Examination of Policy Alternatives to Promote the Expansion of Natural Gas Vehicle Refueling Stations in the United States

by
George M. Baldwin

Dr. Brian C. Murray, Advisor
May 2014

Masters project submitted in partial fulfillment of the

requirements for the Master of Environmental Management degree in

the Nicholas School of the Environment of

Duke University

2014

ABSTRACT

In the United States, nearly a third of our energy is consumed by gasoline and diesel fueled vehicles which emit harmful by-products such as nitrogen oxide, particulate matter, and 28% of the U.S. greenhouse gas emissions. Consequently, concerns about these emissions have created interest in alternative and innovative transportation options. One developing option is the use of compressed natural gas (CNG) to operate vehicles. Natural gas is the cleanest of all fossil fuels, and can be used to reduce transportation sector-related carbon monoxide emissions by 90-97%, carbon dioxide emissions by 25%, and nitrogen oxide emissions by 35%. Additionally, the increased use of natural gas can reduce pollutants in non-attainment areas, and also support our country's effort to meet the National 2020 greenhouse gas emission reduction target of 17%. The natural gas vehicle (NGV) market can be economically viable due to relatively inexpensive equivalent natural gas prices of $2/gallon including taxes. One outstanding obstacle in this market's development is the inadequate number of fueling stations in this country. Despite the 11% annual growth rate for CNG fueling stations in the U.S. since 2009, the number of these stations as compared to retail gasoline outlets remains less than 1%. The capital intensive nature and associated risk of investing in these fueling stations has resulted in an under-developed refueling system network. Absent policy support to subsidize the investment for publicly accessible fueling stations, this network remains generally unavailable to most automobile operators, and fails to maximize the full societal benefit of using natural gas in the transportation sector. This public use will be impossible to achieve without continued efforts from the private sector, and increased federal, state and local policy participation from government. It will be important to integrate these components to form a comprehensive economic and environmental solution to today's existing high vehicle fuel prices, and transportation sector emissions. The expansion of a publicly accessible CNG refueling station network to sustain this market will entail significant collaboration, investment and sharing of associated risk.

TABLE OF CONTENTS

LIST OF FIGURES

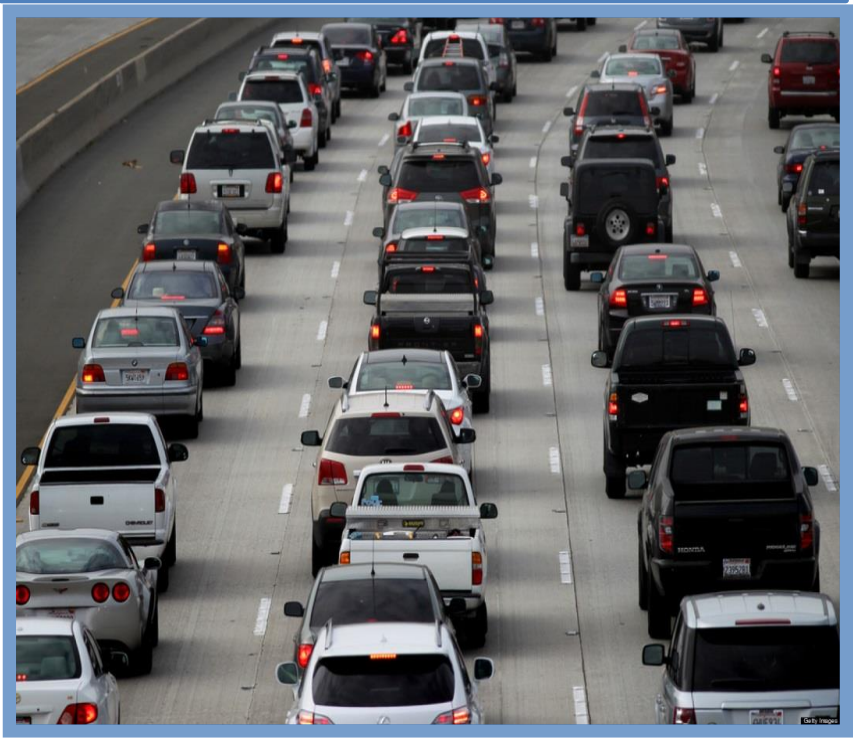
LIST OF TERMS

AFV-Alternative Fuel Vehicles
ARRA-The American Recovery and Reinvestment Act of 2009
CFAT-Clean Fuels Advanced Technology
CFOR-Clean Fuels Outlet Regulation
CMAQ-Congestion Mitigation and Air Quality Improvement Program
CNG-Compressed Natural Gas
CO_2-Carbon Dioxide
DME-Dimethyl Ether
DOE-U.S. Department of Energy
EDF-Environmental Defense Fund
EPAct-The Energy Policy Act of 2005
EIA-The U.S. Energy Information Administration
EPA-The U.S. Environmental Protection Agency
FAA-Federal Aviation Administration
FHWA-The U.S. Federal Highway Administration
FTA-Federal Transit Authority
GAO-US Government Accountability Office
GGE-Gallon of Gas Equivalent
GHG-Greenhouse Gases
GREET-Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
LNG-Liquefied Natural Gas
MOU-Memorandum of Understanding
MP-Masters Project
NAT GAS ACT-The Alternative Transportation to Give Americans Solutions Act of 2011
NGV-Natural Gas Vehicles
NHTSA-National Highway Traffic Safety Administration
NO_X-Nitrogen Oxides
PGC-The Colorado School of Mines Potential Gas Committee
PUC-Public Utility Commission
TCEQ-Texas Commission on Environmental Quality
VALE-Voluntary Airport Low Emissions Program

INTRODUCTION

Transportation has played a historical role in the development of civilization and remains vitally important to the United States by connecting businesses to markets, and providing people with access to goods, services, recreation, jobs, and other people (Figure 1). Chairman of the U.S. House Infrastructure and Transportation Committee Bill Shuster (Congressman Bill Shuster, 2013, para. 3-6) said, "Transportation is important. It's about people and how they live their lives. An efficient national transportation network lowers production costs and enhances productivity and profits. And it is about America. Our national transportation system binds us together." However, this reliance on transportation requires a significant amount of energy. In the United States, nearly a third of our energy is consumed by gasoline and diesel fueled vehicles. Harmful by-products emitted by these vehicles are carbon dioxide, nitrogen oxide, and other particulate matter (U.S. Energy Information Administration, 2013, para. 3). Consequently, these concerns have inspired great interest and efforts to alleviate our country's dependence on gasoline and diesel fuel by displacing its use with alternative options.

Figure 1.Transportation in the United States. Adapted from The Huffington Post, 2013, U.S.-Transportation. Retrieved from http://i.huffpost.com/gen/1107954/thumbs/o-US-TRANSPORTATION-facebook.jpg



There has been significant innovation in the development of technologies that can compete with gasoline and diesel fueled engines. Most recently, alternatives such as natural gas, electric, hybrid, hydrogen, and Dimethyl-Ether (DME) powered vehicles have entered the marketplace. However, despite competitive operating economics, and environmental benefits, commercialization and market penetration for any and all of these alternatives remains a challenge. A prevalent and common hurdle is the capital investment required to introduce and establish these developing technologies and essential infrastructure.

Specific to the natural gas vehicle (NGV) alternative, the design and manufacturing of vehicles/engines, vehicle procurement, and refueling station investment are all incremental costs to the existing transportation market, and thus are fundamental obstacles. The successful development of the natural gas vehicle market depends on these varied, yet inter-dependent elements: vehicle availability, relative operating savings, and accessible refueling station infrastructure. Perhaps the most integral of these challenges, and the topic of this Masters Project (MP) is the limited compressed natural gas (CNG) refueling station infrastructure in the United States. This nascent refueling system network is the central deterrent inhibiting natural gas use in the transportation sector.

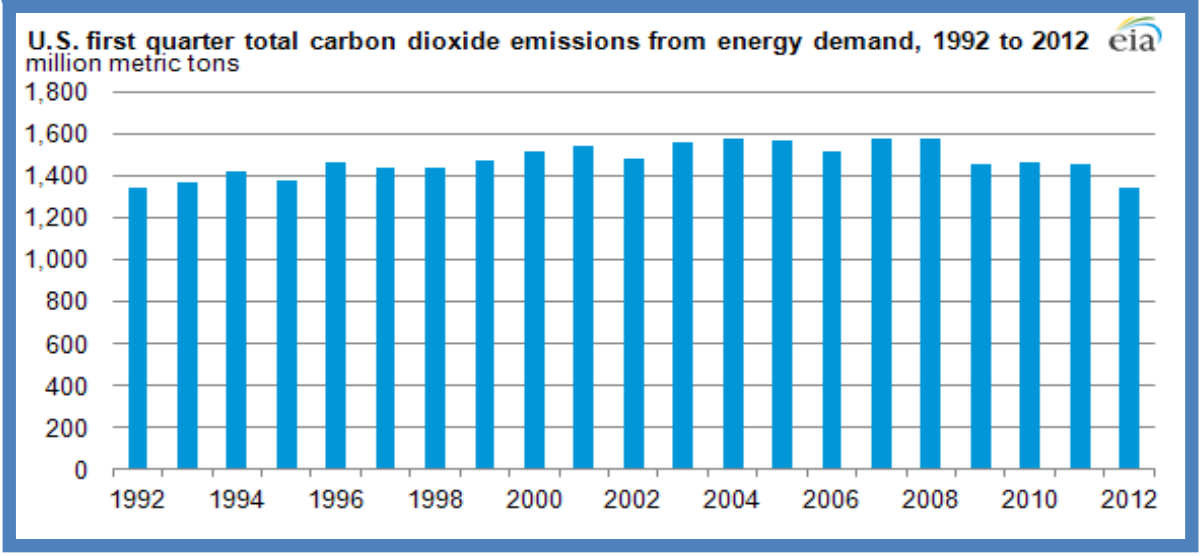
The under-developed refueling system fails to maximize the environmental and societal benefit of using natural gas in the transportation sector. This important market will presumably fail to develop without intervention because the economics for CNG station investment is not compensated for the value of the environmental benefits provided. My MP will examine the public, and private sector support of NGV refueling station expansion, and the potential economic and environmental impact of increased natural gas use in the transportation sector.

ENVIRONMENTAL IMPLICATION

Global Warming and Climate Change

The effects of global warming and climate change have been an increasing concern for several decades. Most climate scientists agree that these changes are the direct result of increased atmospheric greenhouse gases which have been largely attributed to the industrial revolutions and anthropogenic-related activity (Bast &Taylor, 2007, p. 3). Two of the most important greenhouse gases (GHG), carbon dioxide (CO_2) because of its prevalence and methane because of its potency, became a primary point of anxiety during the 1980s and 90s when trends of increased water and air temperatures started to become discernible in observational data, triggering efforts to promote awareness, develop solutions and commit to GHG reduction. The

Figure 2. U.S. $C0_2$ Emissions History. Adapted from The U.S. Energy Information Administration (EIA): *U.S. Energy-Related C02 Emissions in Early 2012 Lowest Since 1992, 2012,* Retrieved from http://www.eia.gov/todayinenergy/detail.cfm?id=7350



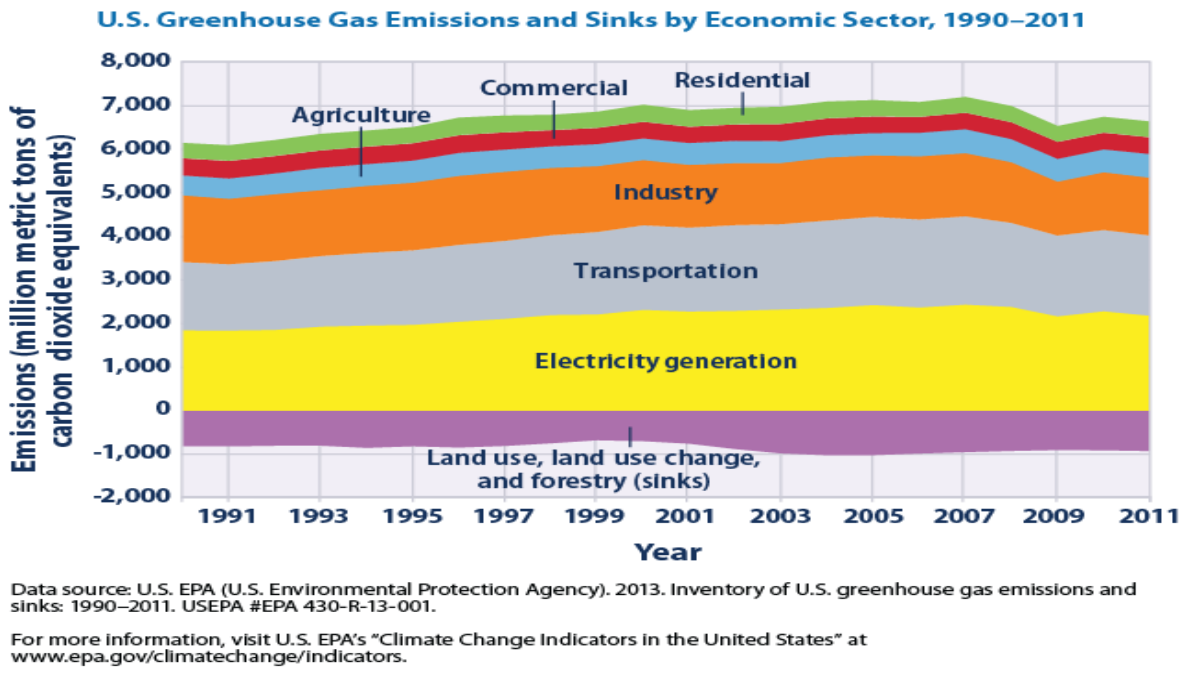
United Nations Framework Convention on Climate Change's 1997 Kyoto Protocol sub-agreement established binding emissions targets for select member countries (CNN World, 2013). The United States did not commit to this agreement citing the economy, and exemption of

certain countries as partial basis for its decision. Remarkably however, the U.S. Environmental Protection Agency (EPA) reports that U.S. greenhouse gas emissions in 2011 decreased 6.9% to below 2005 levels (United States Environmental Protection Agency, 2013, para. 3) reversing the previously increasing trend indicated in Figure 2. The Council of Economic Advisors performed analysis that concluded that the decomposition for this CO_2 emission reduction was 52% due to the recession, 40% resulting from a switch to cleaner fuels, and 8% due to improvements in energy efficiency (2013 Economic Report of the President, 2013, p. 194-195).

Emissions Reduction by Sector

Key factors contributing to this decline were the increased use of natural gas for electricity generation, the 2007-2009 recessions, the increased use of renewable technologies, and energy efficiency (Figure 3).

Figure 3. GHG Emissions History by Sector. Adapted from EPA: U.S. Greenhouse Emissions and Sinks by Economic Sector 1990-2011, 2013, Retrieved from http://www.epa.gov/climatechange/images/indicator_figures/us-ghg-emissions-figure2-2013.gif

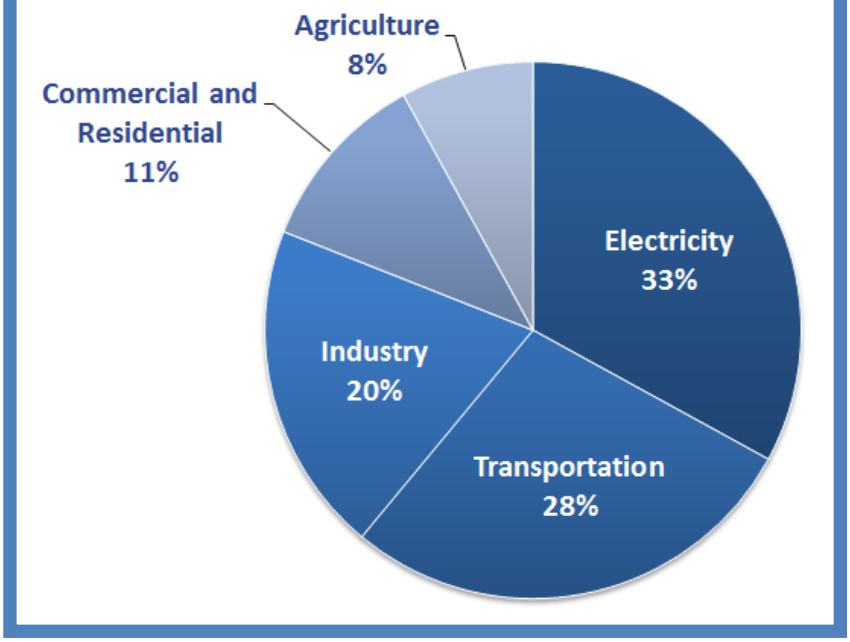


Additionally, the EIA forecasts GHG Emissions to sustain a downward to relatively flat glide-path through 2040, absent any significant new policies targeted at reducing GHG emissions (U.S. EIA: AEO 2014 Early release Overview, 2014, p. 1). Contributing assumptions in this forecast include an expected decrease in residential, industrial, transportation, and power generation sector energy consumption.

1990 Clean Air Act

The 1990 Clean Air Act Amendments created an environmental quality basis for individuals and companies to convert to natural gas because of its relatively clean emissions as compared to coal, oil, refined gasoline and diesel transportation fuels. Specifically, this overwhelming bipartisan supported legislative revision required the phase-out of ozone depleting chemicals, and expanded the scope of the original Clean Air Act to also include emission reductions for automobiles and trucks. The U.S. Department of Energy (DOE)-Alternative Fuels Data Center (AFDC) recognizes natural gas as a low-carbon, clean-burning fuel, and a switch to natural gas can result in substantial reductions of hydrocarbons, carbon monoxide, nitrous oxides, and greenhouse gas emissions (U.S. DOE AFDC, 2013, para. 3).

Figure 4. U.S. GHG Emissions by Sector. Adapted from EPA: Sources of Greenhouse Gas Emissions, 2011, Retrieved from http://www.epa.gov/climatechange/images/ghgemissions/sources-transportation.png



Transportation Sector

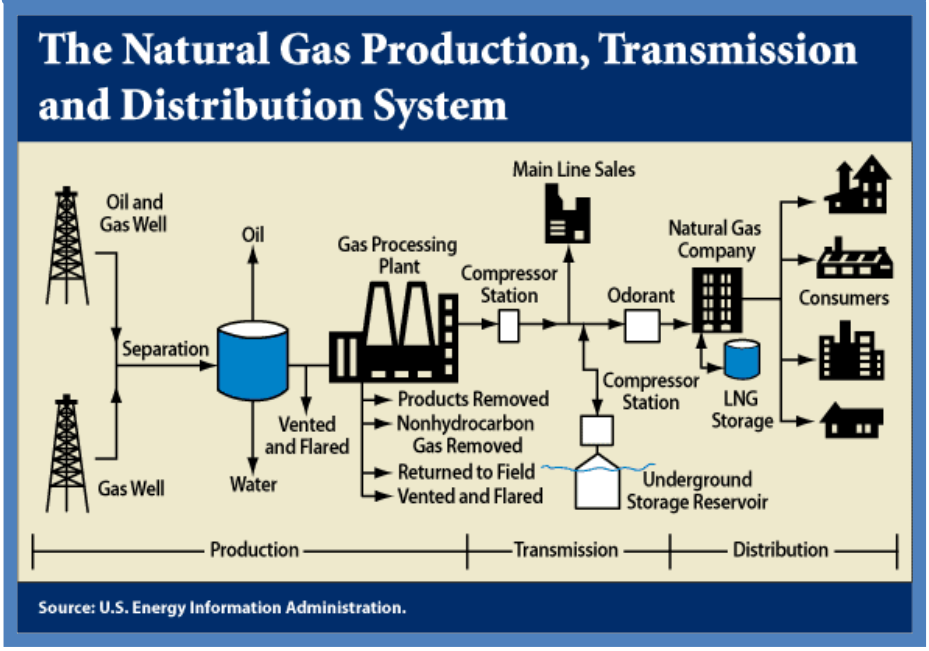
The U.S. transportation sector, which is primarily comprised of gasoline and diesel fueled vehicles, contributes 28% of the U.S. greenhouse emissions, which is the second greatest contributing sector behind electricity generation (Figure 4). Transportation sector related GHG emissions represent an environmental cost to society because of its related effects on global climate change. These costs or damages are externalities imposed on everyone. The inability to assign these costs to the responsible parties, the vehicle owners themselves, constitutes a market failure. The air quality benefit of using natural gas as a transportation fuel takes place at three levels: local, regional and global (Natural Gas.Org, 2013, para. 5,10,14-16). Local air quality is predominately impacted by particulate emissions and smog. Regional emissions are principally comprised of hydrocarbons, nitrous oxides, and carbon monoxide. Global emissions encompass greenhouse gases and take into account the full life-cycle impact of leakage from wellhead, transmission, distribution systems, and also from the operation of the vehicles themselves. According to the EPA, cars and trucks produce about half of all air pollution and is the primary contributor within major cities (U.S. EPA, 2013, para. 1). Additionally, natural gas is the cleanest of all fossil fuels and can be used in the transportation sector to reduce carbon monoxide emissions by 90-97%, carbon dioxide emissions by 25%, and nitrogen oxide emissions by 35% (U.S. DOE, 2014, p. 1). The increased use of natural gas can augment efforts to reduce pollutants in non-attainment areas, and also support our country's efforts to meet the National 2020 greenhouse gas emission reduction target of 17% below 2005 levels (The President's Climate Action Plan, 2013, p. 4).

Fuel Cycle Implications

There is debate about the full benefits of natural gas from a fuel life-cycle perspective (Figure 5).

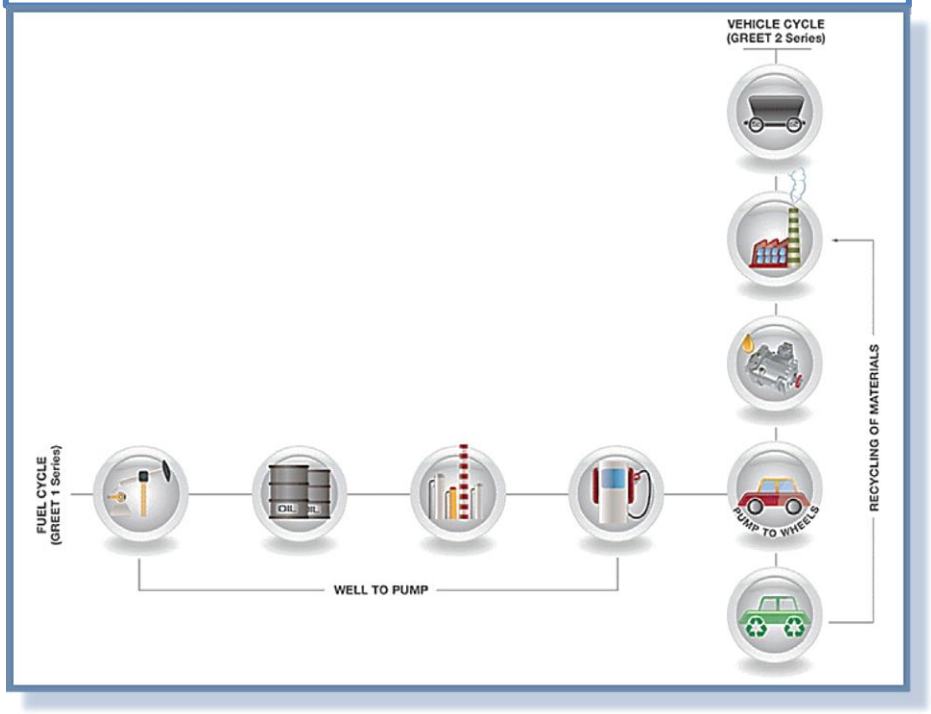
GHG emissions that impact the natural gas fuel life-cycle (production, transmission and distribution) are predominately the result of production-phase fuel leakage. The Environmental Defense Fund (EDF) continues to examine potential environmental concerns such as methane emissions to increase the understanding of the full impact of switching to natural gas from other fuels. The EDF along with partner universities, scientists, research facilities, and industry representatives are expected to complete a sixteen-part study for methane emissions covering production, gathering/processing, transmission/storage, distribution, and transportation phases by the end of 2014 (EDF, 2013, para. 1). Initial reported findings entitled "Measurements of Methane Emissions at Natural Gas Production Sites in the United States" (EDF, 2013, para. 7) indicate that the early phase in of performance standards such as green completion emissions controls is having the desired effect of reducing emissions. Additionally, the EPA is conducting a study to better understand the impacts of hydraulic fracturing on drinking water resources and is compiling a report on the potential impact that is scheduled for release in 2016 (as cited in Natural Gas Intelligence, 2013,

Figure 5. Natural Gas Fuel Life-Cycle. Adapted from Windows on State Government: Chapter 5 Natural Gas, 2013, Retrieved from http://www.window.state.tx.us/specialrpt/energy/nonrenewable/images/exhibit5-11.png



p. 1). Hydraulic fracturing (U.S. EPA: The Process of Hydraulic Fracturing, 2014, para. 2) is "the process of producing fractures in the rock formation and use of fluids delivered at high pressure to stimulate the flow of natural gas, increasing the volumes that can be recovered." These fluids consist of water and other chemicals and there is a concern over the handling, treatment, and storage of these fluids. A progress report published in 2012 for this study identified the scope of research to include water acquisition, chemical mixing, well injection, flow-back/produced water, and wastewater treatment/disposal (U.S. Department of the Interior, Environment, and Related Agencies-Appropriations for Fiscal Year 2013, 2012, Hydraulic Fracturing Testimony). Specific to natural gas use in the transportation sector, Argonne Laboratory has designed a Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model (Figure 6) to measure vehicle life-cycle emissions (U.S. DOE, 2013, para. 1). The GREET model indicates that natural gas vehicles emit 6% to 11% lower levels of greenhouse gas emissions throughout the fuel life-cycle when compared to gasoline and diesel related emissions (U.S. DOE, 2013, para. 4).

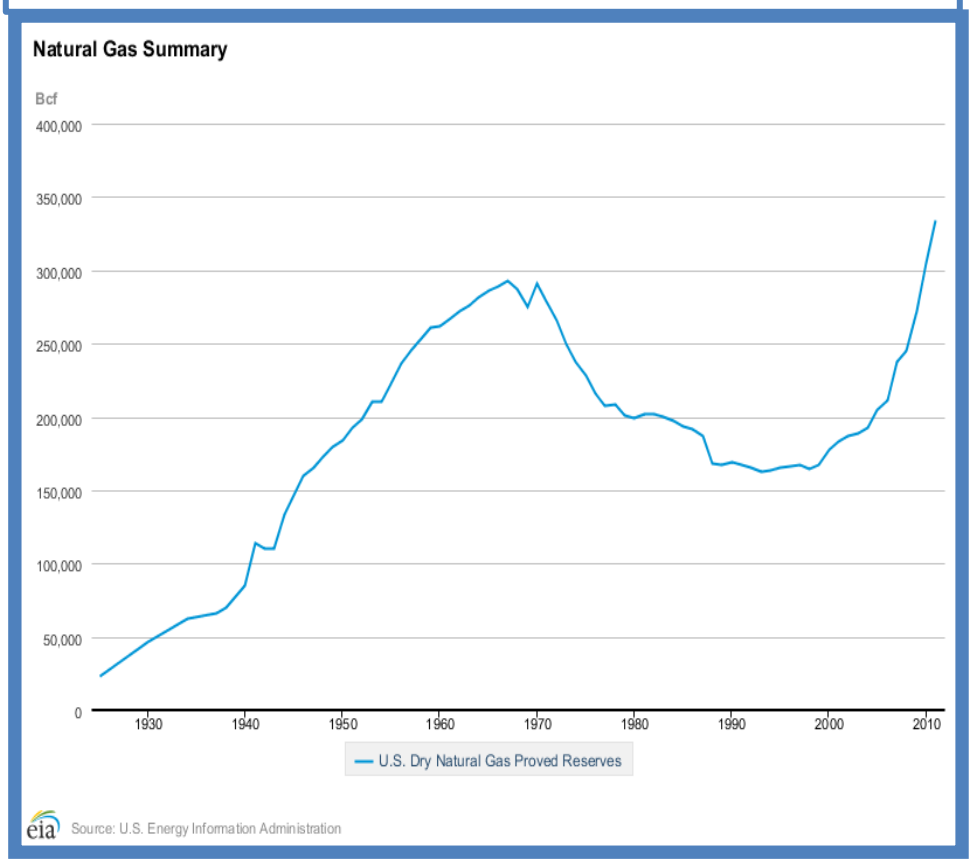
Figure 6. GREET Model. Adapted from Argonne National Laboratory: Transportation Technology R&D Center, 2010, Retrieved fromhttp://greet.es.anl.gov/index_files/greet-chart2.jpg



ECONOMIC IMPACT OF NATURAL GAS on the United States

Natural gas supply in the United States has increased dramatically since the turn of the century until 1980 when natural gas reserves were generally declining to flat through early 2000 (Figure 7). However, as documented in the U.S. General Accountability Office's (GAO) September 5, 2012 report to Congress, improvements in technology have allowed companies to develop natural gas from previously inaccessible shale formations, known as shale gas (U.S. GAO, 2012, p. 1).

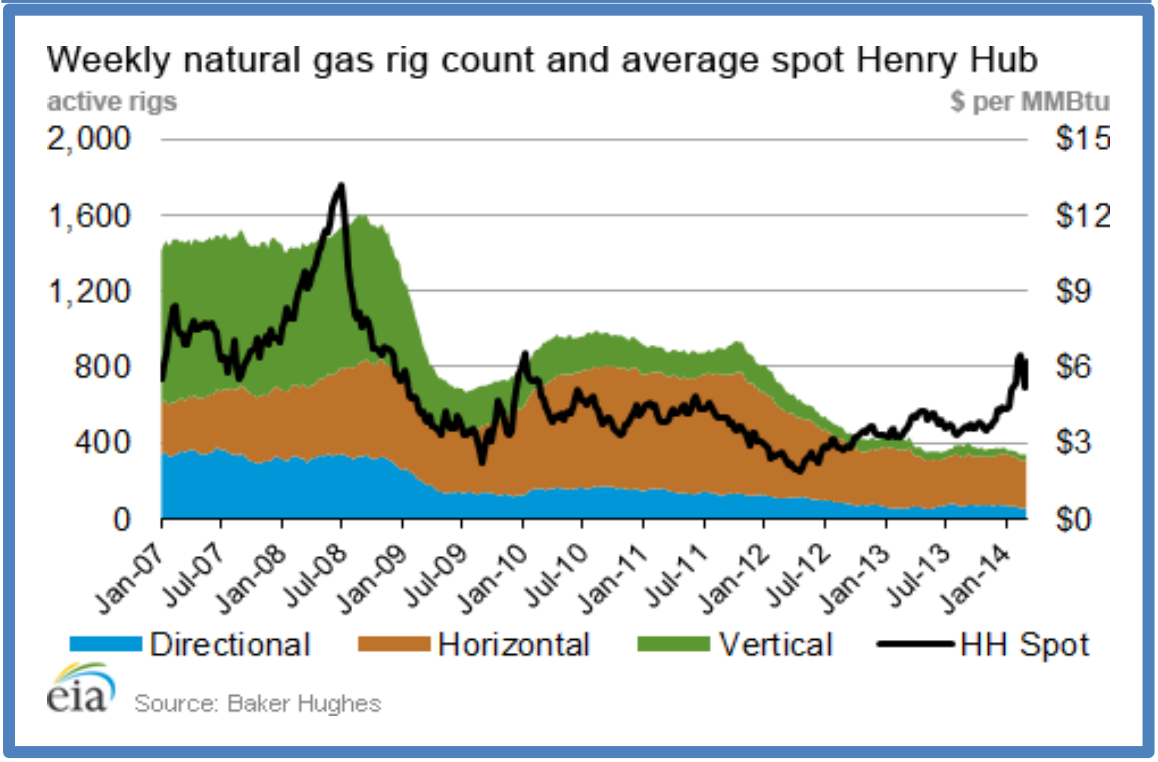
Figure 7. Natural Gas Reserves. Adapted from EIA: U.S. Natural Gas Reserves, 2013, Retrieved from http://www.eia.gov/dnav/ng/hist/rngr11nus_1a.htm



Increased Supply

This shale gas development when combined with hydraulic fracturing technology has dramatically increased supply, and subsequently decreased the price of natural gas. This dynamic has lowered the price from approximately $12-14 per dekatherm (MMBTU) in 2008 to $3-4 per dekatherm in 2012 (Figure 8).

Figure 8. Natural Gas Spot Price History. Adopted from EIA: Natural Gas, 2014, Retrieved from http://www.eia.gov/naturalgas/weekly/img/20140327_rigs.png



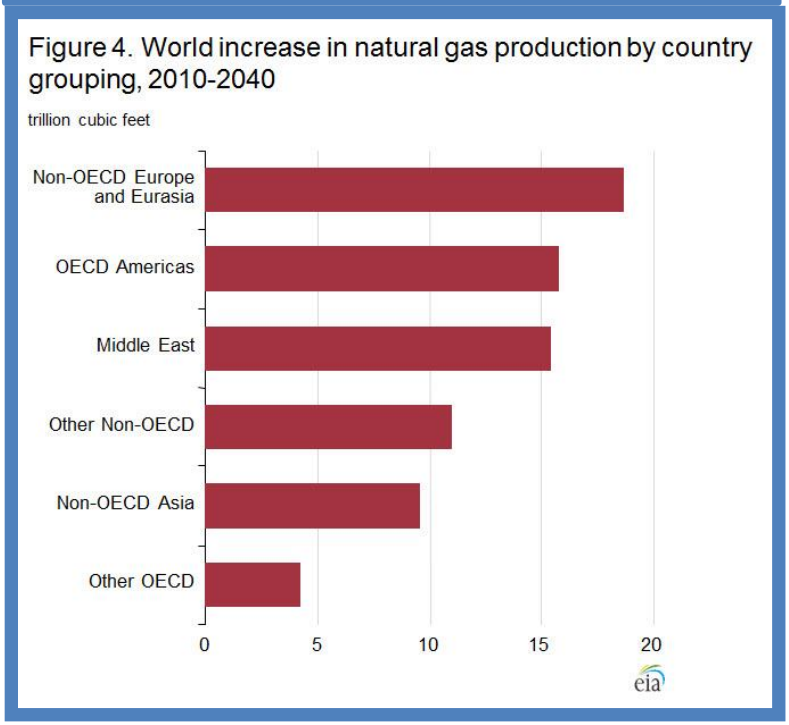
Long-Term Forecast

The EIA, The Colorado School of Mines-Potential Gas Committee (PGC), and other expert bodies now estimate that the United States has in excess of a 100-year supply of natural gas, at current rates of consumption (as cited in American Gas Association, 2014, p. 1). This sustained supply translates into relatively low and competitive natural prices over the long term.

However, there are many factors that can influence the natural gas market, particularly when prices are projected over several decades.

Market considerations such as increased domestic demand, liquefied natural gas (LNG) exports, increased use of natural gas for electricity generation, and the developing transportation sector could all potentially provide upward pressure on pricing. The recent impact of these market influences and corresponding increase in prices are represented in the Henry Hub spot pricing curve in Figure 8. Added government regulations such as a carbon tax or cap & trade mechanism may also increase the cost of delivered natural gas, but likely less than its higher carbon competitors; like coal and oil.

Figure 9. Natural Gas Production. Adapted from EIA: International Energy Outlook, 2013, Retrieved from http://www.eia.gov/forecasts/ieo/images/figure_41.jpg



Conversely, energy efficiency efforts and other demand-side driven policies should provide downward pricing pressure due to decreasing demand. According to the EIA, The Organisation for Economic Co-operation and Development (OECD) Americas region is an active producer of natural gas, and has proven natural gas reserves for many decades (Figure 9). This chart also depicts natural gas production potential to be significant worldwide which may have the effect of further stabilizing the price of natural gas.

Transportation Sector

Natural gas has been a recognized transportation fuel since the early twentieth century, but the expansion of plentiful, cheap crude oil after World War II provided gasoline and diesel fuels a dominating transportation market share (Natural Gas.Org, 2012, p. 5).

During the late 1970s and early 1980s, the effects of the Arab Oil Embargo and concurring recessionary periods provided a short-lived and relatively marginal price advantage for natural gas over gasoline. However, that economic advantage was not sufficient in duration to create or sustain the market for the conversion of vehicles to operate on natural gas.

More recently, shale gas induced price decrease coupled with the improved environmental benefits of using natural gas has triggered a market resurgence. The EIA's long-term forecast projects the price differential between natural gas and petroleum fuels to remain as high as $2 per gallon which has created a sustained commercial interest and increasing demand for natural gas vehicles (as cited in NGV America, 2012, p. 3).

Natural gas for transportation use is sold in Gallon of Gas Equivalent (GGE) units. Based on the BTU energy value of a gallon of gasoline, which averages 116,090 BTUs, a GGE contains the comparable energy value (U.S. DOE, 2014, p. 1). The environmental benefits expressed earlier along with these operational savings combine to present a compelling incentive for the use of natural gas in fleets and select privately owned vehicles.

However, there are other economic challenges associated with this integrated but co-dependent market. The capital requirement and associated risk for vehicle manufacturers and the corresponding fueling station capital investment shape the "chicken or egg" first cost dilemma, which has historically defined the NGV market. This predicament positions the interests of the

vehicle manufacturers against those of the refueling infrastructure investors. Though, both of these entities rely on each other for market development, neither has proven willing to adopt the risk-taker role in this co-dependent relationship. These considerable investment risks have played a role in the delayed development of this market. Unfortunately, this delayed pace is also preventing the environmental and social benefit of replacing gasoline and diesel fuel with natural gas.

NGV Market Components

Natural gas vehicle manufacturers and vehicle owners are both integral to the growth of this market. The risk associated with dedicating resources and the economic expectation of an acceptable return on this significant investment frames the responsibilities that manufacturers must consider. Due to the increased demand for

Figure 10. Original Equipment Manufacturers /Small Volume Manufacturers Product. The American & Oil Gas Reporter: With NGVs Taking Off, U.S. Transportation Sector Accelerating Natural Gas Demand-Table 1, 2012, Retrieved from http://www.aogr.com/images/sized/assets/images/content/img_0712_table_1_cs-

OEMs and SVMs with NGV Product Offerings

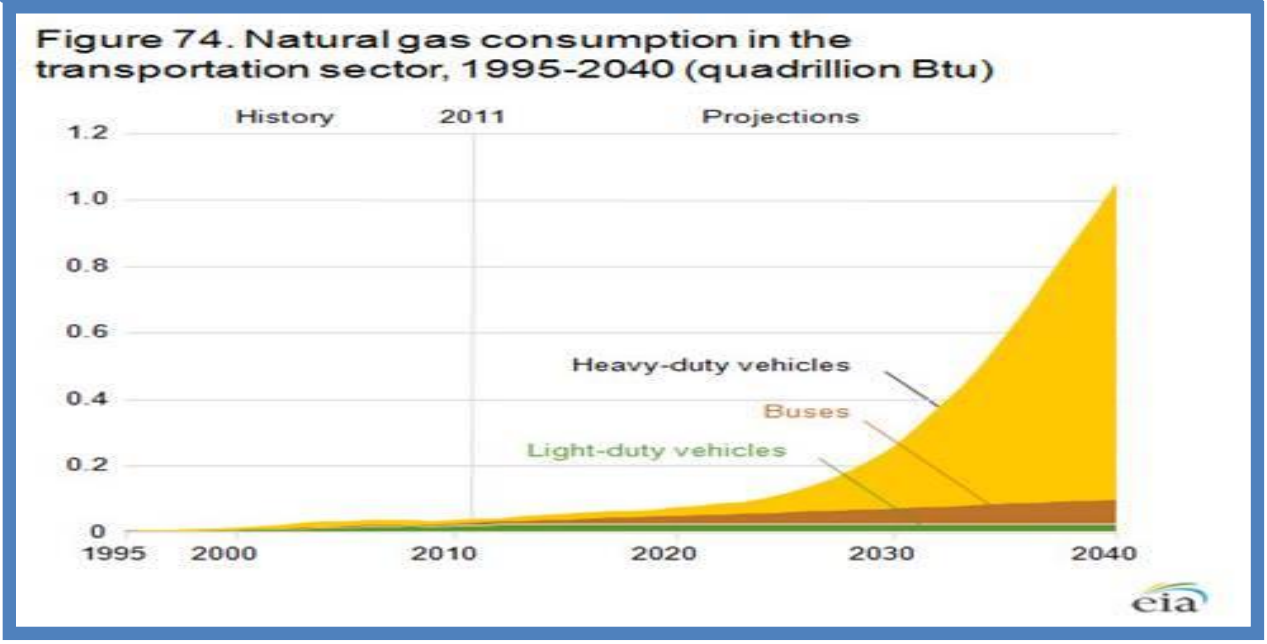
OEMs	OEM/Repower Engines	SVMs (LDVs/MDVs/HDVs)
American Honda	Cummins Westport	Altech-Eco
General Motors	Emission Solutions Inc.	American Power Group
Chrysler Ram Trucks	Westport Innovations	Auto Gas America
Vehicle Production Group	Doosan Infracore America	BAF Technologies
Thomas Built Bus		Clean Air Power
Blue Bird Bus		EcoDual
Optima/NABI		Landi Renzo USA/Baytech
El Dorado		IMPCO Technologies
New Flyer		NGV Motori USA
Gillig		NatGasCar
Elgin		Go Natural CNG
Allianz/Johnston		Greenkraft
Schwarze		Westport LD
Tymco		
Capacity		
Freightliner Truck		
Freightliner Custom Chassis		
Volvo		
International/Navistar		
Kenworth		
Peterbilt		
Mack		
ALF Condor		
Crane Carrier		
Autocar Truck		

NGVs, there is in excess of 50 light-duty sedans, vans and pick-ups now commercially marketed. Additionally, increased factory-built natural gas options for multiple use vehicles, transit/school buses, and trucks as detailed in Figure 10 are available.

Benefits of Purchasing a NGV

Economic- The purchase cost of a NGV is greater than its gas or diesel counter-part. Technology and economies of scale may eventually decrease this cost differential. However, the current incremental cost for an NGV is approximately $6000 for a light duty vehicle, and as much as $80,000 for a heavy-duty vehicle (Kauffmann, B, 2013, p. 5). Despite natural gas' significant lower operating cost advantage over gasoline, the vehicle price differential remains a purchasing obstacle for many vehicle operator/owners with the exception of high mileage vehicles such as fleet, refuse, delivery trucks, and buses as shown in Figure 11.

Figure 11. Transportation Sector Consumption and Vehicle Growth. Adapted from EIA: Annual Energy Outlook 2103 (p.70), 2013, Retrieved from http://www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf



According to Richard R. Kolodziej, former president of NGVAmerica, fleets are willing to pay an incremental cost for vehicles provided that they can recoup that difference in three years or less (Kolodziej, R, 2012, para. 2). Almost 50% of all trash trucks purchased in the United States in 2012 are powered by natural gas engines due to favorable economic payback. Waste Management, one of the largest environmental solutions providers in North America reports that it is saving $3/GGE over diesel prices which results in a very attractive pay-back for the incremental $30,000 it pays for a comparable diesel truck (Shauk, Z, 2012. para. 3). Assuming $1.50-$1.85 per GGE savings, operators of refuse vehicles across the United States are realizing payback periods of less than two years (Kolodziej, R, 2012, para. 2).

As indicated by the basic Net Present Value (NPV) Calculation below, the incremental cost of purchasing a natural gas vehicle is a cost-effective investment:

NPV Economic Analysis for a Typical Refuse Vehicle

NPV= (Discounted Sum of Cost Savings for 10 Years) – (Additional Cost of NGV versus Gasoline/Diesel Vehicle)

NPV=$106,261.26-$30,000**=$76,261.26**

Assumptions:

- *Incremental Cost of NGV over gasoline/diesel vehicle is $30,000*
- *Discounted Sum of Cost Savings is 8,250 GGE x $1.75/Gal Savings= $14,437.50/Yr. Discounted at 6% for 10 Years*

However, light-duty non-fleet passenger vehicles such as a Honda Civic offer a much different economic evaluation than the refuse vehicle NPV calculation above. According to Powered by CNG (2014, p. 1), the incremental price for a similarly equipped CNG Honda Civic is approximately $7,000 greater than its gasoline counterpart. Assuming a conservative GGE price

differential of $1.25/gallon, the distance traveled to account for this price differential is 168,000 miles. Based on an average of 12,000 miles per year, it would require approximately 14 years to make-up the cost difference between the CNG and the gasoline Civic. These economics are likely insufficient to justify the incremental investment for light-duty NGV sedans without quantifying and compensating the owners for the value of the environmental benefits provided. This extended pay-back period likely diminishes demand for light duty NGVs and subsequently, the publicly accessible refueling stations that are essential to expand this market.

Environmental-In addition to GHG emissions presented earlier, it is estimated that vehicles account for 60% of all carbon monoxide pollution, 29% of hydrocarbon emissions, and 31% of nitrogen oxide (NOx) emissions in the United States (Natural Gas-Vehicles.Org, 2013, p. 1). These emissions contribute to smog pollution, ground level ozone, dangerous air pollutants, and carbon emissions.

Societal- The United States and Canadian Natural Gas Vehicle Market Analysis (2012, p. 3) found "The societal cost of operating natural gas vehicles is estimated to be lower than those of conventionally fueled vehicles." Taking into account the costs for energy security, air pollution, and greenhouse gas emissions, the societal cost for conventionally fueled vehicles including externalities is estimated to amount to nearly $1/day for each passenger car on the road. Per the EPA and National Highway Traffic Safety Administration (NHTSA), we pay a calculated energy security premium of $0.46/imported gallon of gasoline (as cited in United States and Canadian Natural Vehicle Market Analysis, 2012, p. 2). Consequently, operating vehicles on gasoline alternatives decreases the sizable security premium associated with imported gasoline.

Refueling Infrastructure

Presently, fueling station infrastructure remains significantly under developed in the United States. NGV America identifies the lack of CNG refueling infrastructure as a key barrier for natural gas growth in the transportation sector (NGVAmerica, 2013, para. 10). According to figures from the EPA, there are fewer than 1,300 CNG fueling stations currently in operation (as cited in Holeywell, 2014, para. 9). These fueling stations are typically configured in either a "time fill" design as shown in Figure 12, or "fast fill" configuration as shown in Figure 13. A CNG time-fill station designed to fuel a fifteen vehicle fleet can cost approximately $500,000 dollars and typically refills vehicles overnight when they are not in service. In contrast and depending on various factors, a fast-fill CNG station which rapidly refills a vehicle in just a few minutes can range in cost from $1 to $2.5 million dollars (Breslin, 2013, para. 10). These capital intensive and incremental investments have impeded rapid expansion of infrastructure.

Figure 12. Time Fill Configuration. Adapted from DOE: Compressed Natural Gas Fueling Stations, 2014, Retrieved from http://www.afdc.energy.gov/fuels/images/time_fill_popup.jpg

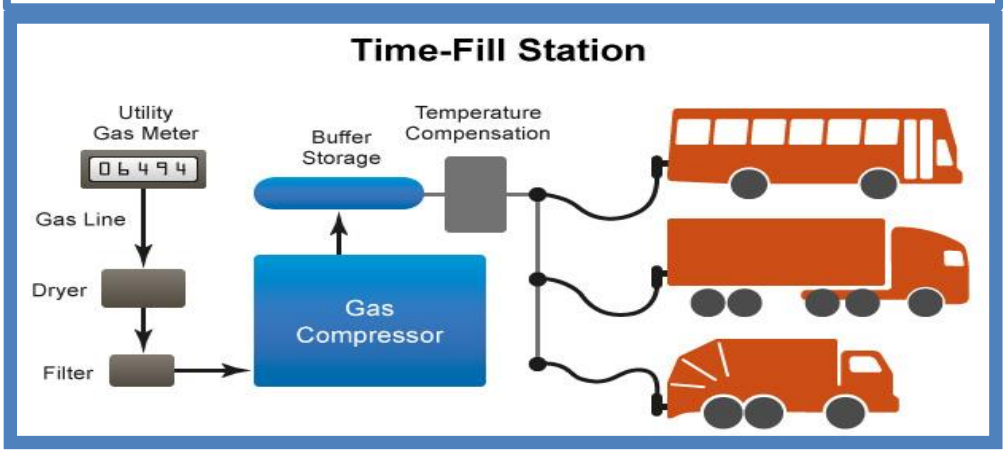
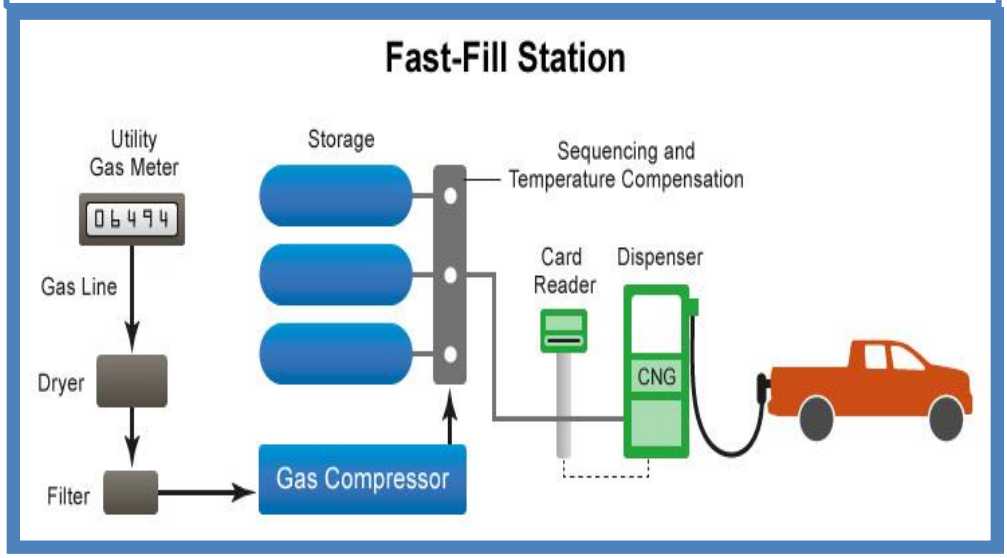


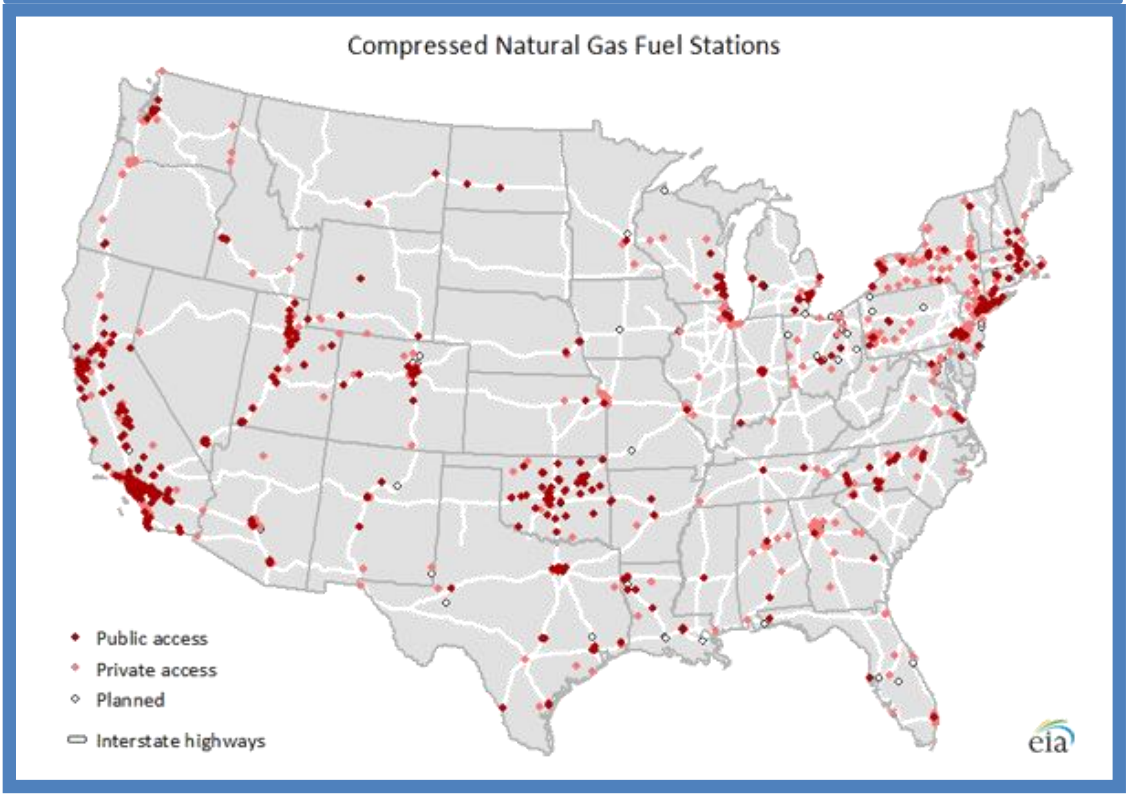
Figure 13. Fast Fill Configuration. Adapted from DOE: Compressed Natural Gas Fueling Stations, 2014, Retrieved from http://www.afdc.energy.gov/fuels/images/fast_fill_popup.jpg



The under-developed refueling network represents a significant deterrent to the full adoption of natural gas powered vehicles and contributes to a network externality because of the unrealized social benefits that NGVs could otherwise deliver.

The DOE's Alternative Fuels Data Center reports that currently 59% of U.S. CNG fueling is private onsite stations as shown in Figure 14. Favorable operating economics for fleet vehicles have justified the capital investment in these dedicated private fueling stations. However, government participation will likely be necessary to increase the number of publicly accessible CNG fueling stations because this investment is otherwise uneconomical. Expanded public retail access would increase awareness, instill confidence and promote potential NGV purchases.

Figure 14. CNG Fueling Station Locations. Adapted from EIA: Access to Alternative Transportation Fuel Stations Varies Across the Lower 48 States, 2012, Retrieved from http://www.eia.gov/todayinenergy/detail.cfm?id=6050#tabs_AltTransportFuelStations-2



Maximum throughput is a fundamental factor in generating volumes needed to justify the refueling station investment. A strategy that includes an anchor fleet, aggregates multiple fleets, and provides public access maximizes throughput.

POLICY ANALYSIS

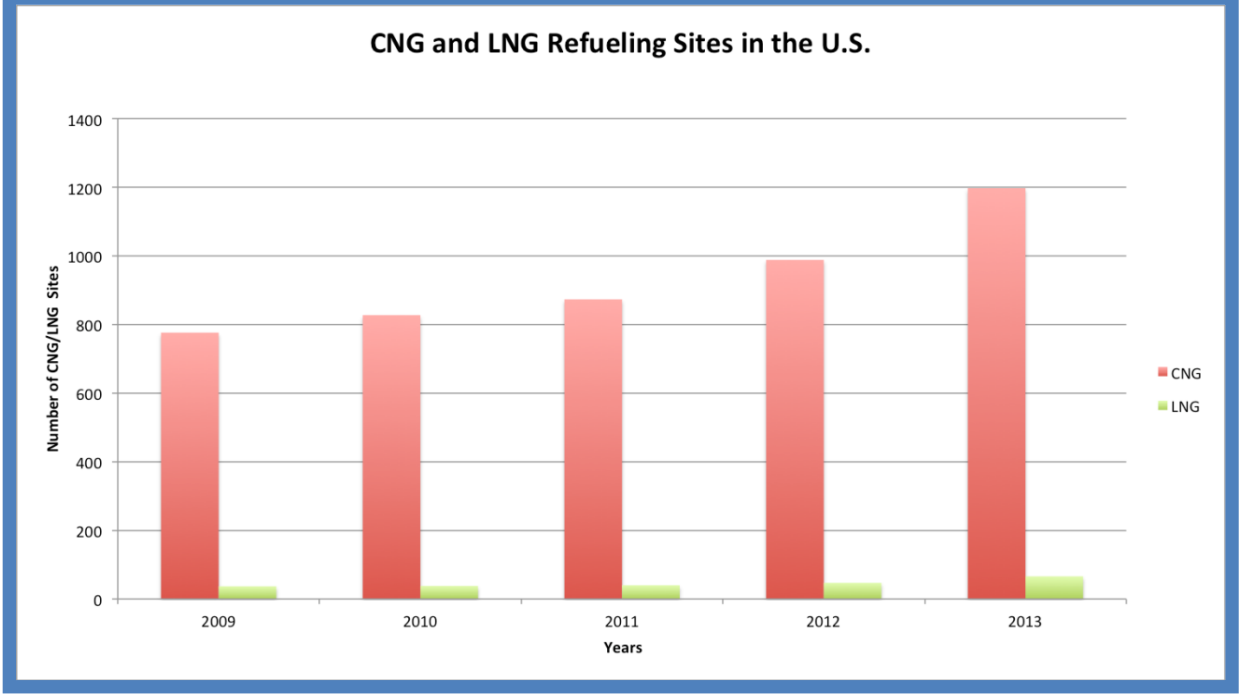
As examined, the NGV market has the potential to be economically and environmentally viable. However, the complexity of this heterogeneous mix of market participants (vehicle manufacturers, vehicle owners and refueling station investors) has inhibited full development. Although these participants are individually motivated, they are co-dependent to the market for function.

Ancillary market beneficiaries are local, regional, and state governments focused on clean air for its citizens and the mitigation of damages resulting from air pollution. An underdeveloped NGV market ultimately limits society from reducing the costs of air pollution. Federal, state and local government subsidization of publicly accessible NGV fueling stations can increase the number of retail refueling stations, and expand the economic and social benefits of using natural gas in the public sector.

Refueling Station Saturation

Comparatively, the United States is a laggard with regard to the number of operating NGVs per capita worldwide. The outstanding obstacle in this market's development is the inadequate number of fueling stations in this country. A variety of methods can be used to determine the appropriate threshold level for the adequate number of refueling stations needed to supply a particular fuel source (Car Group, 2013, p. 34-43). These possibilities range from distance traveled, to network patterns, to fuel consumption per vehicle type, and the ownership model itself. Despite the 11% annual growth rate for CNG fueling stations in the United States between 2009 and 2013, the number of CNG fueling stations in Figure 15 compared to approximately 119,000 retail gasoline outlets, (American Natural Gas Association, 2010, p. 14) remains at less than 1%.

Figure 15. CNG Fueling Station Growth. Adapted from Fuel for Thought: If You Build It They Will Come-Natural Gas Fueling Infrastructure in North America, 2013, Retrieved from http://blog.westport.com/2013_08_01_archive.html



The question of an appropriate penetration rate for CNG fueling stations was examined in the U.S. DOE's Transportation Energy Futures Series, and the general consensus resulting from multiple studies suggest that a CNG station saturation rate of between 10-20% of the traditionally available retail gasoline/diesel fueling stations in a given locality is needed for the NGV market to be self-sustaining (Melaina et al., 2013, p. 21).

Public vs. Private Refueling Infrastructure

The decision to construct a public or private fueling station encompasses multiple considerations. Though there are common elements to both scenarios, such as the environmental and economic

benefit of using natural gas, there are other unique and pertinent factors such as cost, risk, ownership, access, consumption, location, economies of scale, and regulatory environment.

In his 2014 State of the Union address, President Obama declared his Administration's desire to increase the use of natural gas because of its economic and environmental benefit. Specifically, the President expressed his interest to expand the public use of natural gas in the transportation sector (The White House, 2013, p. 2). This challenge of increased use of NGVs can be partially addressed through federal, state, and local policy, many examples of which are currently in use or under consideration across the country. As the transportation sector contributes approximately 28% of our country's GHG emissions (U.S. EPA, 2013, para. 2), reductions by this sector would contribute to meeting our nation's 17% GHG reduction target (President Obama, 2013, p. 4). Additionally, Pennsylvania, Oklahoma, Colorado, and Utah have adopted a strategy to stimulate demand by maximizing the availability of one of its natural resources, natural gas. These factors independently, or in combination all serve as incentive to support refueling infrastructure development.

Federal Policy

Government funding promotes private sector investment, mitigates risk and expands the network of publicly accessible CNG fueling infrastructure. Historically, local, state and federal governments have temporarily subsidized emerging and beneficial "public good" technologies that provide desired economic and social benefit that for various reasons cannot be financed and sustained by the private sector alone.

The majority of federal incentive programs for alternative fuel vehicles were not extended beyond 2013 because of budget constraints. Efforts to extend these provisions continue, but the

political and fiscal climate is not promising. However, a number of beneficial policy measures have been implemented or proposed at the federal level (U.S. DOE, 2013):

- US Department of Energy Alternative Fuel Infrastructure Tax Credit *The Energy Policy Act (EPAct) of 200*5 (Extended for 2012 and 2013), expired on Dec 31, 2013 had provided a 30% tax credit of the station cost not to exceed $30,000.
- Federal Highway Administration (FHWA) Congestion Mitigation and the Air Quality Improvement Program (CMAQ) have provided hundreds of millions of dollars for alternative fuel projects including natural gas fueling stations. It also extended consideration for grants including priority for severe carbon monoxide and ozone nonattainment areas.
- Federal Transit Authority (FTA)-Provides funding for local and regional public transit systems. In 2012, Congress passed the *Moving Ahead for Progress in the 21st Century Act*, which has provided $105 billion for public transportation, and includes the incremental cost of purchasing NGVs and the construction of natural gas refueling projects (Georgetown Climate.Org, 2012, Moving Ahead for Progress in the 21st Century: Key Changes to the Federal Transportation Legal Framework, para. 4).
- U.S. Department of Energy (DOE) Clean Cities Program is a national partnership comprised of 100 local coalitions and over 10,000 public and private stakeholders. This program is designed to advance the country's energy security by providing leveraged matching grants that reduce petroleum consumption.
- Federal Aviation Administration (FAA) Voluntary Airport Low Emission (VALE) program provides funding for NGV infrastructure at airports that are located in designated air quality nonattainment areas. *The American Recovery and Reinvestment Act*

(ARRA) of 2009- U.S. Department of Energy Stimulus Package funded 140 new fueling stations.

- The proposed *New Alternative Transportation to Give American Solutions (Nat Gas Act of 2011*) HR-1380 would have expanded tax credit for the lessor of 50% or $100,000 for the installation of natural gas refueling property (NGV America, 2013, Fact Sheet: Federal Incentive for Alternative Fuel Infrastructure, para. 1-4).

State Policy

In an unprecedented collaborative effort, Governors of twenty-three states signed a joint purchasing memorandum of understanding (MOU) to create a sustained market for NGV vehicles and private investment in NGV infrastructure.

Additionally, many states have actively supported the use of NGVs by enacting policies that subsidize natural gas vehicles and refueling infrastructure (US DOE, 2014):

Arkansas-SB 792 established a rebate for fueling stations for 75% of the qualifying costs up to $400,000.

California

- The Alternative Fuel Vehicle (AFV) and Fueling Infrastructure Grant Program provide funding for fueling infrastructure projects that reduce air pollution. Local air districts allocate funding for this program with cost sharing from other project partners expected.
- Clean Fuels Outlet Regulation (CFOR) mandates that retail fueling station operators must provide an alternative fueling option based on the number of vehicles using that fuel.

Colorado-The Colorado Energy Office will be administering a four-year program to expand the state's network of natural gas refueling stations. This program will receive $30 million dollars from the Federal Highway Administration's CMAQ program to develop thirty new CNG refueling stations.

Connecticut-Offers a 50% business tax credit available for installation of a compressed natural gas refueling facility.

Florida- HB 579 authorizes local governments to use income derived from a surtax on transportation fuel to provide infrastructure loans, grants, or rebates to property owners.

Iowa- Proposed SB 434 and HB 267 would provide a 30% tax credit up to a maximum of $5 million for natural gas refueling stations.

Kansas- Alternative Fueling Infrastructure Tax Credit is available for up to 40% of the total cost of alternative fuel infrastructure, or $100,000 per fueling station.

Louisiana- HB 681, SB 256 permits an income tax credit of 50% of the cost of alternative fueling equipment.

Nebraska-The Nebraska State Energy Office administers low cost loans available for the construction, or purchase of a fueling station through its *Dollar and Energy Savings Loan Program.* These 5% interest loans are capped at $150,000.

North Carolina-The Clean Fuel Advanced Technology (CFAT) Program provides grant funding for infrastructure investment to reduce transportation related emissions in nonattainment areas.

New Jersey-S-2194 has proposed that the New Jersey Turnpike Authority be required to install no less than four natural gas refueling stations at rest areas along the NJ Turnpike and Garden State Parkway. The bill also requires the South Jersey Transportation Authority to install two natural gas fueling stations along the Atlantic City Expressway.

Ohio- HB 59 provides grants and loans for up to 80% of the cost of purchasing and installing fueling facilities.

Oklahoma

- HB 2005 offers an Alternative Fueling Infrastructure Tax Credit for up to 75% of the cost of installing commercial alternative fueling infrastructure.
- CNG Fueling Infrastructure Development- The Oklahoma legislature intends to increase the amount of CNG infrastructure with the overall goal of having one public fueling station located every 100 miles along its interstate highway state by 2015, and one public fueling station every 50 miles by 2025 (U.S. DOE AFDC, 2014, Oklahoma Laws and Incentives for Natural Gas: Compressed Natural Gas Fueling Infrastructure Development).

Oregon-Business owners may be eligible for a tax credit of 35% of eligible costs of alternative fuel infrastructure projects.

Pennsylvania- HB 305 as proposed would create a gas corridor tax credit up to $5 million to encourage the construction of natural gas fueling stations within two miles of select interstate corridors.

Rhode Island- Proposed SB 2202 provides a 30% tax credit for alternative fuel fueling stations, and expires in 2016.

Texas

- The Texas Commission on Environmental Quality (TCEQ) administers the Alternative Fueling Facilities Program, which provides grants for 50% of eligible costs up to $500,000 for fuel dispensing equipment in nonattainment areas.

- To insure that NGVs have access to refueling infrastructure, the TCEQ also awards grants through the *Clean Transportation Triangle Program* to support the development of a network of natural gas fueling stations along the interstate highway system.

Virginia

- Proposed HB 508 provides a 30% tax credit for most stations and a 40% tax credit for stations located within 3 miles of Interstate 95. Credits are capped at $1 million dollars and are scheduled to expire in 2020.
- The Virginia Board of Education may use funding from its *Literary Fund* to provide loans to school boards to construct alternative fueling stations.

Utah-Utah funds an *Alternative Fuel Vehicle and Infrastructure Grant Program* to assist businesses and government to cover the cost of fueling equipment.

West Virginia

- HB 2817 provides state and local government tax credits for NGV related investments up to $2 million per year.
- SB 185 Alternative Fueling Infrastructure Tax Credit of 50% up to $250,000 is available to taxpayers who construct or purchase qualified alternative fueling infrastructure. If the refueling station is available for public use, the credit will be multiplied by a factor of 1.25 increasing the maximum amount to $312,500.

Wyoming-SF 23 authorizes loans to support natural gas fueling stations for 75% of the project cost up to $1 million.

Investor Owned Utilities

Local distribution companies are also playing an important role in advancing the deployment of CNG fuel infrastructure by making rate-based investment or using rate mechanisms for private

and publicly accessible natural gas refueling stations. A number of state lawmakers and regulatory authorities have extended their support of these investments because of the social, economic and environmental benefit that they provide. State utility regulators' willingness to embrace innovative approaches to permit utilities to promote NGV development has proven instrumental in increasing the number of fueling stations across the country.

Current regulatory models implemented by natural gas utilities fall into three categories; Rate Based Models, Non Rate Based Models, and Commercial Models (Natural Gas.Org, 2012, p. 1). Rate based models allow the utility to make a capital investment in a refueling station and with the state Public Utilities Commissions (PUC)'s approval, place these investment costs into its rates. Non-Rate-based models assume that the utilities own the risk to invest in refueling infrastructure to aid in market development. Finally, the Commercial Model is an unregulated investment typically funded by a utility subsidiary company where profit and risk are both subject to the market. Examples of existing utility programs are:

- **Atlanta Gas Light,** a subsidiary of AGL Resources has provided $2.1 million to the City of Atlanta to construct two compressed natural gas fueling stations (Williams, 2012). The Georgia Public Service Commission allows the natural gas utility to utilize a ratepayer-funded mechanism to make Georgia a hub for CNG investment in the Southeast.
- Portland Oregon based **NW Natural** has received approval from the Oregon Public Utility Commission to build and operate natural gas fueling stations for commercial customers.
- **Questar Gas** in Utah has used a NGV tariff to construct thirty-three public access refueling stations.

- **National Fuel Gas** of New York has received approval to issue $3.5 million in grants to build NGV fueling stations.

Additionally, public refueling stations are provided by utilities in the following states (Slavin, 2013, p. 35):

Connecticut (**Chesapeake Utilities**), Indiana (**Citizens Gas & Coke**), Michigan (**DTE Energy**), New York (**Con Edison**), North Carolina (**Piedmont Natural Gas and PSNC**), Washington DC (**Washington Gas**), and Wyoming (**Cheyenne Light Fuel and Power**).

Private Investment

The commercial sector is actively promoting natural gas vehicles by investing in refueling infrastructure. The initial focus is on densely populated regions and along major transportation thoroughfares and corridors where taxicabs, transit vehicles, trucks and couriers can benefit. Clean Energy Fuels, Trillium CNG, AmericaCNG, and Chesapeake NG Ventures are companies that are either constructing to own or building stations for third-party fleet owner/operators. Private sector companies like Frito-Lay (Sakelaris, 2013, para. 2) are investing in fueling stations for operational savings, but are also opening their facilities to the public as part of its sustainability efforts.

Decision making criteria for a dedicated private station differs significantly from a public fueling station. Private stations are designed around known parameters such as fleet size, volumes required, and demand. Fundamental assumptions for investment cost, payback, and profitably are simpler to calculate, control and forecast. Formal partnerships between fleet owners,

municipalities, fuel providers, and equipment manufactures represent a collaborative effort to deliver solutions to this emerging market.

American Clean Skies Foundation recently conducted a survey on natural gas fueling options with stakeholders from gas producers, gas distribution companies, fuel vendors, station developers, component/vehicle manufacturers, and private fleet owners. Survey respondent groups expressed confidence that the NGV market will continue to grow and over 90 % of those surveyed attribute this growth to the projected price differential between natural gas and traditional fuels. Respondents also affirmed that the most significant barrier to building fueling stations was the cost, and that government incentives (tax credits, grants) are the most effective means to accelerate infrastructure development (Slavin, 2013, p. 1-4).

Conclusion

Our nation depends on transportation to connect businesses, provide access to goods, services, recreation and one another. This reliance on gasoline and diesel fueled transportation vehicles creates harmful air emissions, particularly carbon-dioxide, nitrogen oxide, and other particulates. Transportation is the second largest contributing sector of GHG emissions in the U.S. and it is prudent to institute conservation and displacement measures to reduce these emissions and alleviate the externalities associated with petroleum use and dependence.

A number of innovative transportation alternatives have been developed to mitigate these emissions and related damage to our environment. One alternative, CNG is being used to power light-duty passenger vehicles and heavy-duty high consumption fleet vehicles. Both applications are dependent on investment in public and/or private CNG fueling station facilities.

NGVs have the ability to deliver economic benefits through lower operating expenses and environmental benefits by reducing GHG emissions. Moreover, the capital investment for heavy-duty fleet vehicle purchases and dedicated access fueling stations has proven to be cost effective due to relatively low natural gas prices and substantial fuel consumption. Conversely, the economics for light-duty non-fleet passenger vehicles are less attractive because of their low consumption and limited fuel savings. The lack of significant operating savings doesn't justify the incremental cost of purchasing a passenger NGV or the expansion of a public fueling network to a saturation level that will develop and sustain this market segment.

Government has historically subsidized "public good" technologies that provide desired economic and social benefits that for various reasons cannot be financed and sustained by the private sector alone. Consequently, Federal and State public policies have stimulated natural gas fueling station growth across the United States. However, the level of available funding has proven inadequate to develop and sustain the light-duty non-fleet passenger component of this market. Absent compensation for the value of the environmental benefits that NGV passenger vehicles have the potential to provide, the incremental costs for the NGVs themselves, and the publicly accessible CNG fueling station network cannot be economically justified by the fuel savings alone.

Unfortunately, public policies designed to encourage non-fleet NGVs and public fueling station networks do not presently include the economic value of environmental benefits that these passenger vehicles can contribute. Including these contributions may impact the subsequent economic justification and policy treatment. Given this market's potential environmental benefit, I have assumed that our country should pursue the use of natural gas passenger vehicles, though

a full assessment of the monetized environmental benefits of switching from conventional to passenger NGVs is beyond the scope of this paper.

Indeed, public/private collaboration has expanded the economically justified use of natural gas for heavy-duty private fleet vehicles and associated fueling station infrastructure. These public policies should be continued because of the economic and environmental benefit that these fuel intense vehicles are providing to our country.

The combination of operational savings and clean burning attributes delivered by NGVs has created a unique and compelling opportunity for the U.S. to increase its utilization of natural gas in the transportation sector. The use of natural gas is a synergistic and balanced solution because it protects the environment, improves our air quality and benefits the economy by reducing operating expenses.

REFERENCES

2013 Economic Report of the President. *The White House*. Retrieved February 18, 2014, from http://www.whitehouse.gov/administration/eop/cea/economic-report-of-the-President/2013

American Gas Association. (2014). *Supply*. Retrieved April 1, 2014, from http://www.aga.org/OUR-ISSUES/SUPPLY/Pages/default.aspx

American Natural Gas Association. (2010). *US and Canadian Natural Gas Vehicle Market Analysis: Compressed Natural Gas Infrastructure*. Retrieved February 18, 2014, from http://anga.us/media/content/F7D3861D-9ADE-7964-0C27B6F29D0A662B/files/11_1803_anga_module5_cng_dd10.pdf

Bast, J., & Taylor, J. (2007). Scientific Consensus on Global Warming. Heartland.Org (p. 3). Retrieved April 2, 2014, from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CC0QFjAB&url=http%3A%2F%2Fheartland.org%2Fsites%2Fall%2Fmodules%2Fcustom%2Fheartland_migration%2Ffiles%2Fpdfs%2F20861.pdf&ei=H5M6U6v_MtPNsQTPvYCgCA&usg=AFQjCNEzwmJYqkO6K5l1plkPgZEs03j7eg&

Breslin, M. (2013, August). Natural gas-powered refuse truck use flourishes in U.S. *AR News*. Retrieved February 19, 2014, from http://www.americanrecycler.com/0813/2219natural.shtml

Car Group. (2013). *Financing the Infrastructure to Support Alternative Fuel Vehicles*. Retrieved April 14, 2014 from http://cargroup.org/?module=Publications&event=Download&pubID=100&fileID=112

CNN World. (2013). *Kyoto Protocol Fast Facts*. Retrieved February 18, 2014, from

http://www.cnn.com/2013/07/26/world/kyoto-protocol-fast-facts/

Congressman Bill Shuster (2013). Transportation. Retrieved Nov 15, 2013, from https://shuster.house.gov/transportation

Environmental Defense Fund. (2013). *First Academic Study Released in EDF Groundbreaking Methane Emissions Series*. Retrieved February 6, 2014, from http://www.edf.org/media/first-academic-study-released-edf%E2%80%99s-groundbreaking-methane-emissions-series

Gas Foundation.Org. (2012). *Natural Gas as a Transportation: Fuel Models for Developing Fueling Infrastructure. Retrieved October, 13, 2013, from* http://gasfoundation.org/ResearchStudies/AGFTransportationStudySept2012.pdf

Georgetown Climate.Org. (2012). *Moving Ahead for Progress in the 21st Century Act (Map-21):Key Changes to the Federal transportation Framework*. Retrieved Nov 22, 2013, from http://www.georgetownclimate.org/bills/moving-ahead-for-progress-in-the-21st-century-act-map-21

Holeywell, R. (2014). Houston Area gets Eighth CNG Station. *Fuel Fix*. Retrieved April 1, 2014 from http://www.shalemarkets.com/houston-area-gets-eighth-cng-station-201403309386/

Kauffmann, B. (2013). Natural Gas Vehicles: Driving America to a More Prosperous, Secure, and Sustainable Future. *Progress in Policy Institute*. Retrieved Jan 5, 2014, from http://www.progressivepolicy.org/wp-content/uploads/2013/04/4.2013-Kauffmann_Natural-Gas-Vehicles_Driving-America-to-a-More-Prosperous-Secure-and-Sustainable-Future.pdf

Kolodziej, R. (2012). With NGVs Taking Off, U.S. Transportation Sector Accelerating Natural

Gas Demand. *The American Oil & Gas Reporter*. Retrieved February 18, 2014, from http://www.aogr.com/index.php/magazine/cover-story/with-ngvs-taking-off-u.s.-transportation-sector-accelerating-natural-gas-de

Melaina, M.W.; Heath, G.; Sandor, D.; Stewart, D.;Vimmerstedt, L.; Warner, E.; Webster, K.W. (April 2013). Alternative Fuel Structure Expansion: Costs, Resources, Production Capacity, and Retail Availability for Low-Carbon Scenarios. Transportation Energy Futures Series. Prepared for the US Department of Energy by Renewable Energy Laboratory, Golden, CO. DOE/GO-102013-3710.101 pp.

Natural Gas Intelligence. (2013). *Study of the Potential Impact of Hydraulic Fracturing on Drinking Water Resources*. Retrieved February 18, 2014, from http://www.naturalgasintel.com/articles/4952

Natural Gas.Org. (2013). *Overview of Natural Gas*. Retrieved February 8, 2014, from http://www.naturalgas.org/overview/uses_transportation.asp

NGV America. (2013). *Alternative Fuel Infrastructure*. Retrieved Dec 1, 2013 from http://www.ngvamerica.org/gov_policy/107th/107th_clearactsummary.html

NGV America. (2013). *Fact Sheet: Federal Incentive for Alternative Fuel Infrastructure*. Retrieved Dec 1, 2013, from http://www.ngvamerica.org/pdfs/Alternative_Fuel_Infrastructure_Tax_Credit.pdf

NGV America. (2012). *Testimony to US Senate Energy and Natural Resources Committee*. Retrieved February 2, 2014, from www.ngvc.org/pdfs/Statement_of_NGVA_SperawFinal.pdf

NGV Center. (2014). *NGV Statistics*. Retrieved Feb 2, 2014, from http://www.ngvcenter.com/about-ngvs/ngv-statistics

Natural Gas-Vehicles.Org, (2013), *2013 Natural Gas Vehicles*, Retrieved March 2, 2014, from http://www.naturalgas-vehicles.com/

President Obama. (2013). *The President's Climate Action Plan*. Retrieved June 18, 2013 from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CDAQFjAB&url=http%3A%2F%2Fwww.whitehouse.gov%2Fsites%2Fdefault%2Ffiles%2Fimage%2Fpresident27sclimateactionplan.pdf&ei=dU5BU5DRA-HIsASLuIGQBQ&usg=AFQjCNGpFCn12iv93WABfFnWNVnD2pESAw&bvm=bv.64125504,d.cWc&cad=rja

Powered By NCNG. (2014). *Honda Civic CNG Payback*. Retrieved April 12, 2014, from http://poweredbycng.com/honda-civic-cng-payback/

Sakelaris, N. (2013, June 20). Frito-Lay will Build 7 Public CNG Fueling Stations this Year. *Dallas Business Journal*. (2013). Retrieved February 19, 2014, from http://www.bizjournals.com/dallas/news/2013/06/20/frito-lay-will-build-7-public-cng.html

Shauk, Z. (2012). Waste Management Adding Cleaner, Natural-Gas Vehicles. *Houston Chronicle.* Retrieved Jan 13, 2014 from http://www.chron.com/business/article/The-cargo-is-still-garbage-but-the-fuel-is-3550278.php

Slavin, M. (2013, Jan). Where Can I Fill Up? 2013 Assessment. American Clean Skies Foundation. Retrieved February 19, 2014, from http://www.cleanskies.org/wp-content/uploads/2013/01/fill-up-update.pdf

State by State Incentives Guide. *http://www.fleet-central.com/resources/State_Incentives_Alt_Fuel_Use.pdf*. Retrieved January 11, 2014, from

http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&c40d=5&ved=0CEEQFjAE&url=http%3A%2F%2Fwww.fleet-central.com%2Fresources%2FState_Incentives_Alt_Fuel_Use.pdf&ei=RaX7UqG4Ecni0gGftYEI&usg=AFQjCNEafqDksEnntrhiaz2_IDBk4pBo9Q&bvm=bv.61190604,d.dmQ

The President's Climate Action Plan. (2013). *The White House*. Retrieved March 8, 2014, from http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

The White House. (2013). *Remarks by the President in the State of the Union Address*. Retrieved February 18, 2014, from http://www.whitehouse.gov/the-press-office/2013/02/12/remarks-president-state-union-address

United Nations Framework Convention on Climate Change. (2014). *Kyoto Protocol*. Retrieved February 16, 2014, from https://unfccc.int/kyoto_protocol/items/2830.php

US and Canadian Natural Gas Vehicle Market Analysis. *Societal Costs*. (2012). Retrieved April 1, 2014, from http://anga.us/issues-and-policy/transportation/tiax-natural-gas-vehicle-market-analysis#.U0CwrceMo6U

US Department of Energy AFDC. (2014). *Clean Alternative Fuels: Compressed Natural Gas*. Retrieved March 15, 2014, from http://www.afdc.energy.gov/pdfs/epa_cng.pdf

US Department of Energy AFDC. (2013). *Natural Gas Vehicle Emissions.* Retrieved February 18, 2014, from http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html

US Department of Energy AFDC. (2014). *Fuel Properties Comparison*. Retrieved March 16, 2014, from http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf

US Department of Energy AFDC. (2013). *Key Federal Legislation*. Retrieved February 18, 2014, from http://www.afdc.energy.gov/laws/key_legislation

US Department of Energy AFDC. (2014). *Laws and Incentives*. Retrieved February 19, 2014, from http://www.afdc.energy.gov/laws/search?p=search&select_all_location=all&location[]=US&location[]=There arAL&location[]=AK&location[]=AZ&location[]=AR&location[]=CA&location[]=CO&location[]=CT&location[]=DE&location[]=DC&location[]=FL&location[]=GA&location

US Department of Energy AFDC. (2014*). Oklahoma Laws and Incentives for Natural Gas: Compressed Natural Gas Fueling Infrastructure Development*. Retrieved Jan 4, 2014 from http://www.afdc.energy.gov/laws/laws/OK/tech/3253

US Department of the Interior. (2013). Environment, and Related Agencies Appropriations for Fiscal Year 2013. Retrieved March 15, 2014, from http://www.gpo.gov/fdsys/pkg/CHRG-112shrg29104504/html/CHRG-112shrg29104504.htm

US Energy Information Administration. (2013). AEO 2014 Early Release Overview: CO2 Emissions Forecast. Retrieved January 16, 2014, from http://www.eia.gov/forecasts/aeo/er/early_carbonemiss.cfm

U.S. Energy Information Administration. (2013). *Delivered Energy Consumption by Sector: Transportation*. Retrieved February 18, 2014, from http://www.eia.gov/forecasts/aeo/er/early_consumption.cfm

United States Environmental Protection Agency. (2013). *EPA Publishes 18th Annual U.S. Greenhouse Gas Inventory*. Retrieved March 15, 2014, from http://yosemite.epa.gov/opa/admpress.nsf/0c0affede4f840bc8525781f00436213/67cd86a

2cd050b4385257b4e006660d8!OpenDocument

US Environmental Protection Agency. (2013). *Greenhouse Gas Emissions: Transportation Sector Emissions*. Retrieved February 16, 2014, from http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html

US Environmental Protection Agency. (2014). *The Process of Hydraulic Fracturing*. Retrieved March 31, 2014, from http://www2.epa.gov/hydraulicfracturing/process-hydraulic-fracturing

US Environmental Protection Agency. (2013). *The Green Book Nonattainment Areas for Criteria Pollutants*. Retrieved Feb 16, 2014 from

US General Accountability Office. (2012). *Unconventional Oil and Gas Development: GAO-12-874*. Retrieved March 15, 2014, from www.gao.gov/assets/650/647782.pdf

Williams, D. (2012, Jul 18). *Atlanta Accepts Funds for CNG Fueling Stations*. Atlanta Business Chronicle. Retrieved February 19, 2014, from http://www.bizjournals.com/atlanta/news/2012/07/18/atlanta-accepts-funds-for-cng-fueling.html