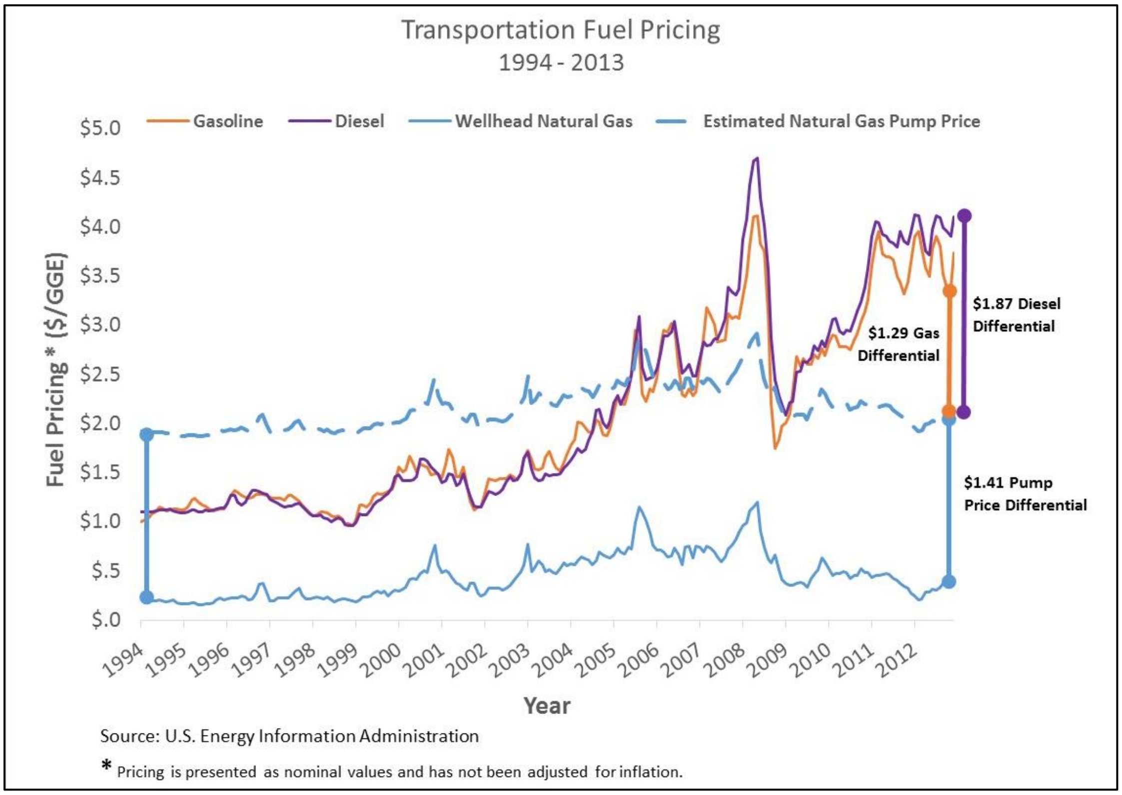
Transportation fuel prices can be highly volatile, as demonstrated by the rapid rise and fall in crude oil prices in 2008/09. The price of crude oil prices has increased 3-fold over the last decade but is stable in the short-term at current prices.[9] If history is any guide, increasing demand for oil in developing nations, the instability of oil exporting countries in the Middle East, speculation among energy traders, potential climate change legislation, and unpredictable events such as natural disasters or wars will continue to create volatility in the market.

As a result of the above, petroleum-based fuel (gasoline and diesel fuel #2) prices have increased with the rising price of oil and fluctuated dramatically relative to historic trends. In contrast, natural gas price fluctuations were considerably lower. The difference in price volatility between oil and gas is more evident in Exhibit 6. This chart normalizes gasoline and diesel prices on an energy content basis ($/GGE) and compares them to natural gas wellhead and estimated pump prices.

In addition to the commodity cost of natural gas the pump price includes transportation to the meter, gas compression, pump maintenance, equipment amortization, and fuel taxes (state and federal). It is important to point out that these costs represent the majority of the retail cost for CNG/LNG. Excluding taxes, all of these costs are subject to reduction over time as competition, economies of scale and technology improvements drive station development costs down and further lower prices at the pump.

[9] Real (2013 USD) crude oil prices increased from $32 to $97 per barrel between May 2003 and May 2013. Source: http://www.eia.gov/forecasts/steo/realprices/

Exhibit 6. Price Volatility in Transportation Fuels (1994 – 2013)



Since January of 2000 to June 2013, gasoline prices averaged $2.42/GGE and ranged between $1.13/GGE - $4.11/GGE with a standard deviation of $0.83/GGE. Diesel fuel prices mirrored those of gasoline with an average price of $2.51/GGE ranging between $1.15/GGE - $4.70/GGE with a standard deviation of $0.97/GGE. As a comparison, compressed natural gas prices (at the pump) over the same time frame averaged $2.26/GGE, with a range between $1.92/GGE - $2.92/GGE with a standard deviation of $0.21/GGE.

As a relevant comparison, from January 2005 to June 2013, gasoline prices averaged $2.98/GGE and ranged between $1.75/GGE - $4.11/GGE with a standard deviation of $0.60/GGE. Diesel fuel prices mirrored those of gasoline with an average price of $3.17/GGE ranging between $1.96/GGE - $4.70/GGE with a standard deviation of $0.69/GGE. As a comparison, compressed natural gas prices (at the pump) over the same time frame averaged $2.31/GGE, with a range between $1.92/GGE - $2.92/GGE with a standard deviation of $0.23/GGE.

3.1.2 Foreign Oil Dependence and State Energy Imports

Petroleum transportation fuels are refined from crude oil and are dependent on an uninterrupted and affordable supply of the resource. Crude oil is a global commodity, so its price is highly influenced by impacts (or speculation on potential impacts) on the global supply. Based on recent data from the EIA, the United States produced approximately 2,378 million barrels of crude oil in 2012. The State of Colorado produced 49 million barrels of that total and held ~1.7% of the nation's proven oil reserves. This same year the United States imported ~3,363 million barrels of crude oil. Since 2010, oil imports decreased steadily to 3,108 million barrels in 2012 with 60% of those imports coming from OPEC[10] and the Persian Gulf.

With the emergence of advanced gas extraction techniques for shale and tight gas sands, new gas reservoirs are now available for production. The United States has an abundant supply of natural gas reserves. In 2010, the total proved reserves were 305 trillion cubic feet (tcf) with total estimated production at 21 tcf[11].

[10] Organization of the Petroleum Exporting Countries
[11] Colorado Dry Natural Gas Proved Reserves. Released 8/2/2012. Source: http://www.eia.gov/dnav/ng/ng_enr_dry_dcu_NUS_a.htm

In 2012, Colorado production of gas was approximately 1.7 tcf or about Colorado produced 7% of the total for the United States. Colorado's proved reserves are approximately 24 trillion cubic feet[12]. Colorado's production of oil and gas over the last 5 year is provided on an energy basis in Exhibit 7 below.

The table shown in Exhibit 8, below, is helpful in illustrating the case for NGVs in Colorado. On a British Thermal Unit (Btu) basis, Colorado produces 18-times more natural gas than gasoline, and 26 times more natural gas than distillate oil. Additionally, the State produces over three times as much natural gas as it consumes[13] (1,687 Trillion Btu production versus 480 Trillion Btu consumed, for a surplus of 1,207 Trillion Btu), making it a significant exporter of gas to surrounding states. In contrast, the state consumes approximately double the amount of gasoline or diesel fuel it can produce from its reserves and production (158 Trillion Btu production versus 340 Trillion Btu Consumption, for a deficit of 183 Trillion Btu). On a Btu basis, Colorado currently consumes twice the amount of natural gas it does gasoline, and almost 6 times as much natural gas as it does distillate oil. Even if Colorado shifted all of its transportation energy from gasoline and diesel over to natural gas without an increase in natural gas production, it would still export a significant portion of its natural gas production. Accordingly, the opportunity to keep energy dollars from flowing out of the state is equally significant. According to EIA, state expenses for gasoline were $7 billion in 2011.

Exhibit 7: Colorado Oil and Gas Production

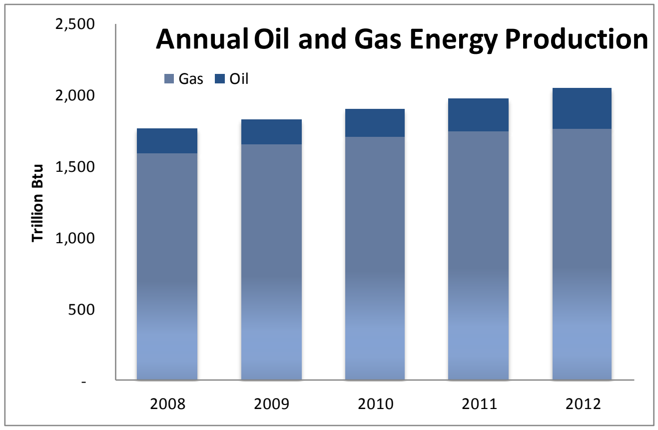


Exhibit 8: Colorado Energy Balance

Colorado Energy Balance

	2011 Data (EIA)			
	Production[3]	Consumption	Net Flow[4]	
Natural Gas[1]	1,637,576	465,985	1,171,591	*million cubic feet*
Distillate Oil[2]	11,205	14,283	(3,078)	*thousands of barrels*
Gasoline	17,741	49,335	(31,594)	*thousands of barrels*
Converted to Trillion Btus				
Natural Gas[1]	1,687	480	1,207	
Distillate Oil[2]	65	83	(18)	
Gasoline	93	257	(165)	

Notes

1) Natural gas for all end uses
2) Distillate fuel for Transportation Sector
3) Production estimated assuming CO oil converted to average gasoline and diesel using average refining breakouts
4) Net Flow = Production - Consumption

[12] Colorado Natural Gas Gross Withdrawals and Production. Released 4/30/2013 Source: http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_sco_a.htm
[13] EIA 2011 Consumption Data

3.2 ENVIRONMENTAL IMPLICATIONS

The transportation sector is responsible for approximately 27 percent of total annual GHG emissions in the U.S., and is the largest end-use source of greenhouse gases. Almost half of the net increase in total U.S. greenhouse gas emissions from 1990-2010 can be attributed to transportation.[14] Estimates from the Colorado Department of Public Health and Environment indicate that in 2010, the state's transportation sector was responsible for 23% of total anthropogenic GHG emissions; this is a 2% increase from the transportation sector's estimated share of gross GHG emissions in 1990.[15] With Executive Order D-004-08, the state of Colorado established a goal of reducing GHG emissions by 20% relative to 2005 levels by the year 2020, and achieving an 80% reduction relative to 2005 levels by 2050.[16] The potential to reduce GHG emissions relative to conventional gasoline and diesel fueled vehicles is a key motivation for using NGVs.

Because natural gas has lower carbon content than gasoline or diesel, it burns more cleanly. Over the past decade, assessments have been conducted by entities such as Argonne National Lab (ANL), the California Air Resources Board (CARB), and the National Renewable Energy Lab (NREL) to evaluate the impact of NGVs on criteria pollutants and GHG emissions.[17] Multiple studies have determined that using natural gas as a transportation fuel results in significant reductions in overall CO_2 emissions and that these reductions outweigh the potential for increased methane emissions associated with gas extraction and other leakage.[18]

At present time, ANL's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model is the most comprehensive source of full-fuel-cycle data , with an extensive database of vehicle technologies, fuels, and fuel pathways. The model was originally released in 1996, and continues to be updated and developed; the current version for vehicle cycle analysis is GREET 2.7, while the latest fuel-cycle analysis is in GREET 1 2012. The GREET model allows assessments of light duty vehicle emissions for various fuel technologies from initial fuel production, through use as a transportation fuel, and for the vehicle life cycle itself. The full fuel cycle, known as "well-to-wheel" (WTW), is generally broken into two stages: well-to-tank (WTT), and tank-to-wheel (TTW). A visual depiction of this cycle is shown in Exhibit 9. WTT emissions include all the emissions from initial fuel production, processing, storage, transportation, distribution, and vehicle fueling. GHG emissions during the WTT stage can vary significantly depending on fuel extraction and production processes. TTW emissions include those generated by vehicle operation, including exhaust and evaporative emissions, and are much more strictly regulated and monitored than WTT emissions.

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[14] (U.S. Environmental Protection Agency, 2013)

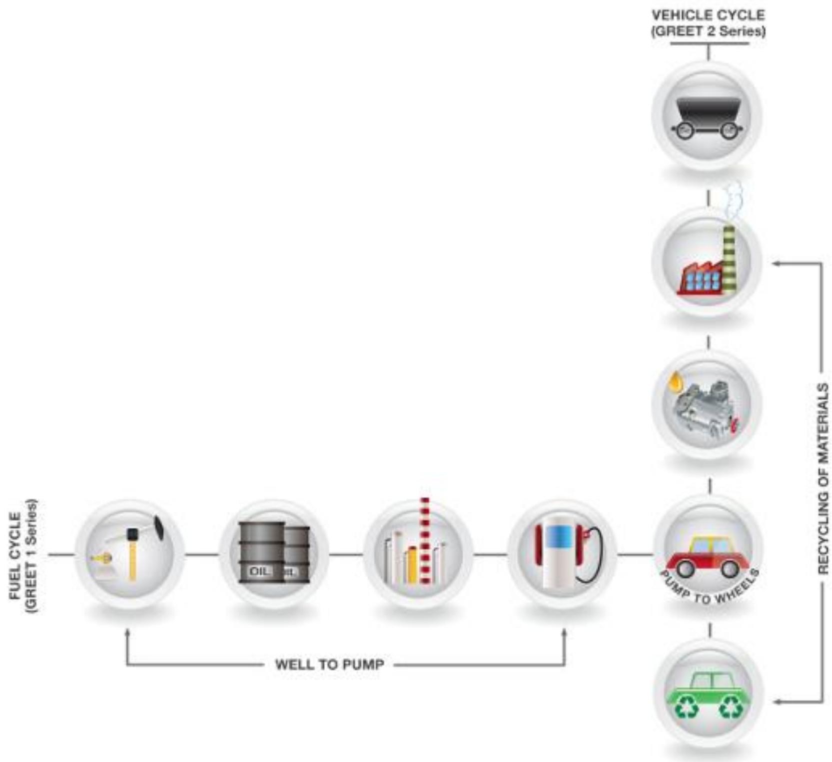
[15] (Strait, R. et al. 2007) Table ES-1. Colorado Historical and Reference Case GHG Emissions, by Sector

[16] (Colorado Governor's Office 2008)

[17] The EPA sets National Ambient Air Quality Standards for six criteria pollutants, including: ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and lead. The principal greenhouse gases include water vapor, carbon dioxide (CO2), methane, and nitrogen oxides (NOx).

[18] (U.S. Environmental Protection Agency, 2013) Natural gas is comprised primarily of methane, itself a GHG that traps heat 21 times more effectively than CO2.

Exhibit 9: GREET depiction of the WTW Fuel Cycle[19]



There have been several recent efforts to evaluate state-specific conditions by modifying the default assumptions in GREET. These efforts include ANL's work with the California Air Resources Board (CARB) to assess the impact of NGVs on criteria pollutants and GHG emissions in California,[20] and a Southwest Energy Efficiency Project (SWEEP) study published in 2012,[21] which used GREET to analyze Colorado-specific emissions characteristics of light duty natural gas and electric vehicles compared to gasoline powered vehicles.

Where possible, SWEEP updated the GREET model assumptions to match electric and gasoline emissions data released in December 2012 as part of the Colorado EV and Infrastructure Readiness Plan. The SWEEP study concluded that with the fuel profile used to generate power in Colorado in 2013, and the default GREET assumptions for methane leakage during the natural gas production pathway, per mile GHG emissions are 7% lower from CNG vehicles than for gasoline and electric vehicles. SWEEP found NO_X emissions from CNG vehicles were 40% lower than for gasoline vehicles and 64% lower than electric vehicles. SWEEP also concluded that CNGs generated lower VOC emissions than gasoline vehicles, although VOC emissions from electric vehicles were lower still.

Beyond the baseline scenario, SWEEP evaluated additional assumptions about GHG calculations, methane leakage during natural gas production, and changes in system efficiency through 2020. These additional scenarios and assumptions changed some results, especially in terms of comparison with electric vehicles. Natural Gas Vehicles for America (NGVA), an industry trade group, challenged SWEEP's conclusions, on the basis that many critical assumptions regarding future efficiency of NGVs, NGV emissions factors, and economics were not correctly estimated.[22] SWEEP has recently published a

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[19] Image courtesy of http://greet.es.anl.gov/

[20] (M. Rood Werpy, 2010)

[21] (Southwest Energy Efficiency Project, 2013)

[22] (Natural Gas Vehicles for America, 2013)

further response to NGVA's document. Regardless of this on-going discussion, nearly all analyses agree that NGVs main market opportunity is to replace gasoline and diesel fuel usage, not electricity. The emissions benefits for replacing light-duty gasoline vehicles with NGVs are seen through the results of the SWEEP study.

3.3 LDV GHG AND CRITERIA POLLUTANT EMISSIONS

GREET models GHG and criteria pollutants for light duty gasoline, diesel, and CNG vehicles, using a default vehicle model year of 2005. For each combination of vehicle technology and fuel system, GREET separately calculates the following:[23]

- Total energy consumption: (energy in non-renewable and renewable sources), fossil fuels (petroleum, natural gas, and coal together), petroleum, coal and natural gas.
- Emissions of CO2-equivalent greenhouse gases - primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).
- Emissions of six criteria pollutants: volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxide (NO_x), particulate matter with size smaller than 10 micron (PM10), particulate matter with size smaller than 2.5 micron (PM2.5), and sulfur oxides (SO_X).

GREET indicates that CNG vehicles produce 18% fewer combined GHG tailpipe emissions than a comparable gasoline-powered LDV, and 4% fewer combined GHG tailpipe emissions than a comparable diesel-powered LDV. CNG vehicles do reduce some criteria pollutant emissions; however, this picture changes when the WTT portion of the fuel life cycle is considered, as the fuel production pathways for gasoline, diesel, and CNG are very different. It should be noted that the adoption of CNG vehicles does not result in an across-the-board reduction in lifecycle emissions. An in-depth analysis of these implications is beyond the scope of this study, and as noted there is significantly more research required to establish current and applicable emission factors for medium duty and heavy duty vehicles.

3.4 HDV GHG AND CRITERIA POLLUTANT EMISSIONS

There are challenges finding comprehensive emissions data for heavy-duty vehicles. As previously mentioned, GREET focuses on LDVs, although ANL's 2010 report "Natural Gas Vehicles: Status, Barriers, and Opportunities" suggested that GREET can be used to generate approximations for larger vehicles by changing the model's default fuel economy assumptions to the appropriate values for HDVs. The fuel economy values used by ANL for this scaling process are based on dynamometer and in-use assessments of CNG and diesel transit buses. ANL ultimately suggests that CNG vehicles can offer a 20-29% improvement in GHG emissions over diesel and gasoline vehicles, respectively.[24] These assessments also indicated that in comparison to diesel powered models, tailpipe emission from CNG delivery trucks contained 49% less NO_x and 95% fewer particulate matter; while tailpipe emission CNG urban transit buses contained 49% less NO_x and 84% less particulate matter. Tables summarizing this data and other relevant data can be found in Appendix A.

The accuracy of scaling the GREET LDV data using fuel economy becomes particularly problematic with regard to the EPA model year 2007 emissions standards for HDVs,[25] which require additional control technologies such as catalytic diesel particulate filters and NO_x catalysts. Because ANL's methodology to adjust the GREET model for HDVs focuses on scaling the LDV assumptions based on the vehicles' fuel efficiency, it does not account for the additional layers of emissions standards that currently apply to HDVs. Multiple studies have concluded that the new EPA standards reduce the emissions benefit that CNG vehicles have historically held relative to diesel vehicles.[26] Due to the uncertainty created by these factors, specific numbers for MDV and HDV emissions of criteria pollutants have not been included in this report.

[23] http://greet.es.anl.gov/

[24] (M. Rood Werpy, 2010)

[25] EPA signed emissions standards in December 2000 for heaving duty engines, dating from model year 2007 and ; the California ARB adopted virtually identical 2007 heavy-duty engine standards in October 2001.

[26] (M. Rood Werpy, 2010), (U.S. Environmental Protection Agency, 2013)

It is also important to note that while GREET assumes that the fuel economy of a CNG vehicle fuel is 5% lower than a comparable gasoline powered vehicle, better results have been seen in Europe with advanced technologies. The 2010 ANL report references a 2005 study by NREL which compared CNG and diesel- fueled urban buses and found that the CNG buses has similar to slightly better fuel economy than the diesel buses: 3.08-mpgde compared to 2.98 mpgde.[27] In addition, improved technologies already available in Europe, such as engines that use direct-injection, double-overhead camshafts, turbocharging and super charging, have been shown to improve fuel economy and create significant reductions in CO_2 tailpipe emissions for CNG vehicles relative to both diesel and gasoline engines.[28] It remains to be seen, however, whether these improved technologies are brought to the U.S. market.

While uncertainty over new engines and emissions controls prevent direct comparison of new diesel and natural gas vehicles, it is clear that replacing older heavy-duty diesel vehicles will result in significant emissions reductions. This is relevant, given that 58% of Colorado's medium and heavy-duty vehicles are older than their expected useful life of 8 years. This also means they were produced before upgraded emissions standards for heavy-duty vehicles. Further, these older vehicles are the most likely candidates for vehicle replacement in any NGV incentive program.

3.5 CREATING COLORADO-SPECIFIC WTW SCENARIOS

In ANL's WTW assessment of the potential impact of NVGs on GHG emissions in California, several modifications were made to more precisely reflect conditions in California, including assumption of a lower fuel loss from transmission and distribution of natural gas, and higher gas compression efficiency. For future study efforts, the GREET model could be modified to include assumptions that more precisely reflect conditions in Colorado.

Of particular concern for future modeling efforts will be the issue of methane emissions during natural gas production, and methane lost during transmission, storage, and distribution. Methane leakage is responsible for the majority of the GHG emissions impacting the CNG lifecycle.[29] The default assumptions used in the GREET model for methane leakage during extraction are 2.0% for conventional gas and 1.3% for shale gas. These values are within the parameters estimated by Cornell University in a 2012 study, which found methane leakage rates from the extraction of natural gas to range from 0.4% to 2.0% for conventional natural gas, and from 0.6% to 4.0% for shale gas.[30] Other recent research by the National Oceanic and Atmospheric Administration and the University of Colorado in Boulder of unconventional wells in Colorado and Utah has shown leakage rates of up to 4% to 9% respectively,[31] although these findings remain controversial with petroleum industry trade groups.

Adaptations of GREET to Colorado-specific model WTW emissions could include updating other aspects of the fuel pathway, such as those involving electricity. For example, electric utilities in Colorado use a higher percentage of renewable energy than the U.S. as a whole and state electrical generation efficiencies also vary. Future modeling efforts could include a detailed GREET assessment of MDV and HDV vehicle emissions, provided that accurate emissions data could be obtained from EPA or another reliable source. This modeling effort could include analysis of the impacts of increasing CNG engine efficiency relative to a diesel baseline.

3.6 ECONOMIC IMPLICATIONS

While the adoption of NGVs has benefits for Colorado in terms of energy security/independence, the most important driver in adoption will continue to be NGVs potential to provide a return on investment for the technology adopters. NGVs also provide an opportunity for businesses and other fleet operators to hedge future fuel costs more effectively through long term pricing agreements.

[27] (Melendez, 2005)

[28] (M. Rood Werpy, 2010) Data points on advanced technologies includes vehicles available from VW, Opel/Vauxhall, Volvo, and Fiat.

[29] (U.S. Environmental Protection Agency, 2013)

[30] (Howarth, 2012)

[31] (Tollefson, 2013)

3.6.1 Reducing Long Term Fuel Costs

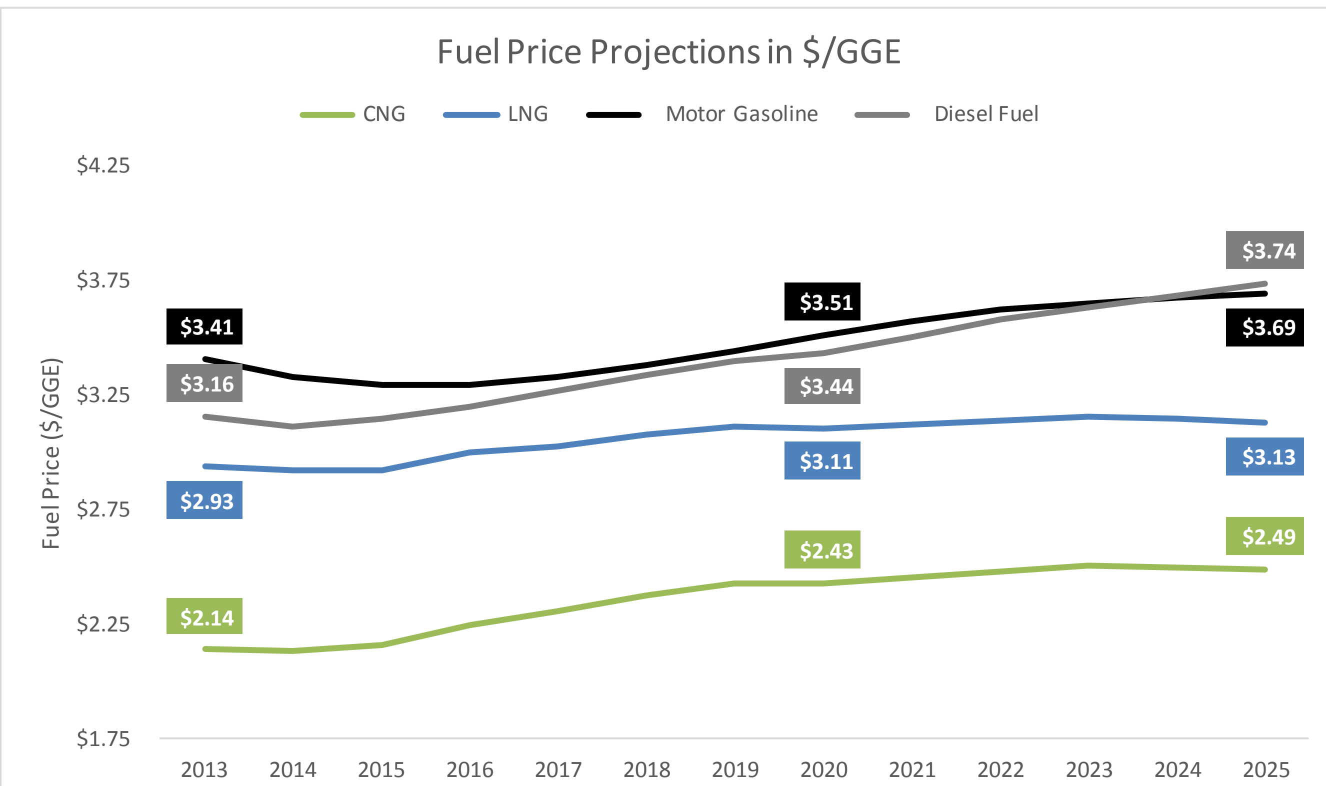
The market penetration forecasting discussed in Chapter 2 utilized fuel cost projections based on EIA Annual Energy Outlook 2013 base case forecasts for the mountain region. The CNG price projection data is tailored by correcting for Colorado specific taxes. Exhibit 10, below, illustrates these fuel price projections through 2025.

The cost projections forecast a small increase in the cost of natural gas commodity prices. Much of the increase shown for CNG is the ramping up of CO fuel taxes from $0.03 to $0.18. The premium for LNG is another point of uncertainty. Limited data about pricing for LNG was available since it is still emerging as a player in the transportation market. There is a premium associated with liquefying and distributing the product which is assumed to be by truck when liquefaction occurs away from the distribution point. The delivered cost for LNG was estimated using data from the America's Natural Gas Alliance LNG Infrastructure report[32] and current projections for natural gas prices.

When compared to petroleum fuels, a relatively small fraction of the cost paid at the pump for CNG/LNG is for the gas commodity. According to recent statistics from ExxonMobil, crude oil is responsible for approximately 71% of the cost of gasoline at the pump. In contrast, ANGA study cited above indicated that natural gas only represented about 38% of the costs for supplying CNG at the pump.

This suggests that there may be a significant opportunity to lower CNG/LNG pump prices. Unlike commodity costs, balance of facility operating expenses and capital costs are subject to market innovation and construction standardization. It is reasonable to conclude that as the market expands and demand for the infrastructure increases, these costs will be reduced over time.

Exhibit 10: Projected Colorado Fuel Price Projections



[32] http://www.ngvc.org/pdfs/Anga_Infrastructure_LNG_Full.pdf

3.6.2 Utilizing CNG as a Hedge

As part of a recent study[33] completed for NYSERDA, a list of case studies was prepared based on conversion success stories for Refuse Hauling fleets around the United States. The feedback provided by those fleet operators is compelling. In each instance, a key factor for converting their fleets was that the natural gas futures market offered long-term fuel price hedging.

The price of natural gas is dictated by supply and demand like any other commodity. However, there are actually two separate markets for natural gas: the spot market and the futures market. The spot market is a daily market and prices are set by what the natural gas is worth that day. The futures market deals with buying gas under contracts that can range anywhere from a month to 10 years into the future. Importantly, the futures market allows one to engage in a contract for delivery of natural gas relatively far into the future at known prices. The futures contract essentially insures (hedges) the fleet against price fluctuations.

It is this last point that has sparked interest among some fleets that are considering NGVs. First, as noted, the natural gas futures market is fairly mature and relatively long-term contracts are available. A municipal refuse fleet, for example, that knows that fuel costs are a very significant part of its variable operating expenses, would naturally be interested in being able to more precisely budget for those costs over a 3-10 year period. This allows them to minimize emergency budget requests (needed during big diesel price swings) and subsequent hauling rate changes which are unpopular. Instead, rates and hauling contracts (if third parties are used) can be established with a high percentage of price certainty.

Since futures contracts represent a type of insurance, there is a premium with using them. It is informative to examine the 3 year “strip” to illustrate this point. The table in Exhibit 13 represents the futures contract prices for natural gas purchased 3 years in the future. As prices into the future are less certain than prices in the near-term, the out year prices reflect the cost of the contract seller’s exposure to future price volatility. However, for a relatively small, predictable premium, CNG/LNG fuel providers can provide stable prices going forward.

As a final note, it is worth mentioning that commodity prices (NYMEX Henry Hub) are only part of the cost of delivering natural gas. Transportation and distribution costs must also be considered, and these prices are subject to some volatility as well. This volatility is driven in part by pipeline capacity (which is also a commodity subject to supply and demand). However these costs are generally a fraction of the total costs and mechanisms also exist for locking in much of those costs.

Exhibit 11: 3-Year Strip NYMEX Futures

As of	Futures Contracts - 3 Year Strip ($/Mcf)			
06-13	2013	2014	2015	2016
Jan	*Settled*	4.330	4.530	4.675
Feb	*Settled*	4.313	4.510	4.654
Mar	*Settled*	4.258	4.441	4.579
Apr	*Settled*	4.097	4.171	4.294
May	*Settled*	4.102	4.181	4.309
Jun	*Settled*	4.135	4.205	4.338
Jul	3.998	4.169	4.239	4.378
Aug	4.015	4.185	4.259	4.398
Sep	4.010	4.185	4.261	4.402
Oct	4.023	4.206	4.285	4.434
Nov	4.094	4.280	4.375	4.532
Dec	4.247	4.447	4.566	4.727

3.6.3 Creating Colorado Jobs

The oil and gas industry in Colorado is a significant contributor to the State’s job market and GDP. This is evident in a recent report[34] prepared by the Leeds School of Business. Data offered in that report includes the following for calendar year 2010:

- Colorado’s oil and gas industry had a production value of $9.2 billion in production value.
- There were 22,400 jobs associated with direct drilling, extraction, and support with average annual wages in excess of $103,000 per year.

[33] Guidebook – Natural Gas for Refuse Fleets in New York, 2012, ANTARES Group Inc.

[34] ASSESSMENT OF OIL AND GAS INDUSTRY ECONOMIC AND FISCAL IMPACTS IN COLORADO IN 2010, Leeds School of Business University of Colorado at Boulder, December 2011, R. Wobbekind et. al.

- Oil and gas supply chain jobs within Colorado (which includes transportation, refining, wholesales, parts manufacturers, and gasoline stations) represented an additional 43,800 jobs, with average wages of more than $72,000.
- The industry supported nearly $3.2 billion in employee income to Colorado households.
- Public sector payments (taxes, public leases, etc.) amounted to more than $1.1 billion, of which $572 million derived directly from severance taxes, public leases, public royalties, and property taxes.

The primary job benefits associated with wide-spread transportation sector use of natural gas in Colorado will include the following:

- New construction jobs associated with building new stations and supply infrastructure;
- Employment associated with retrofits of existing engines;
- Expanded industry support for in-state, rather than out-of-state energy production and use; and
- Jobs related to manufacturing or supplying parts and equipment needed to expand the industry.

In general, there is little data to support the magnitude of some of these benefits, but some anecdotal information was identified. According to the Department of Transportation in New York State[35], every $1M of investment in transportation related projects supports approximately 24 temporary construction jobs. Given that an average CNG/LNG station costs approximately $1 million, then each station would support this number of jobs.

Employment related to existing engine conversion kit installations and parts/support are certainly real, and the services industry support would certainly need to be local. As noted above, there are benefits of having producers and consumers engaged in commercial transactions associated with a Colorado-sourced product. Even if they are difficult to quantify, any additional policies or incentives that encourage these relationships are likely to pay dividends through enhanced job and energy security.

It is also interesting to note that some of Colorado's top gas producing counties (including Weld and Garfield) are leading the way on NGV deployment. This would seem natural as NGVs represent a local market for a locally produced commodity. This natural reinforcement provides opportunities for natural gas producers and end-users to establish relationships that might be value added for both entities, including joint development of refueling stations and favorable pricing.

3.7 MARKET PENETRATION ECONOMIC RESULTS

As the penetration curves in Chapter 2 suggest, the results between the two scenarios (reference case and high demand) is significant. The investment project tables are presented below in

[35] https://www.dot.ny.gov/recovery/jobs

Exhibit 13. Projections regarding infrastructure development are based on average station utilization factors derived from a recent Tiax LLC report. Using these factors, the model offers a forecast of when these average-sized CNG/LNG public stations (shown in Exhibit 12) will have to be built to meet the forecast CNG/LNG demand. However, it is certain that the actual size of the stations and the investment per station will vary based on the application. In the reference case it is possible that more, smaller stations[36] will be built than the average size shown below. In both the Reference and the High Demand cases, it estimated that 12% of HDVs are for long haul and that LNG is the more appropriate fuel. Correspondingly, all MDVs, LDVs and 88% of HDVs are used to calculate the demand for CNG stations. This breakout is based on vehicle use survey information contained in annual Oak Ridge National Laboratory Report[37] covering transportation energy.

In the High Demand case, a significant number of new stations are built over the next 12 years, with corresponding incremental investments by the public and private sector in new vehicles and infrastructure. In addition, between 43 and 141 million GGEs will be required to meet the needs of the new NGVs over the same period. This represents a significant displacement of imported petroleum products and represents a potential conservation of around $150 to $450 million for in-state purchases of energy. By 2025, energy purchases shifted away from gasoline and diesel are estimated to be about $27 million per year for the High Demand case.

Exhibit 12: Average Stations Used for Modeling

Station Type	Cost per Station	Vehicles Supported
CNG Station - Light Duty Public	$ 1,000,000	2,050
CNG Station - Heavy Duty Public	$ 1,000,000	268
LNG Station (base station only)	$ 770,000	104

[36] As noted previously in the report, the Colorado DMV shows that approximately 700 NGVs with active registrations. At the same time, there are 32 public and private stations being operated in the state, suggesting a much lower “average” utilization. This would suggest very low utilization rates more indicative of early market emergence. In forecasting a growing and sustainable industry, the use of higher utilization rates was viewed as a better choice.

[37] TRANSPORTATION ENERGY DATA BOOK: EDITION 31—2012, ORNL, 2012

Exhibit 13: Vehicle and station investment projections for the state of Colorado.

Est. Vehicle Investments ($M) from 2013-2025

	Total
Reference	
Incremental Vehicle Costs	70.7
CO Tax Credits Received	4.1
Hi Demand	
Incremental Vehicle Costs	392.8
CO Tax Credits	19.2

Estimated Station Investments from 2013-2025

	Total
Reference	
Total Investment ($M)	6.5
CNG Stations Built (LD, MD/HD)	5.0
LNG Stations Built	2.0
Hi Demand	
Total Investment ($M)	23.3
CNG Stations Built (LD, MD/HD)	21.0
LNG Stations Built	3.0

Exhibit 14: Fuel and Energy Benefits

(millions of dollars)	Reference	Hi Demand
Avoided Out of State Energy Purchases	149.1	454.0
Total Fuel Savings	25.9	100.8

Achieving these and the other benefits described previously will require significant investment. Taken collectively, approximately $410 million in additional vehicle costs and stations will be required to meet the High Demand penetration scenario. Annual fuel savings from this investment will reach $27 million/year and total savings over the period are estimated to total more than $100 million.

This does suggest a long payback on the infrastructure, which is something the industry must contend with going forward. However, the model built for this exercise does not seek to optimize investment choices, and more careful investment will likely reduce payback periods.

3.7.1 Fleet Economics and Critical Mass

The market penetration results treat deployment using generalities and averages that are useful for gauging overall potential, but it does not provide enough resolution to understand what strategies might be employed to optimize deployment. An examination of fleet level economics is more useful in this regard. A significant number of variables contribute to determining break even points (BEP), return on investments (ROI), and life cycle cost/savings (LCC) of an NGV project. While a comprehensive breakdown and financial analysis is outside the scope of this project, a basic model was developed that allows the consideration of the primary variables of the vehicles, the fuel and infrastructure, and various levels of incentives.

As summarized by Exhibit 15, below, there is an opportunity for significant per-vehicle savings over the course of a vehicle lifetime and in some cases within a few years, depending on incentive level offered. Even when accounting for the cost of on-site fueling infrastructure and with no incentives, payback periods for the incremental cost of the up-fit to NGV power can be as low as 7.5 years for a high use, heavy duty NGV. With incentives, these payback periods can be decreased to as little 4 years. Arguably, more aggressive incentives targeted at achieving a 2-3 year payback could be employed while still spurring private sector investment.

The most rapid returns on investment occur when fueling infrastructure is not part of the expense, and instead a higher per-GGE premium is paid for fuel. Through our analysis, it was determined that an average HDV fleet with on-site fueling would see a 10-year breakeven point of $0 LCC if they ran 17 HDVs with 50% IC state incentive, or 24HDVs with no incentives. Further scenarios and tests may be performed by using the model.

Exhibit 15: Vehicle-level economics of NGV deployment, by incentive availability and vehicle class

Off-site fueling (1)						
	Vehicle Class	Vehicle Purpose	Vehicle Cost	Quantity	IC Payback (years)	10 Yr LC Savings
No Incentives	Medium Duty	Delivery - Local	$ 70,000.00	100	9.3	$ 160,000.00
	Heavy Duty	Refuse - Local	$ 200,000.00	100	7.4	$ 1,400,000.00
With Incentives (3)	Medium Duty	Delivery - Local	$ 70,000.00	100	4.6	$ 1,160,000.00
	Heavy Duty	Refuse - Local	$ 200,000.00	100	3.7	$ 3,400,000.00
No Incentives	Medium Duty	Delivery - Local	$ 70,000.00	20	7.4	$ 140,000.00
	Heavy Duty	Refuse - Local	$ 200,000.00	20	7.4	$ 280,000.00
With Incentives (4)	Medium Duty	Delivery - Local	$ 70,000.00	20	3.7	$ 340,000.00
	Heavy Duty	Refuse - Local	$ 200,000.00	20	3.7	$ 680,000.00
No Incentives	Medium Duty	Delivery - Local	$ 70,000.00	5	7.4	$ 35,000.00
	Heavy Duty	Refuse - Local	$ 200,000.00	5	7.4	$ 70,000.00
With Incentives (4)	Medium Duty	Delivery - Local	$ 70,000.00	5	3.7	$ 85,000.00
	Heavy Duty	Refuse - Local	$ 200,000.00	5	3.7	$ 170,000.00
On-site fueling (2)		Station Cost	$ 1,000,000.00			
	Vehicle Class	Vehicle Purpose	Vehicle Cost	Quantity	IC Payback (years)	10 Yr LC Savings
No Incentives	Medium Duty	Delivery - Local	$ 70,000.00	100	11.1	$ (300,000.00)
	Heavy Duty	Refuse - Local	$ 200,000.00	100	6.2	$ 3,100,000.00
With Incentives (4)	Medium Duty	Delivery - Local	$ 70,000.00	100	7.2	$ 750,000.00
	Heavy Duty	Refuse - Local	$ 200,000.00	100	3.6	$ 5,150,000.00
No Incentives	Medium Duty	Delivery - Local	$ 70,000.00	20	17.3	$ (590,000.00)
	Heavy Duty	Refuse - Local	$ 200,000.00	20	11.1	$ (180,000.00)
With Incentives (4)	Medium Duty	Delivery - Local	$ 70,000.00	20	14.2	$ (340,000.00)
	Heavy Duty	Refuse - Local	$ 200,000.00	20	8.3	$ 270,000.00
No Incentives	Medium Duty	Delivery - Local	$ 70,000.00	5	81.5	$ (965,000.00)
	Heavy Duty	Refuse - Local	$ 200,000.00	5	29.6	$ (795,000.00)
With Incentives (4)	Medium Duty	Delivery - Local	$ 70,000.00	5	74	$ (865,000.00)
	Heavy Duty	Refuse - Local	$ 200,000.00	5	26	$ (645,000.00)

(1) Assumes a CNG Price of $2.50/DGE and no infrastructure cost

(2) Assumes a CNG price of $2.00/DGE and $1,000,000 Infrastructure cost

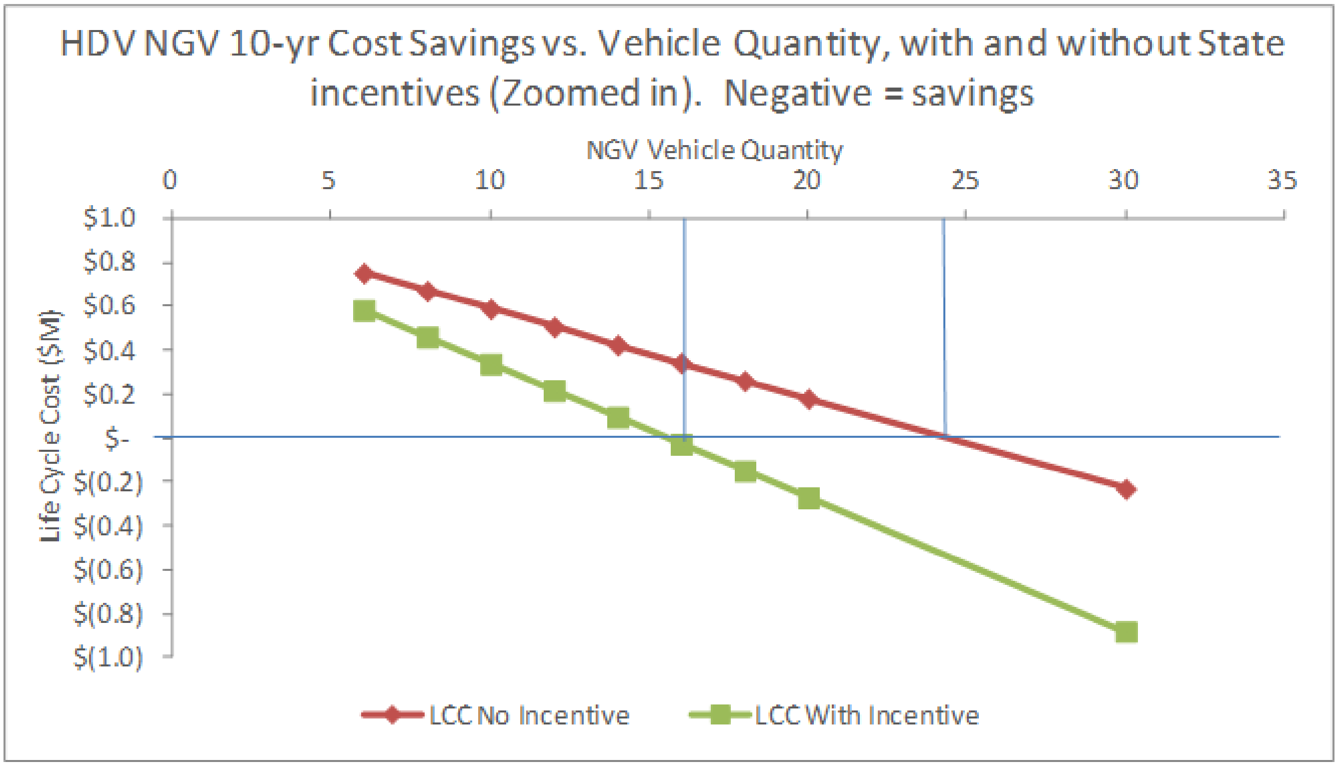
(3) Incentive to offset 50% of incremental cost of natural gas upfit ($10,000/HDV for MDV, $20,000/HDV)

(4) Incentive to offset 50% of incremental cost of natural gas upfit and $50,000 toward fueling infrastructure

**All calculations assume Diesel cost of $3.50/gal, 10-year vehicle lifetime, 90 miles/day, 300 days/yr, 5dmpg HDV, 10dmpg MDV*

Exhibit 16, below, is a sample chart that illustrates the relationship between NGV quantity, life cycle cost, and the impact of a 50%-of-incremental-cost incentive program. In the model, this chart updates dynamically depending on input variables.

Exhibit 16: HDV 10-yr savings vs. vehicle quantity, w/ & w/o 50% state IC incentive (accounts for cost of on-site fueling)



Given the same variables as the chart in Exhibit 15, two additional analyses were performed. Exhibit 17, below, illustrates a matrix of total lifecycle costs or savings based on a variety of incentive levels and fleet sizes. Anything highlighted in green indicates an overall savings given a 10-year timeline. Exhibit 18 takes this same information and investigates ROI in years.

Exhibit 17: Lifetime Cycle Cost (Savings), incentive/vehicle vs. NGV quantity

	State Incentive Level								
NGV Vehicle Quantity	$ -	$ 1,000.00	$ 2,500.00	$ 5,000.00	$ 7,500.00	$ 10,000.00	$ 12,500.00	$ 15,000.00	$ 17,500.00
2	$ 868,000.00	$ 866,000.00	$ 863,000.00	$ 858,000.00	$ 853,000.00	$ 848,000.00	$ 843,000.00	$ 838,000.00	$ 833,000.00
4	$ 786,000.00	$ 782,000.00	$ 776,000.00	$ 766,000.00	$ 756,000.00	$ 746,000.00	$ 736,000.00	$ 726,000.00	$ 716,000.00
6	$ 704,000.00	$ 698,000.00	$ 689,000.00	$ 674,000.00	$ 659,000.00	$ 644,000.00	$ 629,000.00	$ 614,000.00	$ 599,000.00
8	$ 622,000.00	$ 614,000.00	$ 602,000.00	$ 582,000.00	$ 562,000.00	$ 542,000.00	$ 522,000.00	$ 502,000.00	$ 482,000.00
10	$ 540,000.00	$ 530,000.00	$ 515,000.00	$ 490,000.00	$ 465,000.00	$ 440,000.00	$ 415,000.00	$ 390,000.00	$ 365,000.00
12	$ 458,000.00	$ 446,000.00	$ 428,000.00	$ 398,000.00	$ 368,000.00	$ 338,000.00	$ 308,000.00	$ 278,000.00	$ 248,000.00
14	$ 376,000.00	$ 362,000.00	$ 341,000.00	$ 306,000.00	$ 271,000.00	$ 236,000.00	$ 201,000.00	$ 166,000.00	$ 131,000.00
16	$ 294,000.00	$ 278,000.00	$ 254,000.00	$ 214,000.00	$ 174,000.00	$ 134,000.00	$ 94,000.00	$ 54,000.00	$ 14,000.00
18	$ 212,000.00	$ 194,000.00	$ 167,000.00	$ 122,000.00	$ 77,000.00	$ 32,000.00	$ (13,000.00)	$ (58,000.00)	$ (103,000.00)
20	$ 130,000.00	$ 110,000.00	$ 80,000.00	$ 30,000.00	$ (20,000.00)	$ (70,000.00)	$ (120,000.00)	$ (170,000.00)	$ (220,000.00)
40	$ (690,000.00)	$ (730,000.00)	$ (790,000.00)	$ (890,000.00)	$ (990,000.00)	$ (1,090,000.00)	$ (1,190,000.00)	$ (1,290,000.00)	$ (1,390,000.00)
60	$ (1,510,000.00)	$ (1,570,000.00)	$ (1,660,000.00)	$ (1,810,000.00)	$ (1,960,000.00)	$ (2,110,000.00)	$ (2,260,000.00)	$ (2,410,000.00)	$ (2,560,000.00)
80	$ (2,330,000.00)	$ (2,410,000.00)	$ (2,530,000.00)	$ (2,730,000.00)	$ (2,930,000.00)	$ (3,130,000.00)	$ (3,330,000.00)	$ (3,530,000.00)	$ (3,730,000.00)
100	$ (3,150,000.00)	$ (3,250,000.00)	$ (3,400,000.00)	$ (3,650,000.00)	$ (3,900,000.00)	$ (4,150,000.00)	$ (4,400,000.00)	$ (4,650,000.00)	$ (4,900,000.00)
125	$ (4,175,000.00)	$ (4,300,000.00)	$ (4,487,500.00)	$ (4,800,000.00)	$ (5,112,500.00)	$ (5,425,000.00)	$ (5,737,500.00)	$ (6,050,000.00)	$ (6,362,500.00)
150	$ (5,200,000.00)	$ (5,350,000.00)	$ (5,575,000.00)	$ (5,950,000.00)	$ (6,325,000.00)	$ (6,700,000.00)	$ (7,075,000.00)	$ (7,450,000.00)	$ (7,825,000.00)
175	$ (6,225,000.00)	$ (6,400,000.00)	$ (6,662,500.00)	$ (7,100,000.00)	$ (7,537,500.00)	$ (7,975,000.00)	$ (8,412,500.00)	$ (8,850,000.00)	$ (9,287,500.00)
200	$ (7,250,000.00)	$ (7,450,000.00)	$ (7,750,000.00)	$ (8,250,000.00)	$ (8,750,000.00)	$ (9,250,000.00)	$ (9,750,000.00)	$ (10,250,000.00)	$ (10,750,000.00)
225	$ (8,275,000.00)	$ (8,500,000.00)	$ (8,837,500.00)	$ (9,400,000.00)	$ (9,962,500.00)	$ (10,525,000.00)	$ (11,087,500.00)	$ (11,650,000.00)	$ (12,212,500.00)
250	$ (9,300,000.00)	$ (9,550,000.00)	$ (9,925,000.00)	$ (10,550,000.00)	$ (11,175,000.00)	$ (11,800,000.00)	$ (12,425,000.00)	$ (13,050,000.00)	$ (13,675,000.00)
275	$ (10,325,000.00)	$ (10,600,000.00)	$ (11,012,500.00)	$ (11,700,000.00)	$ (12,387,500.00)	$ (13,075,000.00)	$ (13,762,500.00)	$ (14,450,000.00)	$ (15,137,500.00)
300	$ (11,350,000.00)	$ (11,650,000.00)	$ (12,100,000.00)	$ (12,850,000.00)	$ (13,600,000.00)	$ (14,350,000.00)	$ (15,100,000.00)	$ (15,850,000.00)	$ (16,600,000.00)
325	$ (12,375,000.00)	$ (12,700,000.00)	$ (13,187,500.00)	$ (14,000,000.00)	$ (14,812,500.00)	$ (15,625,000.00)	$ (16,437,500.00)	$ (17,250,000.00)	$ (18,062,500.00)
350	$ (13,400,000.00)	$ (13,750,000.00)	$ (14,275,000.00)	$ (15,150,000.00)	$ (16,025,000.00)	$ (16,900,000.00)	$ (17,775,000.00)	$ (18,650,000.00)	$ (19,525,000.00)

Exhibit 18: Total IC Payback Period (years) based on IC incentive/vehicle and fleet size

	State Incentive Level								
NGV Vehicle Quantity	$ -	$ 1,000.00	$ 2,500.00	$ 5,000.00	$ 7,500.00	$ 10,000.00	$ 12,500.00	$ 15,000.00	$ 17,500.00
2	63.6	63.5	63.3	63.0	62.7	62.3	62.0	61.7	61.4
4	34.3	34.1	34.0	33.6	33.3	33.0	32.7	32.4	32.1
6	24.5	24.4	24.2	23.9	23.6	23.3	22.9	22.6	22.3
8	19.6	19.5	19.3	19.0	18.7	18.4	18.1	17.7	17.4
10	16.7	16.5	16.4	16.0	15.7	15.4	15.1	14.8	14.5
12	14.7	14.6	14.4	14.1	13.8	13.5	13.2	12.9	12.6
14	13.3	13.2	13.0	12.7	12.4	12.1	11.8	11.5	11.2
16	12.3	12.1	12.0	11.7	11.3	11.0	10.7	10.4	10.1
18	11.5	11.3	11.1	10.8	10.5	10.2	9.9	9.6	9.3
20	10.8	10.7	10.5	10.2	9.9	9.6	9.3	9.0	8.6
40	7.9	7.7	7.6	7.3	6.9	6.6	6.3	6.0	5.7
60	6.9	6.8	6.6	6.3	6.0	5.7	5.3	5.0	4.7
80	6.4	6.3	6.1	5.8	5.5	5.2	4.9	4.6	4.2
100	6.1	6.0	5.8	5.5	5.2	4.9	4.6	4.3	4.0
125	5.9	5.8	5.6	5.3	5.0	4.6	4.3	4.0	3.7
150	5.7	5.6	5.4	5.1	4.8	4.5	4.2	3.9	3.6
175	5.6	5.5	5.3	5.0	4.7	4.4	4.1	3.8	3.4
200	5.5	5.4	5.2	4.9	4.6	4.3	4.0	3.7	3.4
225	5.5	5.3	5.2	4.8	4.5	4.2	3.9	3.6	3.3
250	5.4	5.3	5.1	4.8	4.5	4.2	3.9	3.6	3.2
275	5.4	5.2	5.1	4.7	4.4	4.1	3.8	3.5	3.2
300	5.3	5.2	5.0	4.7	4.4	4.1	3.8	3.5	3.2
325	5.3	5.2	5.0	4.7	4.4	4.1	3.8	3.4	3.1
350	5.3	5.1	5.0	4.7	4.3	4.0	3.7	3.4	3.1

4 EXISTING POLICY EFFORTS

As evident from Chapter 3, utilizing NGVs has clear benefits to Colorado as well as the nation. For those reasons Colorado has implemented multiple policies to support the adoption of NGVs within state and county fleets and to foster the development of statewide fueling infrastructure. While the various initiatives have made progress toward the ultimate goal of creating a sustainable NGV market in Colorado there are key sectors such as heavy duty vehicles that, to date, have been under incentivized despite their potential. For this reason, this chapter includes a review of current Colorado policies and policies that have been implemented in other states. A discussion of lessons learned from prior efforts concerning market development and technology deployment is also included.

4.1 CURRENT AND PRIOR COLORADO POLICY INITIATIVES

There are a variety of both legislative initiatives and government agency supported policies that support NGVs in Colorado. Legislative initiatives impact how fuel taxes are collected and provide tax credits to qualifying vehicles. Government agencies also have multiple policies and programs that help support public deployment and industry partnerships.

4.1.1 LEGISLATIVE INITIATIVES

Colorado has recently enacted multiple refinements to existing NGV incentives including those summarized below.

Vehicle Income Tax Credit: HB13-1247- Signed on May 15th 2013, HB13-1247 extends the motor vehicle tax credit though 2021, preventing the original expiration in 2015. The tax credit applies to electric vehicles, natural gas vehicles, diesel-electric vehicles and idling reduction technologies as well as vehicle fuel conversions. The law offers an income tax credit valued as a percentage of the manufacturer's suggested retail price for the vehicle (12.25% in years 2014-2016 and scaling down in subsequent years). For converted NGV the credit is capped at $6,000 and is calculated based on the conversion cost, providing 35% of those costs in 2013, 25% in 2014-2018 and scaling down through 2021. It is only available to vehicles up to 26,000 GVWR, thus excluding heavy-duty NGVs.

Reduced Fuel Taxes: HB13-1110-Signed on May 15th 2013, this bill revises how fuel taxes are collected for AFVs. With respect to NGVs it does two things: Repeals the natural gas fuel tax decal system and replaces it with a special fuel excise tax which is lower than current gasoline and diesel fuel taxes. Prior to HB13-1110 NGV were required to pay an annual fee based on weight class of vehicle. The new system charges a special fuel excise tax rate paid at the pump and based on gallon of gasoline equivalent (GGE)[38] starting at $0.03/GGE in 2014 and escalating to $0.18/GGE in 2019 for CNG (LNG only rises to $0.12/GGE). This approach is more equitable as it is a pay for use system rather than the blanket decal fee. The tax structure also offers additional savings to early adopters of CNG/LNG as current Colorado conventional fuel taxes are $0.22/Gal. for gasoline and $0.205/Gal. for diesel.

State Vehicle Purchases: SB13-070- Signed into law on April 26th 2013, this bill requires the state to purchase NGVs if the lifetime costs of the vehicle do not exceed the lifetime costs of gasoline vehicles by more than 10%. This more strongly favors NGVs as the statute SB13-070 replaces only factored in the upfront cost of NGVs and didn't value the lifetime fuel savings. This bill will further foster adoption of NGVs by state agencies.

Energy Savings Contracting: SB13-254- This newly authorized legislation extends the authority for government entities to enter into energy savings contracts for vehicles that reduce operational and fuel costs. Prior to this bill similar policies were enacted that allowed these types of contracts as a means of funding facility renovations which serves as a framework for this expansion. Under an energy cost savings contract the government entity contracts with a third party to purchase or convert NGVs in exchange for forfeiting a portion of the fuel savings over the contract term. This bill will give government entities another option when it comes to financing NGVs and reduces the burden of high upfront capital investments. This

[38] Gallon of Gas Equivalent (GGE) is an energy based unit, not a volumetric unit.

model has been successfully employed in building and facility energy systems for years and is now a common approach for both industry and government agencies to hedge deployment risks.

Other Natural Gas Initiatives

- HB12-1258- Affirms deregulation of natural gas for vehicle fueling stations thus lowering barriers to entry for fueling stations as well as permitting a wider variety of business models.
- C.R.S. 39-26-719- Provides an exemption from sales tax for vehicles over 10,000 lbs. (Class 3 Light Duty Trucks, Medium Duty Trucks and Heavy Duty Trucks) meeting or exceeding the low-emitting vehicle emission standards—applicable to NGVs.
- C.R.S. 25-7-106.8 and 42-4-508- These statutes allow AFV gross vehicle weight rating limits an additional 1,000 lbs. over comparable conventional vehicles operating on a state highway system. This is to accommodate the lower energy density of natural gas fuels which requires larger fuel tanks for equal transportation range.
- Colorado Air Quality Control Commission Regulations Number 3, Part A, Section II.D.1.hhh- This regulation has determined that natural gas fueling stations are exempt from the requirement to file Air Pollution Emission Notices. This is because Natural Gas is almost entirely CH4 which does not pose the same environmental hazards as the more complex chemistry of gasoline and diesel fuel.

4.1.2 Government Initiatives and Industry Partnerships

The development of a sustainable NGV market impacts many stakeholders in both public and private sectors as well as those in the community itself. Bringing stakeholders together has proven to be a critical step in making progress on issues that have such a diverse group of stakeholders such as the adoption of NGVs. There are national, state, and local endeavors all of which have environmental, security and economic interests that are at times competing. In Colorado, there is a diverse and growing group of organizations that are seeking to convert their fleets, install a CNG station, and improve air quality. For state agencies and localities there is a strong incentive to adopt NGVs because the Multi-State MOU has streamlined the acquisition process while reducing costs.

4.1.2.1 Multi-State NGV MOU

The Compressed Natural Gas Vehicle (CNG) Initiative is a key aspect of meeting those objectives. The CNG Initiative began in November 9, 2011 when Governor John Hickenlooper signed an MOU[39] with the governor of Oklahoma to utilize CNG vehicles in the two states' fleets; ultimately 14 other governors (16 states in total) have signed on to the MOU. This collective effort serves to aggregate demand and leverage multi-state buying power in order to stimulate the production of CNG vehicles by automotive manufactures and reducing adoption costs. The states came together to issue a single Request for Proposal (RFP) in order to negotiate the best possible terms. In Colorado, this resulted in the state planning on purchasing 100s of CNG vehicles in the 2013-2014 timeframe with 45 vehicles added already. Through the RFP, there are at least 15 different vehicle models now available for acquisition, up from 4 in 2012. Colorado has entered into an MOU with the Colorado Municipal League in order to allow cities to purchase vehicles using the RFP pricing agreements expanding the impact of the RFP.

4.1.2.2 Key Players and Organizations Supporting NGV market development

Beyond providing financial incentives and supporting the purchasing of NGV in the private sector the development of a sustainable NGV industry for Colorado will require the collaboration and coordination of many diverse stakeholders. There are already many grassroots organizations and interest is growing because of the strong economic case for natural gas along with the many other benefits.

- **Roaring Forks Transportation Authority**: Has deployed 22 CNG buses
- **Weld County's Natural Gas Vehicle Corridor Plan**: Has installed 5 public stations, attracting interest and support from locally operating oil and gas companies. The comprehensive plan layouts a pathway to develop an additional 7-10 stations in order to support the thousands of vehicles they anticipate in the 10 years.

[39] the Multi-State NGV MOU

- **Colorado Natural Gas Vehicle Coalition (CNGVC):** Brings together industry, government and non-profit stakeholders.
- **Clean Cities Colorado (Northern Colorado, Denver Metro, and Southern Colorado):** A network of stakeholder groups that support alternative fuel vehicles.
- **Western Slope Compressed Natural Gas Collaborative:** Conducts education and technical assistance for the region.
- **Glenwood Springs:** The City is in the process of developing a CNG station.

4.2 LESSONS LEARNED FROM OTHER STATE NATURAL GAS INITIATIVES

NGV America identifies eight focus states as leaders in the deployment of natural gas vehicles, infrastructure, and policy: California, Colorado, Ohio, Oklahoma, New York, Pennsylvania, Texas, and Utah. The following tables highlight the key approaches to facilitating adoption of both vehicles and fueling infrastructure. Only key programs that either represent similar programs or are unique are presented. Some funding listed may be related to or a derivative of the Federal Highway Administration’s Congestion Mitigations and Air Quality Improvement program (CMAQ). Following the full extent of funding source was outside the scope of this analysis, however researching such information is highly advisable.

4.2.1 Summaries of Key States' Vehicle Funding Strategies

Exhibit 19: NGV VEHICLE FUNDING

Location	Funding Type	Value (Vehicle)	Funding Source	Timeframe
Canada[40]	Rebate	Light Duty - $2,500 Medium Duty - $5,000 Heavy Duty - $10,000	Private Utility (FortisBC)	5/31/2012-5-2013
Oklahoma[41]	Tax Credits and interest loans	50% of incremental cost of purchasing new OEM AFV or converting a vehicle to alt fuel. CNG, LNG, LPG, Hydrogen only. 75% of cost of alternative fueling infrastructure 0% interest loans to government fleets, 3% interest loans for private fleets	$0.25/GGE CNG Surcharge, private funding	6/2012-1/1/2015
West Virginia	Income Tax Credit	35% of vehicle purchase 50% of conversion cost Max $7,500 <26,000# GVWR $25,000 >26,000# GVWR	State	12/31/2021
West Virginia (Cont.)	Reimbursement	School Bus, 10% reimbursed to county	State	12/31/2021
New York	Voucher	Class 3-8, up to $40,000	NYSERDA/State	11/2012
Texas[42]	Grants	>8,500#GVWR, on-road, 100% of incremental cost, new or repower	Texas Commission on Environmental Quality (State)	8/2017
Pennsylvania [43][44]	Grants	50% of Incremental cost, max $25,000/veh Light, Med, Heavy Duty	State	

[40] http://www.fortisbc.com/NaturalGas/Business/NaturalGasVehicles/Incentives/Pages/default.aspx
[41] http://www.afdc.energy.gov/fuels/laws/3253/OK
[42] http://www.tceq.texas.gov/airquality/terp/tngvgp.html/
[43] http://www.portal.state.pa.us/portal/server.pt/community/act_13/20789/natural_gas_vehicle_program/1157504
[44] http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-95195/0340-BK-DEP4077%20%20AFIG%20%202013%20guidelines.pdf

Exhibit 20: CNG Station Funding

Location	Funding Type	CNG Rebate (Station)	Funding Source	Timeframe
Oklahoma	Tax Credit	Up to 75% of cost of infrastructure (Large Scale) Up to $2,500 (Residential)	State	N/A
West Virginia	Tax Credit	50% of construction cost Max: $250,000/private Max $312,500/Public		Expires 12/31/2021
New York	N/A	None	N/A	N/A
Texas45	Grants	50% of costs, up to $500,000	Texas Commission on Environmental Quality (State)	8/2018
Pennsylvania	None	None	None	None

4.2.2 State Summaries

Utah - The Utah Public Service Commission (PSC) has allowed the local distribution companies and utilities in the state to develop natural gas fueling stations and infrastructure from revenues generated from all residential and commercial users of natural gas (not just vehicle natural gas) through the standard rate mechanism. Because of this, Questar Gas has developed and operates over 20 CNG fueling stations in Utah with extremely competitive fuel costs to the public.

Recently, the Utah PSC has decided to implement a specific tariff for natural gas purchased for vehicle fuel use. Under this new tariff structure, there were fewer ratepayers to share the base cost structure, and thus the price of natural gas fuel increased. Even with this rate increase, however, CNG at the utility-owned stations remains considerably cheaper than anywhere else in the United States. Average pricing at the CNG pump, as of January 2011, was $1.27 per GGE, and continued investment in new fueling stations remains strong.

In addition to the favorable utility structure, Utah has experienced success in expanding its natural gas market via the Utah Clean Cities Coalition (UCCC), which is extremely active in recruiting fleets and seeking grant funding. The UCCC reports that the Coalition and its members have received funding to help offset the cost for 16 new CNG and three LNG/LCNG public access fueling stations. These stations will be in addition to the 24 existing stations and service more than 1,500 NGVs in varying applications. In total, the state has successfully incentivized the deployment of approximately 5,000 NGVs that fuel at 85 public and private CNG stations. The excellent station redundancy increases consumer confidence, which is a cornerstone of Utah's overarching plan to massively expand the NGV market. These combined utility and coalition efforts have had tremendous success thus far, and their momentum is a strong indication that this market will help trigger critical economies of scale that will help drive down the incremental cost of NGVs.[46]

Southern California - SCAQMD has enacted regulations that apply to most public and private fleets that support public services. The fleets affected by these regulations are street sweepers, transit buses, refuse-collection vehicles, school buses, airport ground access vehicles (including taxis and shuttle buses), and other public fleet vehicles. SCAQMD has seven fleet rules (the 1190 Series Rules) that regulate each of these types of fleets. The rules vary in content, with most requiring the purchase of only alternative-fueled versions of affected vehicles; NGVs are thus far the most popular alternative fuel compliance strategy under these rules due to the wide range of commercially available natural gas powered equipment in the marketplace.

While the Southern California Air Quality Management District may have regulations requiring the purchase of alternatively-fueled vehicles, it has also offered substantial monetary incentives in the form of competitive grants to

[45] http://www.afdc.energy.gov/laws/law/TX/9456
[46] NGV Roadmap for Pennsylvania Jobs, Energy Security, and Clean Air. April 2011

purchase alternative-fueled vehicles, alternative-fueled stations, upgrades to existing stations, upgrades to maintenance facilities to maintain alternative-fueled vehicles, personnel training, etc. These grants are funded through a variety of creative programs including fees, emission reduction credits (ERCs), penalties, alternatives to ridesharing requirements, bonds and federal assistance. One example is the successful Mobile Source Reduction Review Committee (MSRC)[47], which is funded by a portion of Department of Motor Vehicle (DMV) fees imposed when purchasing a new car or renewing vehicle registrations on cars in Southern California. The fees collected by the DMV and distributed to the SCAQMD are then used to fund various emissions-reduction programs, including those that apply to natural gas trucks, natural gas fueling stations, maintenance facility upgrades to accommodate NGVs, NGV training, and even outreach and education.

The dedication and investment extended by SCAQMD has resulted in a world-renowned local proliferation of natural gas stations and vehicles. The prevalence of NGVs in SCAQMD's jurisdiction is so great that in January 2011, 7% of the cargo hauled to and from the Port of Long Beach was pulled by natural gas powered trucks[48]. Also in January 2011, the Los Angeles County Metropolitan Transit Agency replaced all of its 2,221 diesel buses with CNG transit buses. There are thousands of natural gas powered refuse trucks operating in Southern California, in addition to hundreds of others delivery trucks, street sweepers, shuttle buses, taxi cabs, and a variety of other NGVs. In total, SCAQMD reports 210 public and private stations fueling 38,000 NGVs with 100 million cubic feet of natural gas per year. This incredible success story allows SCAQMD to enjoy significantly reduced emissions from the one of the most prolific and congested regions in the nation.

Oklahoma - While Utah and Southern California have developed programs around the gas utilities and grant programs for fleets, the state of Oklahoma has chosen to incentivize fleets and fuel station owners through state tax credits. Current legislation in Oklahoma authorized through 2014 provides a one-time income tax credit covering 50% of the incremental cost of purchasing new, original equipment for AFVs or converting a vehicle to operate on an alternative fuel. Oklahoma also provides a tax credit for up to 75% of the cost of installing alternative-fuel infrastructure. A tax credit up to $2,500 is also available for up to 50% of the cost of installing a residential CNG fueling system.

Oklahoma is becoming a national leader in alternative energy by focusing on making the transition to lower-cost, locally produced alternative fuels feasible for its residents and businesses. Oklahoma's CNG laws have attracted enough attention as potential model for a national program that Oklahoma House Speaker Chris Benge was asked to testify about the State's alternative energy credits before the Congressional Natural Gas Caucus in Washington D.C. in 2010.

The state's income tax credits and focus on take-or-pay fuel contracts has led to the construction of 50 CNG stations that refuel 4,000 NGVs statewide:[49]

- Tulsa Public Schools is converting its fleet of 177 diesel-powered buses to compressed natural gas. The change is expected to save the district up to $1 million a year.
- The city of Norman will purchase its third natural gas refuse hauler in early 2011. All three vehicles operate exclusively on CNG, reducing dependence on petroleum, reducing tailpipe emissions, reducing noise pollution and saving fuel costs.
- Oklahoma City owns, operates and maintains a fleet of 80 light-duty, CNG vehicles, many of which were dedicated CNG, as well as two heavy-duty CNG refuse haulers.
- Chesapeake Energy has successfully leveraged this program to support its aggressive CNG vehicle and refueling infrastructure development program.

New York - The state of New York has a combination of incentives for alternative-fuel vehicles, including state tax incentives (like Oklahoma) and a state-funded grant program (like Southern California).New York provides a state tax credit covering 50% of the cost of the installation of infrastructure used to store or dispense an alternative fuel into the fuel tank of alternative-fuel vehicles. In addition to the state tax credit, the state provides various alternative-fuel vehicle grants through the New York State Energy Research and Development Authority (NYSERDA).

[47,23] US And Canadian Natural Gas Vehicle Market Analysis, America's Natural Gas Alliance
[48] Page 2, Port of Long Beach Truck Activity Report (Tars), Clean Trucks, Feb. 16, 2011

NYSERDA currently has specific programs providing funds to state and local transit agencies and schools for up to 100% of the incremental cost of new, alternative-fuel buses and associated infrastructure. This program has been very successful in helping to deploy large volumes of NGVs. For example, the Metropolitan Transportation Authority utilized this program to secure $10.2 million in funding for the purchase of 192 full-size CNG buses.

New York City also runs a Private Fleet Program to help provide funding to private firms for up to 50% of the incremental cost of light-duty natural gas and electric vehicles, and up to 80% of the incremental cost for new and converted medium- and heavy-duty natural gas vehicles.

These combined efforts have resulted in nearly 100 public and private access CNG stations that fuel approximately 10,000 NGVs.[50]

Indiana - The state of Indiana, through their Alternative Fueling Station Grant Program, provides grants of up to $20,000 for installing new alternative fueling stations or converting existing fueling stations to dispense alternative fuels.[51] This program is not CNG-specific, and the value amounts for infrastructure assistance are notably lower than other states.

To promote alternative fuel use in local government, The Alternative Fuel Vehicle Grant Program offers grants to counties, cities, towns, townships, or school corporations to purchase original equipment manufacturer (OEM) AFVs and for the cost of AFV conversions. Qualified entities may receive $2,000 for each OEM AFV purchased, and up to $2,000 for each AFV conversion. Eligible AFVs include dedicated and bi-fuel liquefied petroleum gas (propane) and compressed natural gas vehicles. A recently passed bill adds to this by requiring state fleet operations to purchase alternative fuel vehicles if the incremental costs are less than 20% greater than petroleum-derived vehicles.

Recently, Indiana also passed a bill that provides incentives to heavy-duty NGVs (Class 8, 33,000lb max GVWR). This incentive can cover up to 50% of incremental costs of moving to or converting to natural gas power, and has a maximum yearly allotment of $3 million[52].

The Indiana Economic Development Corporation (IEDC) may award tax credits under the Hoosier AFV Manufacturer Tax Credit to foster job creation, reduce dependence on imported energy sources, and reduce air pollution resulting from the manufacture or assembly of light-duty AFVs in Indiana. AFV manufacturers are eligible for tax credits of up to 15% of qualified investments, which include expenditures in the state that are reasonable and necessary for the manufacture or assembly of AFVs. To be eligible, the manufacturer must compensate its employees at least 150% of the state's hourly minimum wage and agree to maintain operations for at least 10 years.

From a utility and private incentive perspective, Citizens Energy Group offers rebates for qualified compressed natural gas (CNG) vehicle conversions or for the purchase of an original equipment manufacturer dedicated or bi-fuel CNG vehicle.

Federal Tax Credits - In addition to the various grant and state tax incentives described above, federal tax credits for alternative fuel vehicles and infrastructure have been very important financial drivers over the past several years. The three primary credits that have been available include:

- A $0.50 excise tax credit for each gallon of LNG or gasoline gallon equivalent of CNG[53];
- A vehicle-purchase tax credit of up to $32,000 for the largest and cleanest of natural gas engines (Currently expired);
- A refueling-equipment tax credit of up to $30,000 for large equipment and $1,000 for home refueling equipment.[54]

Federal tax credits, unlike grant funding, allow the value to not be considered taxable income to a private entity. It is therefore equivalent to a cash rebate, or grant funding at 100% of the value. A grant, for example, is typically treated as taxable income, and so some percentage of the grant is effectively used for taxes, and as such, the full value of the grant is not applied to the project.

[50] NGV Roadmap for Pennsylvania Jobs, Energy Security, and Clean Air. April 2011
[51] http://www.afdc.energy.gov/laws/law/IN/6526
[52] http://www.in.gov/legislative/bills/2013/HE/HE1324.1.html
[53] http://www.afdc.energy.gov/laws/law/US/319

[54] http://www.ngvc.org/incentives/federalTax.html

Private Investment Model - Another method for financing a new natural gas fueling station is via a private investment, where the investment is paid back through the sale of CNG or LNG to vehicles. In this scenario, a natural gas fueling station provider may design and build a new CNG or LNG fueling station. The end users would then buy the dispensed LNG or CNG at some price per gallon that allows the station provider to recover their investment into the initial build within a reasonable amount of time, typically 10 years.

Natural gas fuel suppliers such as Clean Energy Fuels, Trillium, Pinnacle and others have been very successful in the application of this business model. It has been one that allows these companies to invest their capital to build and operate a fueling station to support heavy-duty fleet conversions to natural gas.

Because fuel-cost savings for NGV fleet programs have been so significant in recent years, especially when the added benefit of $0.50-per-gallon federal tax credits and other possible incentives are also applied, many heavy-duty fleet operators have begun to recognize the tremendous value to the bottom line that an aggressive NGV program can bring. This realization, often gained through experience, has often resulted in the fleet making its own private investment in its NGV project so it can recognize such cost savings and not have to pay a premium for such investments.[55]

4.2.3 Notable Lessons Learned

Lessons deemed as key or important are emphasized in **bold.**

4.2.3.1 Canada

- Overview of Program Objectives
  - Reducing the risk of early adoption of both vehicles and fueling by:
    - Initiating temporary fiscal measures to **offset risk of localized investment** and early adoption of medium and heavy duty vehicles and associated fueling infrastructure.
    - Facilitating strategically located, timely installation of fueling along key corridors
    - **Encouraging collaboration among fleets** to allow access to otherwise private fueling facilities to fleets outside of who owns the facility.
    - Increased **demonstration programs** around appropriate and successful use of CNG as a transportation fuel, to address technical barriers, develop standards, and conduct feasibility studies and business cases.
    - Facilitate or Initiate Research, Development, Demonstration, and Deployment (RDD&D) focused on both sides of supply and demand and centered mostly around heavy duty application. Canada's 5-year focus includes engine development and vehicle integration, as well as fueling infrastructure and storage, with a 10-year focus around off-road applications (rail and marine) as well as more effective and efficient production of CNG and LNG.
  - Address Information Gaps
    - Implement an **educational and outreach strategy** targeting both end users and market influencers. Content addresses both region-wide and localized resources.
  - Increase Capacity to Sustain Markets
    - **Streamline coding and inspection process** via working groups of state, municipal, and industry stakeholders
    - Develop appropriate training materials for stations, vehicle repairs, and NGV fleet operations, as well as for cylinder inspection
    - Establishment of a **NGV roundtable**, to oversee issues such as adherence to roadmap milestones, advising on current and future state of the art, overall guidance for other local support groups, and to serve as a discussion forum and stakeholder support group.
  - Ensuring Ongoing Competitiveness
    - Supplementing funding of private NGV industry to **reduce the incremental cost** of CNG versus diesel engines

[55] NGV Roadmap for Pennsylvania Jobs, Energy Security, and Clean Air. April 2011

      - Exploration of other transportation-based uses for natural gas
- Program Results
  - This deployment roadmap was released in December 2010. While some of these efforts have not yet been completed, Canada has already seen notable interest and adoption from three main industries – LNG Highway tractors (along corridors), CNG Refuse Trucks, and marine ferries around Quebec. **From 2006 to 2010, Canada reported a total of 12,000 Natural Gas Powered vehicles on the road each year. In 2011, this figure jumped over 18% to 14,205[56].**
- Future Plans
  - Continued implementation of the Roadmap, leveraging a strong roundtable group for guidance, stakeholder transparency, and stakeholder support.

4.2.3.2 Oklahoma

- Overview of Program objectives
  - **Utilize in-state energy resources** by enhancing production of fossil fuels while complementing their use with renewable fuels.
  - Initiate **multi-state MOU** for state automobile purchases powered by natural gas, goal of 5,000NGV purchases per year.[57]
  - **Collaborate and leverage relationships** with utilities and private developers to steadily increase CNG stations along key corridors and in key areas
  - Place **CNG stations within every 100 miles of highway by 2015** and every 50 miles of highway by 2025.[58]
    - As part of that plan, the state provides **a tax credit for up to 75% of the cost of CNG stations**.[59]
    - Oklahoma also provides **a tax credit for 50% of the incremental cost of NGV purchase** or conversion.[60]
- Program Results
  - **73 CNG stations with public access, 23 private CNG stations**, as of 6/10/2013.

4.2.3.3 Texas

- Overview of Program Objectives
  - State agency fleets with more than 15 vehicles, excluding emergency and law enforcement vehicles, **may not purchase or lease a motor vehicle unless** the vehicle uses compressed or liquefied natural gas, propane, ethanol or fuel blends of at least 85% ethanol (E85), methanol or fuel blends of at least 85% methanol (M85), biodiesel or fuel blends of at least 20% biodiesel (B20), or electricity including plug-in hybrid electric vehicles.
  - Covered **state agency fleets must consist of at least 50%** of vehicles that are able to operate on alternative fuels and use these fuels at least 80% of the time the vehicles are driven.
  - Owners and operators of equipment used exclusively to store and dispense motor fuels, including alternative fuels, into motor vehicles are permitted by rule, so long as their stations meet emissions limits set by the Texas Commission on Environmental Quality (TCEQ), and are therefore exempt from registering or paying for an air pollution permit.
  - Clean Energy Fuels as well as other natural gas fueling infrastructure providers offer varying levels of **private, alternative fuel vehicle financing** for both public and private fleets.
- Program Results
  - 33 CNG stations with public access, 60 total including private stations (including 20 in the Dallas-Fort Worth area).

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[56] http://www.iangv.org/current-ngv-stats/
[57] http://www.ok.gov/energy/documents/PowerEngineering-%2011%2011%2011-CNG%20is%20Key%20for%20Oklahoma.pdf
[58] Oklahoma Statutes §74-78f
[59] Oklahoma Statutes §68-2357.22. http://www.afdc.energy.gov/fuels/laws/3253/OK
[60] Oklahoma Statutes §68-2357.22. http://www.afdc.energy.gov/fuels/laws/3253/OK

4.2.3.4 Pennsylvania

- Overview of Program Objectives
    - Policy and Vehicles Plan
        - Recognize and highlight existing Pennsylvania Natural Gas Vehicle (NGV) success stories
        - Adopt aggressive policy positions which promote NGVs as an economic stimulus for Pennsylvania
        - Modify existing and develop new in-state incentive programs focused on **high-fuel use fleet applications** and infrastructure development, and encourage the federal government to do the same
        - **Allow bi-fuel NGVs** certified by the U.S. Environmental Protection Agency to be sold in Pennsylvania as a critical refueling infrastructure and overall market-development strategy. This is an excellent stop-gap measure **to address range anxiety and station placement.**
        - **Develop strategic partnerships** that support effective long-term growth of the regional NGV market via effective outreach, education, programs, policies and strategic coordination
    - Infrastructure Plan
        - **Two-phase approach**, "Foundation" phase and "Developed" phase
        - Foundation Phase = 8 strategically located stations in Pittsburgh (3), Harrisburg (1), Philadelphia (3), and Scranton (1), designed to serve return-to-base fleets
        - Developed Phase = 17 additional stations in the same areas as foundation phase plus middle points between the large metropolitan locations to enable corridor routes.
- Program Results
    - Plan is at proposal stage and has not been fully implemented.
    - 18 public CNG stations and 24 private stations, as of 6/10/2013.

4.2.3.5 Indiana

- Overview of Program Objectives
    - Power Indiana vehicles with domestic, more cost effective fuel
    - Take advantage of recent shale technology that is increasing availability of natural gas in Indiana
    - Promote NGV use among heavy duty public and private fleets
    - **State passed bill** on May 11, 2013 that:
        - **Increased incremental cost limit** to state-purchased alternative fuel vehicles from 10% to 20%
        - Increased weight restrictions 2,000 pounds for vehicles that use natural gas
        - Provided for a $**15,000 tax credit for class 8 NGV vehicles** purchased in the state
        - Provided for an income tax credit for vehicles weighing at least 33,000 pounds
- Program Results
    - Program has not been fully implemented as legislation recently passed.
    - 9 public CNG station and 9 private stations, as of 6/10/2013.

4.3 HOW TO BEST SUPPORT PRIVATE INDUSTRY ADOPTION

A classic conundrum is faced by both consumers of NGVs and those seeking to serve this emerging market. Currently, additional investment is required for both of these market participants to access the benefits NGVs may have to offer, but it is unreasonable to assume that either party will outlay significant capital or make significant behavioral changes to secure the benefits of an NGV market without a clear value stream, incentive, or mandate.

4.3.1 Support Mechanisms

On the surface this would seem to be a significant problem, especially in context of a completely voluntary market. However, this problem has been encountered innumerable times in products as diverse as electronic payment systems and specialty food production. While the "chicken vs. egg" dilemma is real, considerable data exists on the options and opportunities for addressing it, including significant discussions outlined in other sections of this report. For background, three potential mechanisms to encourage private industry adoption of NGVs are discussed generally below. More specific recommendations follow.

Government Regulation – Clearly, government regulation can have a profound impact on market dynamics and is capable of overcoming the above dilemma. For example, in 2005 fuel ethanol use as an oxygenate for gasoline was about 4 billion gallons per year. At that time, the fuel ethanol market had seen some boost since the prior fuel oxygenate of choice, MTBE, was under attack as a result of some high profile groundwater contamination cases. However, in 2005 (EPACT 2005) mandated that ethanol be used as an oxygenate to displace 10% of gasoline fuel volumes. By 2010, fuel ethanol use reached nearly 13 billion gallons per year. Gasoline providers were forced to buy the product and the rest of the industry moved forward with some initial certainty about the market. Admittedly this is an extreme case, but it is inarguable that government regulation can and has been responsible for overcoming technology entry barriers. Of course, one of the reasons that these solutions should be considered very carefully is that they can have extreme and widespread unintended consequences. In the case above, one should reference the “Food versus Fuel” debate.

Government Incentives – Government action does not need to be as heavy handed as passing new regulations or mandates to be effective. Tax incentives and grants are a staple of government policy makers and may allow technologies to break through a variety of deployment barriers. As these programs are well understood and widespread and discussed at length above, no additional discussion is required. However, it is interesting to note that fuel ethanol enjoyed a significant producer tax credit for many years prior to EPACT 2005. While it was effective in creating and maintaining a market, the big results came when the mandate for use were handed down. Additionally, it has been argued that government subsidies like producer tax credits can create “incentive addictions” that do not necessarily create stable, long-term investment environments. The deployment history of wind power (which has seen boom/bust cycles that depended on extensions to federal tax credits) has been cited by critics as an example of this potential pitfall.

Lightly Subsidized or Voluntary Market Options – In markets that are lightly subsidized or in which voluntary actions by consumers and producers are expected to facilitate market transformation, the private investment market must identify transitional strategies or technologies. In alternative fuel vehicles, the market appears to be testing a few options including bifuel technologies and targeted exploitation of niche opportunities.

Bifuel technologies allow early fleet or vehicle owners to invest in a technology without completely exposing themselves to the risk of failed or slow expansion of alternative fuel infrastructure. In addition, CNG station infrastructure developers still receive some early market signals on the mainstream potential which may allow innovators to make a leap of faith into the market. Government subsidies can also be used to further spur participation of both parties.

4.3.2 Recommendations

For mainstream vehicle adoption and the development of a widespread station infrastructure, the market must become self sustaining. In the absence of strong changes in government mandates, this means that vehicle and fleet owners will have to be convinced that NGVs offer a significant, long-lasting economic benefit. Give the number of fleet conversions already occurring in the absence of strong governmental forcing functions in most states, the fact that some fleets have already made these calculations and have chosen to adopt the technology is an encouraging sign.

In evaluating options for further encouraging growth in this market specifically in Colorado, the data collected for programs in other states is informative. Chapter 5 also provides more data on general opportunities to set and stage incentives.

- Relatively large incentives are required, especially for heavy duty vehicles. As discussed in Chapter 3 there are significant economies of scale with respect to fleet size, so balancing incentives appropriately is challenging (refer to market analysis presented previously). Most vehicle incentives seem to be targeting at least 50% of the incremental costs for NGVs, but higher rates will undoubtedly spur more rapid adoption.
- Station investment incentives will also help especially until critical mass is achieved. It would seem reasonable that these incentives could be capped at a certain number of stations or mixture of station counts and size. Once a minimal level of infrastructure coverage is provided, further public investment may experience diminishing returns. Initial target levels could be calculated using the type of siting analysis discussed in Chapter 5.
- Establishing a working relationship with fleet owners and station operators will also be critical. It is probably no coincidence that states experiencing some success in this arena are also served by strong Clean Cities programs and industry trade groups. NYSERDA has published several guides and conducted numerous workshops that have garnered significant interest. In a recent state-wide outreach effort to fleets, NYSERDA hosted 5 workshops across the state. The events were well attended and resulted in considerable follow-up activity.

- Identifying the appropriate number, size and type of stations to build is clearly very important. Stations need to be sufficient in number and appropriately sited so as to guarantee connectivity. There are a variety of station sizes and optimizing infrastructure usage will provide efficient use of investment and incentive money.

5 MARKET IMPLEMENTATION STRATEGIES

This chapter focuses on the market implementation strategies that will enable sustainable growth and ongoing success of NGVs in the State of Colorado. The subsequent sections will discuss investment levels and incentives, ideal vehicle-class and fueling station frequency needed for widespread NGV adoption, as well as the steps and timing required for NGV to succeed without incentives.

5.1 MEASURING SUCCESS

The creation of a sustainable, market driven NGV industry will depend on many factors including:

- A strong ROI for vehicle fleets that in the long term does not depend on incentives,
- Overcoming and educating the public on both real and perceived market/technological risks,
- Developed public fueling infrastructure to make NGVs a viable alternative for small fleets and individuals,
- A sufficient number of vehicles to support a distributed refueling infrastructure that allows for ease of intrastate and interstate transportation of goods and passengers, and
- Continuous technological and cost improvements in NGVs and station infrastructure to remain competitive with other alternative energy options.

Much of the data needed to measure the above is already in place:

- Publically available databases already exist that track alternative fuel infrastructure;
- A growing database of information is available on the incremental cost for vehicles and NGV use; and
- DMV records can be used to track CNG vehicle registrations.

These data can be used to establish comparative metrics such as vehicle market penetration, station density along major corridors or in metropolitan locations and cost reductions over time. Although it is beyond the scope of this study to define precise targets for each of these, the research in this report suggests the following figures as useful targets:

- Distances between refueling stations of less than 50 miles will be an important milestone
- Market penetrations (as a percent of total class sales) of more than
    - 2% for LDVs (referencing HEVs as a model)
    - 15% for MD/HD vehicles (based on projections provided in a variety of studies)

If these targets are met over the next 10-15 years, it will be easy to justify that NGVs have a permanent and growing place in the Colorado's transportation market.

5.2 INVESTMENT AND INCENTIVE REQUIREMENTS

Exhibit 21 provides a summary of the modeling results with respect to State investment and tax revenue impacts, **if the state pursues all policies recommended above**. For the High Demand scenario and based on the current incentives available through the State, the analysis suggests that approximately 90% of the required upfront capital investment will be carried by the entities other than the State of Colorado. This funding would most likely come from Federal incentives and private sector investment.

On the one side, the projected economic activity from Colorado's investment is about 10 times the investment (refer to State Ratio of Economic Activity/Investment) regardless of the deployment scenario. However, as stated previously, tax credits or other grants that pay for greater than 50% of the incremental cost to upgrade to natural gas capable vehicles appears to be the emerging norm. The proposed incentives do not seem to rise to that level and may hamper market growth for Colorado based fleets.

With respect to the split on the incentives analyzed, state fuel tax breaks are forecasted to be more significant than capital investment credits by a margin of 2:1.

Exhibit 21: Colorado Incentive Analysis

(millions of dollars)	Reference	Hi Demand
CO Tax Credits	4.1	19.2
Foregone State Fuel Taxes	8.3	29.0
Total CO Public Investment	12.3	48.1
Total Vehicle/Infrastructure Investment	77.2	416.2
Ratio Public/Private	16.0%	11.6%
New, In-state Energy Purchases	149.1	454.0
State Ratio of Economic Activity/Inv.	12.1	9.4

Many models exist for financial supporting an emerging industry, but nearly all of them strive to strike a balance of sources, levels, and timelines of funding and to reach a financial break-even point as effectively as possible. Specifically to the state of Colorado, it is recommended that three funding strategies be considered in a holistic manner:

- Tax credits to offset the construction of publically accessible natural gas fueling infrastructure, preferably with weighting to emphasize the installation of infrastructure at target areas that address air quality, corridor development, target fleet proximity, or other prioritizing factor.
- Tax credits and grant programs to offset the incremental cost and conversion costs for NGVs. While all vehicle weight classes could be considered for this, it is suggested that such a program focuses especially on medium and heavy duty weight classes due to the high per-vehicle volume of fuel used and general characteristic of return-to-home logistics.
- Fuel supply incentives per GGE or DGE of natural gas. This serves to lower the breakeven point of a project and encourage long-term use of the technology, and is an important complement to the two above recommendations. The open market typically results in the fuel savings being passed to the end consumer. The previous two recommendations serve to catalyze equipment and infrastructure, and this recommendation serves to further justify the results of the above while also stimulating further equipment investment without the up-front incentives. While this fuel credit does exist on a federal level as $0.50/GGE Fuel Excise Tax Credit, it is set to expire in 2013. It has been renewed for several years, and has also disappeared completely for some periods of time. Determining the exact amount of the state incentive would require additional research.

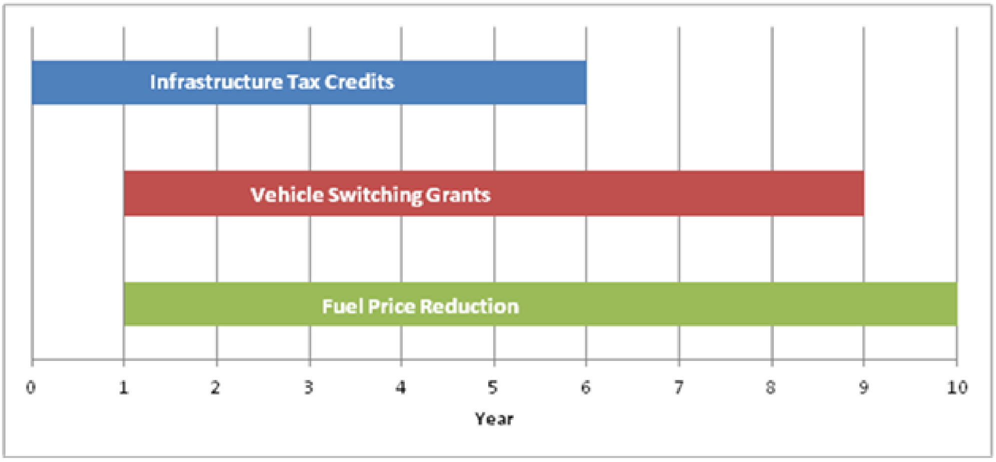
In this strategy, these three incentives are phased in and overlapped in time such that each bolsters the purposes of the others to meet a sustainability timeline (Exhibit 22). The ideal outcome is that sustainability is achieved before the end of the incentive program, but not so far in advance that the incentives are unnecessarily used to provide a windfall for early market entrants.

An important parameter is that infrastructure incentives are provided first to lay the groundwork for future NGV adoption. For example, Oklahoma is becoming a national leader in alternative energy by focusing on making the transition to lower-cost, locally produced alternative fuels feasible for its residents and businesses. The state's income tax credits and focus on take-or-pay fuel contracts has led to the construction of 50 CNG stations that refuel 4,000 NGVs statewide. Chesapeake Energy, for example, has successfully leveraged this program to support its aggressive CNG vehicle and refueling infrastructure development program.[61] This strategy of incentivizing infrastructure development does not have to apply to utilities alone either, and such incentives are equally attractive to other private station developers, fuel marketers, and large fleets that need private stations.

[61] NGV Roadmap for Pennsylvania Jobs, Energy Security, and Clean Air. April 2011

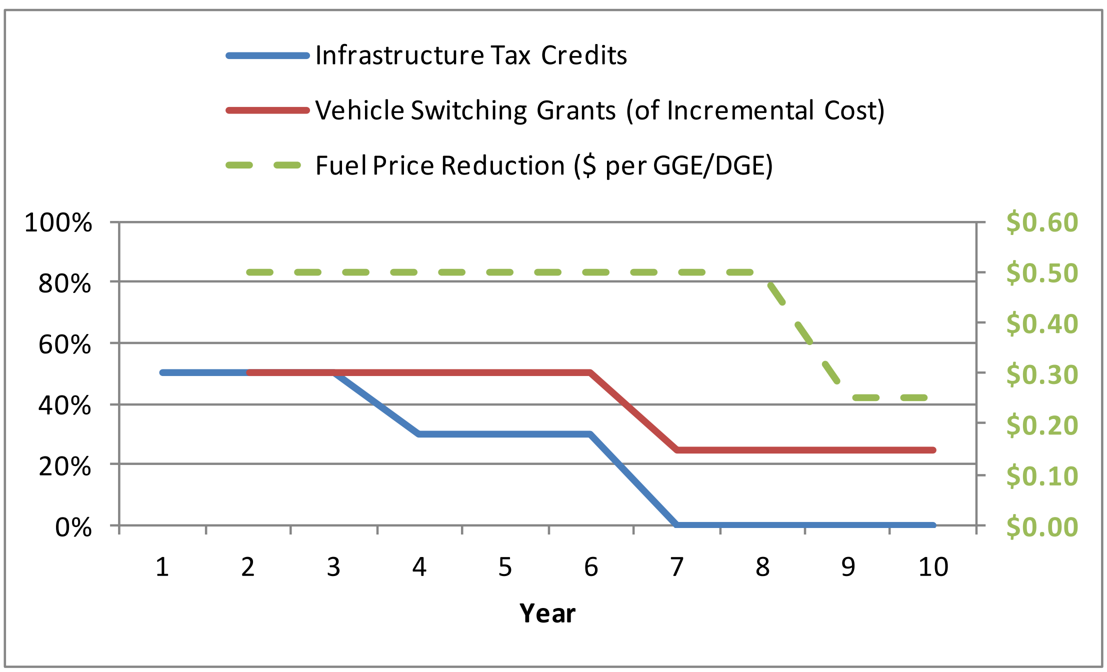
Exhibit 22, below, illustrates the phasing of the proposed incentives. Infrastructure tax credits end after year 7 with the goal that sufficient NGVs are in use to financially justify additional private investment for infrastructure. A one-year (or even two-year) delay before vehicle switching cost grants are implemented allows time for infrastructure construction to be started or possibly completed in some areas, as well as time for adequate outreach, education, and engagement of potential fleets. Instituting a fuel price reduction at the same time as the switching grants improves the business case for NGVs. The switching grants end two years before the fuel price reduction program because it is essential that savings from fuel cost and usage is the essential building block of a strong business case.

Exhibit 22: Incentive Phasing Program



The levels of each incentive are not expected to stay constant though their life span, as Exhibit 23, below, shows. A balance between budget, timing, needs, and administration costs must be met that keeps the incentives relevant but does not overwhelm the system or create too many changes. As shown in Exhibit 23, infrastructure tax credits and vehicle switching grants are reduced at a consistent level, while fuel price reductions remain more consistent. All the programs fade out as the market, hopefully, becomes self-sustaining.

Exhibit 23: Incentive levels over time



Clearly, Colorado already has established incentive programs and a complete rework of those incentives is impractical. However, since not all of the above options are in play or are not in play at the levels that other states are employing, there are opportunities to improve these programs on the margin. For example, vehicle tax credits, tax credits for HDVs or fuel use credits are still available options. Regardless of the incentives, ANTARES recommends that the timing and respective synergies of these incentives be considered carefully to ensure maximum return on public investment.

5.3 NEAR TERM OPPORTUNITIES

The ideal targets for near-term NGV policies include high-return vehicle classes and fueling station development. Spurring their early adoption and development are crucial for building a sustainable NGV economy in Colorado. To be clear, considerable activity is already underway, but to identify additional near term targets, CNG/LNG fueling stations and target vehicle classes were evaluated in tandem through spatial data analysis.

5.3.1 High Return Vehicle Classes and Fueling Station Development

All vehicle classes are suitable to be considered targets. These include light-duty, medium-duty, and heavy-duty trucks and passenger vehicles. However, based on the analysis contained in this report and others, effort should be focused on vehicle classes operated by most centralized fleets: medium duty and heavy duty vehicles. Light duty vehicles are not considered “high return” vehicle classes because they do not have as much of an impact as medium and heavy duty vehicles. Medium and heavy duty vehicle classes are ideal targets since these vehicle classes get poorer fuel economy (5 – 13 mi/GGE) and often drive more miles per year than passenger vehicles, resulting in greater potential for fuel savings.

The current fueling infrastructure only covers a small portion of the state and is a primary limiting factor to increased NGV adoption. For Colorado, this study sought to identify siting opportunities by cross referencing the location of existing inventory of CNG/LNG fueling stations to the location of target vehicle classes. This assessment was conducted and is described in the subsequent discussion.

5.3.1.1 Geospatial Opportunity Analysis

A spatial data analysis was conducted to identify the areas of the state where the targeted vehicle classes (medium and heavy duty), including conventionally fueled vehicles and NGVs, were most prevalent. Vehicle class and natural gas fueling station data was collected from the Colorado Department of Motor Vehicles (CO DMV)[62], FleetSeek[63], and the Department of Energy’s Alternative Fuels Data Center (AFDC) and conditioned to build a county-level assessment of potential target areas. A county-level analysis was chosen because the data was aggregated at this level by the DMV. Ideally, this data would be granular enough to identify the locations of fleets based on their street addresses. This assessment could be refined with more detailed data including the location and other relevant information for each fleet. Light duty vehicles were excluded from the analysis, as they are considered a lower priority target, at least in the near-term.

The study objective was to identify areas of opportunity in the State where there was a relatively high population of medium and heavy duty vehicles and potential for CNG/LNG station development. The existing and currently announced planned locations of CNG and LNG fueling stations in Colorado at present are shown in Exhibit 24[64].

[62] Provided by Colorado Energy Office with data current through the end of 2012
[63] FleetSeek Private Fleet Directory. Downloaded May, 2012. http://www.fleetseek.com/
[64] US Department of Energy, Alternative Fuels Data Center. Accessed June, 2012. http://www.afdc.energy.gov

Exhibit 24. Locations of Existing and Planned CNG & LNG Fueling Stations

Data source: AFDC. Accessed: June 10, 2013

Exhibit 24 shows all of the existing and planned CNG and LNG fueling stations in the state of Colorado based on the most recent data available from the AFDC. Clearly, the CNG infrastructure is more developed than that for LNG. The data shows that there are 34 existing CNG stations in the state, with 18 of those for exclusive private use[65]. The remaining 16 stations are open to the public. One CNG station is planned for construction along Interstate 70 (I-70) in Garfield County. The majority of the CNG stations are located in the Denver metropolitan area with others located predominately along I-70 to the west and Interstate 25 (I-25) south of Denver. Private fueling stations are likely used to fuel private sector fleets or co-ops in the area and present the first near term opportunity for fueling station development.

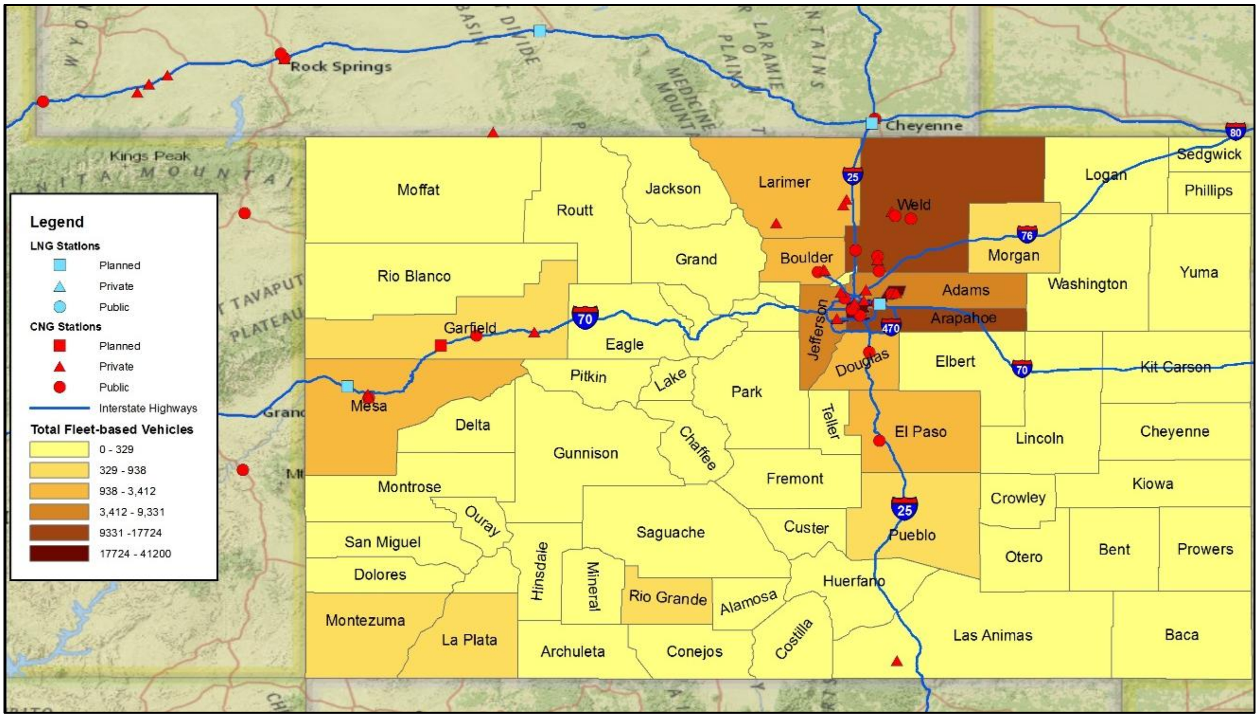
TARGETING "PRIVATE" CNG FUELING STATIONS TO ALLOW PUBLIC ACCESS

Over half (54%) of the existing CNG stations are operated for private consumption. They have an established natural gas supply and have a minimum capacity to meet the needs of the vehicles they currently serve. Existing private stations, depending on a variety of factors could be expanded or retrofitted to permit public access with a significantly lower capital investment than developing a new station. As capital requirements are a major hurdle to station deployment, these existing stations present an opportunity for rapid deployment. New York State has seen initial success in this strategy, and it should be noted that several refueling stations in Colorado have had similar successes as well. The City of Grand Junction worked with a private sector partner to provide fast-fill refueling station access to the public. In addition, Denver International Airport (DIA) provides public access to refueling infrastructure at its rental car refueling station. While it should be noted that opportunities such as DIA are few in number, as a case study it still provides useful lessons. State incentives to allow public access would improve the profitability and payback of their stations through increased use by the public. Utilization data was not available for this analysis, but that data would further inform the analysis and should be gathered for future efforts. It will be necessary to understand whether "private" stations have the capacity to meet a public demand, or if additional public stations are required for a given area. Fueling station utilization data, along with NGV market projections, will enable a more detailed study of where existing CNG fueling infrastructure is lacking and further development will be needed.

[65] The CNG station in Grand Junction, CO has both public and private access

Data for medium and heavy duty vehicle classes were collected from two separate sources with similar data: the FleetSeek Private Fleet Database for Colorado (FleetSeek) and the CO DMV vehicle registration database. Both datasets were refined and aggregated to show the total medium and heavy duty vehicles in operation[66]. Maps of these vehicles' population density by county are shown in Exhibit 25 (for fleet-based vehicles) and Exhibit 26 (CO DMV database).

Exhibit 25. Fleet-based Vehicles in Operation by County

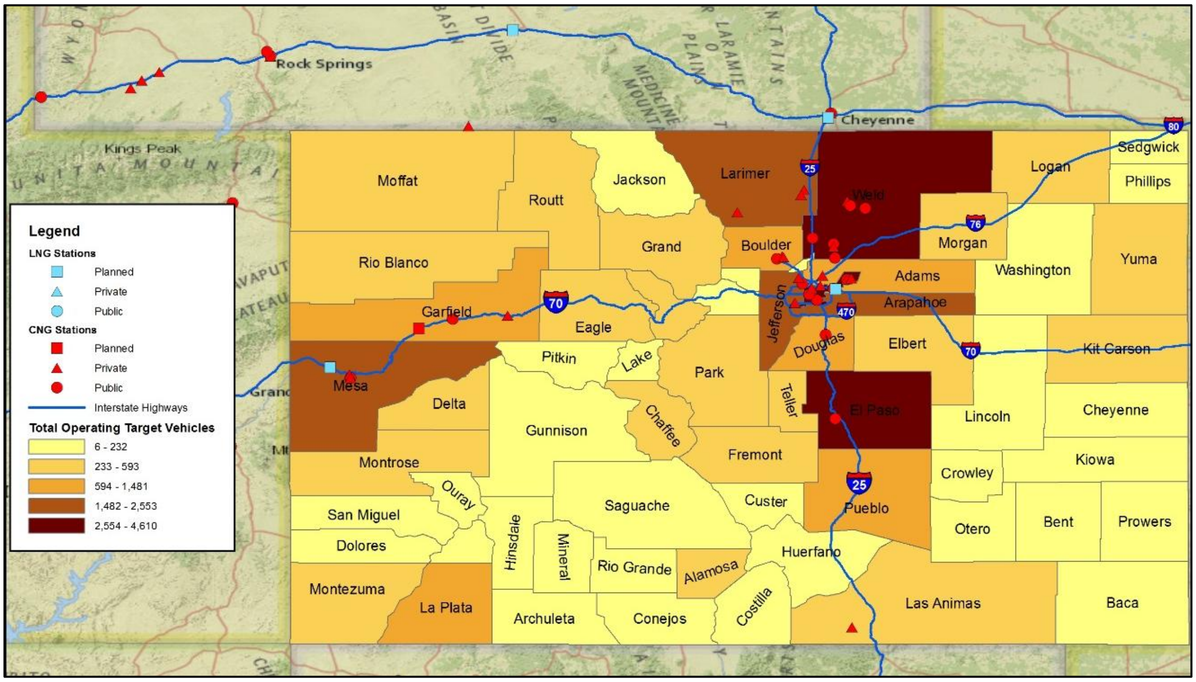


Data source: FleetSeek Private Fleet Directory. Accessed May, 2012.

Exhibit 25 shows the population of operating fleet-based vehicles in each county and their relative proximity to existing or planned CNG fueling stations. It illustrates a strong correlation between the number of fleet-based vehicles in a county and the presence of a CNG station. This data contains all vehicle classes, including LDVs, so it was not used for detailed analysis. It is presented, however, because it is indicative of the vehicle populations throughout the state. The same correlation is seen in Exhibit 26 when looking at all currently operating medium and heavy duty vehicles in the state, including those that are not fleet-based.

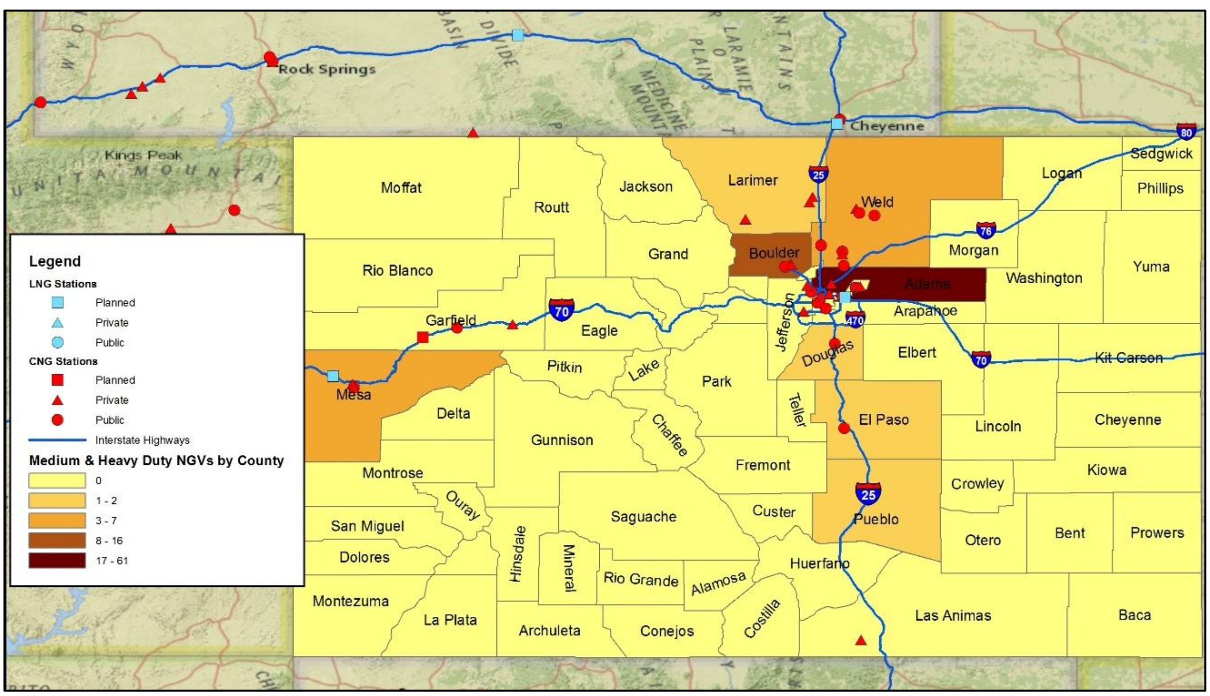
[66] Operational life was assumed to be 18 years and 9 years for medium and heavy duty vehicles, respectively, based on the same assumptions made for market projections in Section 2.

Exhibit 26. Total Medium & Heavy Duty Vehicles in Operation by County



This phenomenon is not a coincidence and should be expected. Counties with higher populations of medium and heavy duty vehicles have a greater population of NGVs. This is illustrated in Exhibit 27.

Exhibit 27. Total Medium & Heavy Duty NGVs in Operation by County



There are approximately 95 medium and heavy duty NGVs in the state of Colorado (based on DMV records). Not surprisingly, almost all counties containing CNG stations also have medium and heavy duty NGVs (based on registrations). Las Animas and Garfield Counties contain CNG stations but are not shaded in Exhibit 27 because they only contain light-duty vehicles. Cross-referencing Exhibit 26 and the existing CNG fueling infrastructure provides potentially valuable insight for geographical development targets.

TARGETING AREAS WITH HIGH POPULATIONS OF TARGET VEHICLE CLASSES WITH ACCESS TO EXISTING CNG FUELING STATIONS

Exhibit 25 and Exhibit 26 showcase the counties with the most vehicles in the target classes. Areas with higher populations of medium and heavy duty vehicles as well as CNG stations are prime areas for increased NGV deployment, as potential adopters have greater access to the fueling stations. Likewise, counties with high populations of MDV/HDV that don't currently contain CNG/LNG stations are potential targets for expanded infrastructure. The top 5 counties with the greatest populations of operating medium and heavy duty vehicles are:

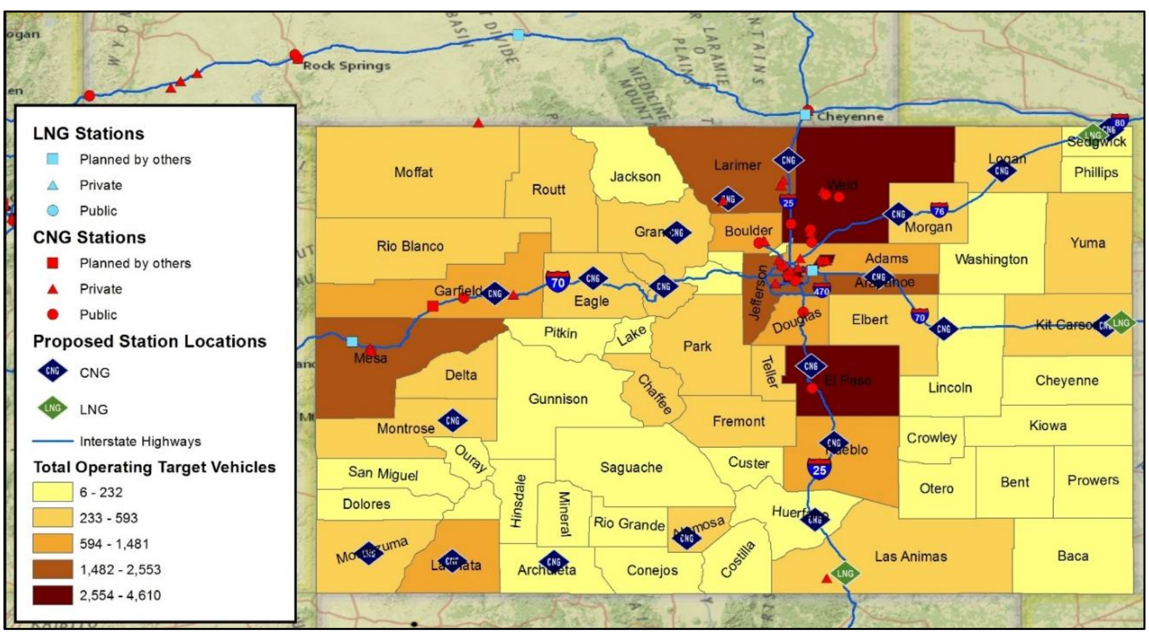
1. Weld (4,610 vehicles),
2. Denver (4,303 vehicles),
3. El Paso (4,114 vehicles),
4. Jefferson (2,553 vehicles), and
5. Mesa (2,299 vehicles)

CREATING FUEL CORRIDORS THROUGH FOCUSED CNG & LNG STATION DEVELOPMENT

The market project analysis is Section 2 revealed that roughly 21 CNG and 3 LNG publicly accessible fueling stations will be needed to support the growing NGV implementation in Colorado. A geospatial analysis was conducted to identify potential locations for these stations based on the county-level target vehicle class populations and existing fueling station locations throughout the state. The I-70, I-25, and I-76 corridors are prime targets for additional fueling stations. Most counties with greater populations of MDVs and HDVs can access these roadways. There is also potential to develop a fuel corridor along U.S. Route 160 in the southwest region of the state, based on the relatively high populations of target vehicle classes and the lack of CNG fueling infrastructure there.

The geospatial analysis was used to distribute the total number of required CNG stations along these potential fuel corridors. Little data is available to determine adequate spacing of CNG stations to support a robust fueling infrastructure, so it was inferred from the spacing of publicly accessible CNG fueling stations in other states. Both Utah and California have well-developed CNG fuel corridors along major highways. Measuring the distances between each publicly accessible CNG station on these corridors revealed that there was a CNG station every 50 miles, approximately. As such, a 50-mile spacing was used to identify potential locations for CNG fueling stations in Colorado. Measurements originated in the Denver Metropolitan Area and continued along I-70, I-25, and I-76 outward. When distributing the stations, priority was given to areas that currently did not have stations, but have higher populations of vehicles of the target classes.

Exhibit 28. Map of Proposed Locations for CNG & LNG Fueling Stations



All 21 CNG fueling station locations were distributed throughout the state using the provided spacing methodology. Fourteen stations were located along the interstate corridors (I-70, I-25, & I-76). Four additional locations were identified along State Highway 160 while the three remaining stations were distributed in areas of high target vehicle class population. These stations should be given the least priority, as they are not located in the suggested fuel corridors. The proposed CNG locations are listed in Exhibit 29.

Exhibit 29. Proposed Locations for CNG & LNG Fueling Stations

ID	Proposed Location	Street Name	Station Type
1	Wellington, CO	I-25	CNG
2	Pueblo, CO	I-25	CNG
3	Walsenburg, CO	I-25	CNG
4	Trinidad, CO	I-25	CNG
5	Colorado Springs, CO	I-25	CNG
6	Dillon, CO	I-70	CNG
7	Wolcott, CO	I-70	CNG
8	New Castle, CO	I-70	CNG
9	Byers, CO	I-70	CNG
10	Limon, CO	I-70	CNG
11	Burlington, CO	I-70	CNG
12	Wiggins, CO	I-76	CNG
13	Sterling, CO	I-76	CNG
14	Julesburg, CO	I-76	CNG
15	Alamosa, CO	State HWY 160	CNG
16	Pagosa Springs, CO	State HWY 160	CNG
17	Durango, CO	State HWY 160	CNG
18	Cortez, CO	State HWY 160	CNG
19	Estes Park, CO	State HWY 36	CNG
20	Granby, CO	State HWY 40	CNG
21	Montrose, CO	State HWY 50	CNG

Long-haul, high-mileage vehicles favor LNG because of its higher energy density, and thus greater range. As such, current and planned LNG fueling stations are/will be located along interstate and major highways Two LNG stations are planned for development in the cities of Fruita (Mesa County) and Aurora (Adams/Arapahoe Counties) along I-70[67]. A third LNG station is planned for development in Cheyenne, WY, along I-25. Once developed, these stations will enable trucks to travel north to Cheyenne, WY or west to Grand Junction, CO from Denver, CO on a single tank of LNG. More LNG stations will be needed in the state to spur deployment of NGV long-haul trucking. LNG station development along the interstate corridors is expected to follow the same pattern for diesel fueling stations, roughly one station every 250 miles[68]. I-25 travels approximately 200 miles from Denver, CO to the border with New Mexico. By adding a LNG station near the border, the I-25 corridor will open to LNG-fueled NGVs. The same achievement would be made by adding LNG stations near the border with Kansas (I-70) and along I-76 in the northeast of the state (Julesburg, CO). The proposed LNG locations identified in this study are listed in Exhibit 30.

[67] US Department of Energy, Alternative Fuels Data Center. Accessed June, 2012. http://www.afdc.energy.gov

[68] TIAX, LLC. *U.S. and Canadian Natural Gas Vehicle Market Analysis: Liquefied Natural Gas Infrastructure*

Exhibit 30. Proposed LNG Fueling Station Locations

ID	Proposed Location	Street Name	Station Type
1	Trinidad, CO	I-25	LNG
2	Burlington, CO	I-70	LNG
3	Julesburg, CO	I-70	LNG

5.4 PROPANE AUTOGAS

Liquefied Petroleum Gas (LPG), commonly referred to as Autogas, is quickly gaining momentum and exposure as a viable alternative fuel for transportation, particularly in Light Duty Market applications. Autogas is frequently refined from the same process and source as natural gas. Also, Autogas/LPG is often included in incentives and tax credits geared toward CNG. Groups such as Alliance Autogas and Autogas for America offer compelling cases for Autogas. The recently completed Southeast Propane Autogas Development program successfully implemented over 1,200 light duty vehicles in 13 southeast states, with applications such as municipal fleets, law enforcement, taxi, and limousine services. Veolia Transportation in Denver, CO successfully operates over 100 Autogas-powered taxis[69].

Autogas is typically $0.50/$0.60/GGE more expensive than CNG; however, fueling infrastructure can cost as little as $45,000 and can be installed in less than a week. According to Alliance Autogas, 15 Autogas stations can be built for the same investment as 1 CNG Station, 2 LDV Autogas conversions can be completed for the price of 1 LDV CNG conversion, and the two fuels have nearly the same positive reduction in emissions over gasoline and diesel[70].

Several vehicle equipment manufactures also exist. Roush Cleantech, for example, offers a wide range of light and medium duty vehicles, including chassis-cab trucks and school buses. Alliance Autogas offers turn-key bi-fuel conversions for most popular light duty fleet vehicles[71].

It is recommended that the State of Colorado consider Autogas as part of its holistic strategy.

5.5 LONG TERM POSITIONING

The EIA estimates heavy duty vehicles energy consumption nationwide will increase nearly 46% from 2011 to 2040, from 5.2 quadrillion Btu to 7.6 quadrillion Btu, compared to a decline in light duty vehicle energy consumption of nearly 19%, from 16.1 to 13 quadrillion Btu. Of all transportation-related activities (light and heavy duty vehicles, marine, air, and rail), heavy duty vehicles account for the largest increase in energy consumption[72].

Additionally, some EIA projections show that between 2011 and 2040, natural gas (CNG and LNG) use in the transportation sector could grow at an average annual rate of 11.9%. Heavy duty vehicles are estimated to lead this growth substantially, increasing from nearly zero to more than 1 quadrillion Btu by 2040.

As such, the highest return will be met by focusing on heavy duty applications, both nationally and in Colorado. This does not mean that light duty should be completely ignored. On the contrary, properly designed policy, technology, and outreach will also service the light duty segment. For example, ensuring a new station has public access and provisions for fueling light duty applications allows for duplicative use, a reduced ROI, and an expanded user base. However, all indications are that HDVs (and to a lesser extent MDVs) will have to do the heavy lifting if the industry is to move forward.

Traditionally, the highest success rate for initial fleets are those that return to a central home each evening, and have mostly predictable-length routes. New York State, for example, is focusing heavily on refuse and delivery fleets and tailoring funding, tools, and outreach programs specifically for these industries.

[69] http://www.usepropaneautogas.com/

[70] http://www.allianceautogas.com/wp-content/uploads/2012/05/Autogas_vs_Natural_Gas_Share_Sheet1.pdf

[71] http://www.allianceautogas.com/vehicle-conversions/

[72] EIA Annual Energy Outlook 2013, p 68

Currently, Colorado has approximately 65,000 medium and heavy duty vehicles, 58% of which are over the generally accepted “useful life” of 8 years old. If 10% of the vehicles beyond their useful life (3,760) were replaced by NGVs of equivalent specifications and use over the course of the next 5 years, 13 Million DGE/yr of petroleum could be reduced. Exhibit 31 provides a simplified look at what is possible in each of the vehicle classes.

Exhibit 31: Petroleum Reduction Opportunities by Weight Class

Vehicle Weight Class	# of vehicles registered	> 10 yrs old	GGE of natural gas used if 10% are replaced with NGVs
Light	4,200,000	59%	129 Million
Medium	44,200	63%	6 Million
Heavy	20,600	47%	7 Million

In context of the above, it is useful to review and summarize the opportunities and threats to developing a sustainable NGV industry in Colorado.

Strengths/Opportunities

- Colorado has a positive oil and gas energy balance with an abundant supply of natural gas. NGVs offer a great opportunity to improve on this situation if local consumers can increase their use of a locally generated product. Doing so will create a virtuous market cycle that adds value to Colorado’s economy. Coloradans spend $7 billion in gasoline every year, creating plenty of market opportunity.
- Although much more analysis can be done with respect to the environmental benefits of switching to NGVs (especially with regards to criteria pollutants), early studies suggest potentially significant GHG benefits.
- Significant momentum has already been established by the existing industry. Even with the modest additions forecasted in this analysis, enough CNG/LNG stations can be deployed to build a skeleton infrastructure that spans all of the major state corridors. Station densities in 12 years would likely approach levels targeted by other states without incentives.
- Large fleet conversions will minimize the need for government incentives. Stakeholder outreach should be focused on developing “anchor” fleets that can help get the market moving quickly.
- Bi-fuel technologies offer a transitional technology pathway that can be supported by additional research and development.

Weaknesses/Threats

- Gasoline and diesel prices must remain at or above current levels in order for there to be an economic justification for investing in the vehicles and infrastructure to realize this market’s potential. While this analysis does not suggest that this will be an issue, there were periods in the last decade when petroleum fuel prices would have been lower than CNG prices. However, natural gas market developments over this period have provided some security in long-term supply at reasonable cost. Additionally, it is possible that in the event of a dip in price of gasoline and diesel prices, natural gas would also drop in price.
- Current Colorado incentives may not be sufficient to move the market, especially because they do not address heavy duty vehicles. Other states appear to be investing more heavily in financial incentives.
- New standards for medium and heavy duty vehicle emissions are pushing down on potential emissions benefits associated with NGVs. Considerably more work needs to be done on updating Well to Wheel analyses before a complete emissions difference between petroleum and natural gas vehicles is clear.
- Equipment availability, ranging from engines and vehicles to infrastructure components, must be further investigated. Other recent studies, such as the CNG for Refuse and Delivery for New York State, indicate that a limited supply of such equipment has significantly hampered CNG development efforts. Strong collaborations among fleets, suppliers, and the government will be needed to approach this challenge collectively. Additionally, market response to this demand will likely result in an increased supply of needed equipment.

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APPENDIX A

EMISSION PERFORMANCE DATA – STATUS OF CURRENT RESEARCH

As discussed in the body of the report, the GREET model and most previous analyses of WTW emissions focuses on light duty vehicles. The 2010 ANL report, "Natural Gas Vehicles: Status, Barriers, and Opportunities," discusses the utility of evaluating HDV emissions by scaling the GREET data using fuel efficiency as a factor. However, this procedure does involve some analytical simplifications and can only be used to approximate the results for HDV WTW emission calculations. This approximation does not account for the different emissions rates and standards that apply to heavy duty vehicle classes. As this approach could potentially have been the source of considerable error for the analyses in this report, it was not used in this report. However, for reference, ANL's summary table of fuel economy and GHG emissions for transit buses is shown below in Exhibit 32.

Exhibit 32: Energy Use and GHG Emissions of Selected Transit Buses[73]

		GREET Results		
Fuel	Fuel Economy (mpgde)/ Testing Mode	Fossil Energy Use (Btu/mi)	Petroleum Energy Use (Btu/mi)	GHG Emissions (g/mi)
Diesel	2.84/in-use	48,131	43,753	3,936
CNG	2.34/in-use	55,918	292	3,791
Diesel	2.98/dynamometer	45,870	41,698	3,751
CNG	3.08/dynamometer	42,483	222	2,882

Sources: GREET (2009); Melendez et al. (2005); Chandler et al. (2006).

The HDV class is subdivided into several other categories by gross vehicle weight rating (GWVR). EXHIBIT gives the current EPA emissions standards for vehicles within the HDV sub-classes. Emissions standards for heavy duty diesel vehicles and for the heaviest spark ignition engines given in grams per brake horse power hour (g/bhp-hr).

A table comparing EPA exhaust emissions standards for Heavy-Duty Highway Spark-Ignition Engines and Heavy-Duty Highway Compression-Ignition Engines and Urban Buses is shown below in Exhibit 33.

Exhibit 33: EPA standards for Heavy Duty Highway Vehicles

	Heavy Duty Compression Ignition Diesel Engine				Spark Ignition Heavy Duty Engine		
	Heavy Duty Diesel Engine	converted: LHHDE (8501-10,000 lb)	MHDDE (10,001-14,000 lb)	Urban Bus	Heavy Duty Engine	8,500-10,000 lb (complete vehicle)	10,000-14,000 lb (complete vehicle)
	g/bhp-hr	g/mi	g/mi	(~33,000 lb)	g/bhp-hr	g/mi	g/mi
	EPA Standard	converted	converted	converted	EPA Standard	EPA Standard	EPA Standard
Emission Type							
NMHC	0.14	0.15344	0.1561	0.6552	0.14	.195 g/mi	.230 g/mi
Nox	0.2	0.2192	0.223	0.936	0.2	.2 g/mi	.4 g/mi
PM	0.01	0.01096	0.01115	0.0468	0.01	.02 g/mi	.02 g/mi
CO	15.5	16.988	17.2825	72.54	14.4	7.3 g/mi	8.1 g/mi

[73] (M. Rood Werpy, 2010), p. 18

For heavy duty diesel engines, emissions standards are given in grams per brake horsepower hour (g/bhp-hr). To convert this to grams per mile, a conversion factor that is based on a factor of fuel density, brake-specific fuel consumption, and fuel efficiency must be applied. Because large engines perform more work per mile of travel than large engines, the EPA calculates a different conversion factor for each class of heavy duty diesel engines. Further discussion of conversion factors can be found in EPA documentation.[74]

[74] EPA Report No. EPA420-R-00-010 report can be found online at http://www.epa.gov/otaq/regs/hd-hwy/2000frm/r00010.pdf and EPA letter to vehicle manufacturers, dated July 21 2005, available online at: http://www.tceq.state.tx.us/assets/public/implementation/air/sip/bpa/App_A_pro.pdf