

The Feasibility of Natural Gas as an Eventual Substitute for Gasoline

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HSA10-5 The Economics of Oil and Energy

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I. Introduction

In today's world, oil is everywhere: social media, television, and newspapers. Especially with the recent decline in the price of oil, drivers who use gasoline aren't encouraged to consider cleaner, alternative fuels. And why should they? Gasoline is cheap, effective, and has been a fuel standard for decades ever since the first gasoline cars were built. However, this honeymoon phase may be short lived. As America's infatuation with oil dwindles, we may find ourselves face-to-face with pressing environmental and political problems. Economics concerns itself with scarcity. With oil as an "unclean" fossil fuel, we see that a change in our fuel is inevitable. Over time, natural gas is a clean, suitable alternative for gasoline for transportation such that we reduce our reliance on imported oil and strive to be more environmentally friendly.

II. Gasoline - Sources and Use for Transportation

The United States consumes, as a whole, over 840 million gallons or 20 million barrels of petroleum products each day.¹ Petroleum is the black liquid often associated with the thought of

Products Made from a Barrel of Crude Oil (Gallons) (2011)

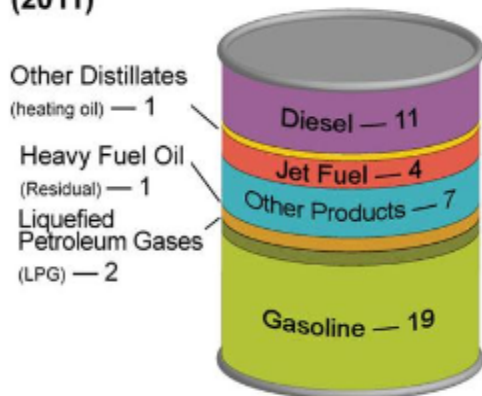


Figure 1: Distribution of products made from a barrel of petroleum. Source: http://www.eia.gov/energyexplained/index.cfm?page=oil_home

oil. This petroleum or crude oil is the very oil seen pumped out of the ground if one drives around Bakersfield, CA. 76% of the 6.97 billion barrels of petroleum products in the U.S. in 2014 were gasoline.² Gasoline fuels the over 200 million vehicles that travel a combination of over seven billion miles each and every day. Gasoline is made from crude oil. Crude oil is created by millions-year-old aquatic plant and animal remains. These remains are covered by sediment and subject to extreme pressure and temperature. The combination of such environmental influence leads to a

¹ <http://dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=244>

² <https://www.eia.gov/tools/faqs/faq.cfm?id=41&t=6>

liquid hydrocarbon mix that refineries break down into useable products. Some include:

“gasoline, diesel fuel, heating oil, jet fuel, residual fuel oil.”³ The hydrocarbons of petroleum have different lengths with different properties. Most notable is varying boiling points.

Distillation at oil refineries separates these hydrocarbons, which is what will eventually form the gasoline we utilize in our vehicles.⁴ Specifically, the process involves a “fractional distillation.”

In essence, this is simply heating crude oil, vaporizing it, and then condensing it. However, this technique is old. A new technique is chemical processing,

which translates diesel fuel into gasoline if necessary.

Regardless of the technique used, the fractions - the accumulation of gasoline - must be “treated to remove impurities.” The fractions combine to create product.⁵ But how did gasoline come to be as a fuel source? In 1859, Edwin Drake dug the first oil well and utilized the oil for kerosene.

Gasoline and other products were produced, yet no real use was available then, so they were discarded. It was only until 1892, when the automobile was invented, that gasoline was regarded as valuable.⁶ But where do Americans get their gas from? In fact, the answer isn’t as simple as it may seem. In July 2015, the major source of America’s oil imports (crude oil and products) was Canada. That same month, OPEC

contributed 89,785 thousand-barrels out of the total 294,833 thousand-barrels imported.⁷ In July 2015, the United States produced 9,433 thousand-barrels domestically in comparison.⁸ Gasoline, derived from crude oil, is the main transportation fuel in the United States, accounting for 56%

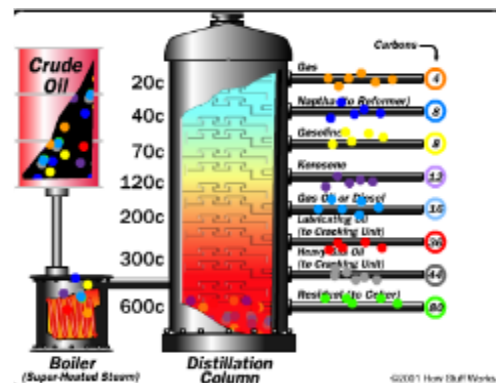


Figure 2: A Fractional Distillation column, the first step of fractional distillation. It refines the crude oil into various liquid fractions that may pass to condensers or other areas for chemical processing. Source: <http://science.howstuffworks.com/environmental/energy/oil-refining4.htm>

³ <http://dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=244>

⁴ <http://science.howstuffworks.com/gasoline2.htm>

⁵ <http://science.howstuffworks.com/environmental/energy/oil-refining3.htm>

⁶ https://www.eia.gov/energyexplained/index.cfm?page=gasoline_history

⁷ http://www.eia.gov/dnav/pet/pet_move_impqus_a2_nus_ep00_im0_mbbld_m.htm

⁸ https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbldpd_m.htm

of total U.S. transportation energy in 2014. It is used mainly in cars, motorcycles, and trucks. Gasoline consumption averaged 8.8 million barrels per day for transportation use.⁹

III. Natural Gas - Sources and Use for Transportation

Natural gas is currently utilized more for heavy-duty vehicles. Quantitatively, Natural gas accounts for 3% of transportation in the United States when compared to Gasoline's 56%.¹⁰ But where does Natural gas come from? Why is its role in transportation so minimal, especially when

Fuel used for U.S. transportation, 2014¹

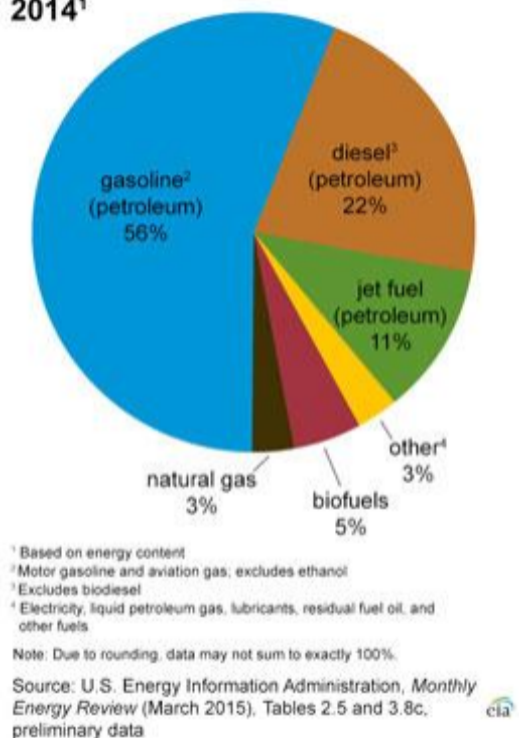


Figure 3: Fuel used for U.S. Transportation

the U.S. Department of Energy calls it the “ideal fossil fuel?”¹¹ To begin, Natural gas is gas found deep below the earth's surface. It consists mainly of methane, non-hydrocarbon gases, and hydrocarbon liquids.

Similar to gasoline, the process of natural gas formation begins with the millions-years-old animal and plant remains. These remains decay, occasionally mix with other sediments, and stack in thick layers which are buried. Extreme pressure and heat change these layers into natural gas, coal, and petroleum.

Other sources of natural gas include porous sedimentary rocks, such as sandstone and shale.¹² One common method of extracting natural gas is the “horsehead” pump. This is the same device utilized to obtain crude oil. The gas flow through a reservoir is improved by creating fractures. Through a process

called “hydraulic fracturing,” drillers force fluids like water with high pressure into formations. This cracks the rock. “Propping agents” are added to the fluid to open these fractures when the pressure decreases. Another unconventional method of retrieving natural gas is through “tight sand lenses. This involves cracking rock structures to create thin passages for the gas to flow.¹³ It

⁹ http://www.eia.gov/Energyexplained/?page=us_energy_transportation

¹⁰ http://www.eia.gov/Energyexplained/?page=us_energy_transportation

¹¹ http://www.fossil.energy.gov/education/energylessons/gas/gas_production.html

¹² http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_home

¹³ http://www.fossil.energy.gov/education/energylessons/gas/gas_production.html

is important to note the importance of shale gas fracking. Shale gas is formed from hydraulic fracturing in shale and produced over 25% of America's natural gas resources in 2012.¹⁴ In terms of non-domestic production, 2,718,239 million cubic feet of Natural Gas were imported from non-domestic sources. Canada, Trinidad, and Egypt were the three top exporters of Natural Gas to America.¹⁵ But how did natural gas come to use as a fuel? In America, the first Natural Gas source was devonian shale in New York. This, however, was not the first discovery of the energy source. Natural Gas, unlike Gasoline, has a history that spans hundreds of years.

Early human civilizations were not aware of the cause of “burning springs” that potentially arose from lightning igniting some of this gas. The Greeks believed the occurrence was of divine origin and built the temple which the Oracle of Delphi was housed around these “springs.”

Britain, in 1785, commercially produced natural gas from coal to use in lamps.¹⁶

Natural gas vehicles were invented in the 1930s, yet there are only 150,000 Natural Gas Vehicles in the United States today.

Most Natural Gas Vehicles (NGV) are filled with CNG (Compressed Natural Gas) or LNG (liquified natural gas).

Natural Gas is safe and NGVs have “stronger and sturdier” storage tanks currently than gasoline tanks - dissipating gas instead of leaving a pool of flammable liquid in the event of an accident.¹⁷

Hydraulic fracturing

Hydraulic fracturing, or fracking, unlocks natural gas from massive reservoir rock formations that otherwise could not be extracted economically. Some people worry hazardous chemicals used in the process pollute air and water.

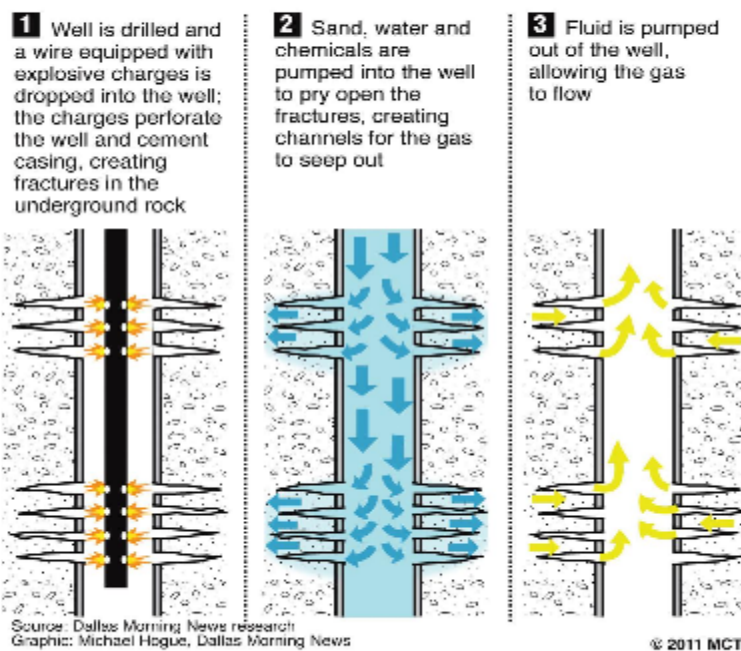


Figure 4: A diagram explaining visually how Hydraulic Fracturing - a method of retrieving Natural Gas from the ground/rocks - works. Source: <http://www.theloquitur.com/wp-content/uploads/2011/12/Fracking003.jpg>

¹⁴http://thebreakthrough.org/images/main_image/Where_the_Shale_Gas_Revolution_Came_Fro_m2.pdf

¹⁵ https://www.eia.gov/dnav/ng/ng_move_imp_s1_a.htm

¹⁶ http://www.ems.psu.edu/~pisupati/ACSOutreach/Natural_Gas.html

¹⁷ <http://naturalgas.org/overview/uses-transportation/>

The potential of NGVs for reducing pollution and the dependence of the U.S. on foreign oil bolsters interest in Natural Gas as an alternative substitute to Gasoline.

IV. The Specifics of Natural Gas for Transportation

Under the Energy Policy Act of 1992, CNG and LNG are considered alternative fuels. CNG is produced by compressing Natural Gas to “less than 1% of its volume at standard atmospheric pressure.” It’s stored onboard via cylinders. Liquid Natural Gas is formed when

natural gas cooled below its boiling point. This leaves methane and other hydrocarbons behind.

However, it’s more expensive in production cost and must be stored in expensive cryogenic tanks.

LNG’s more dense than CNG, which means that more energy per volume can be stored. However, 1.5

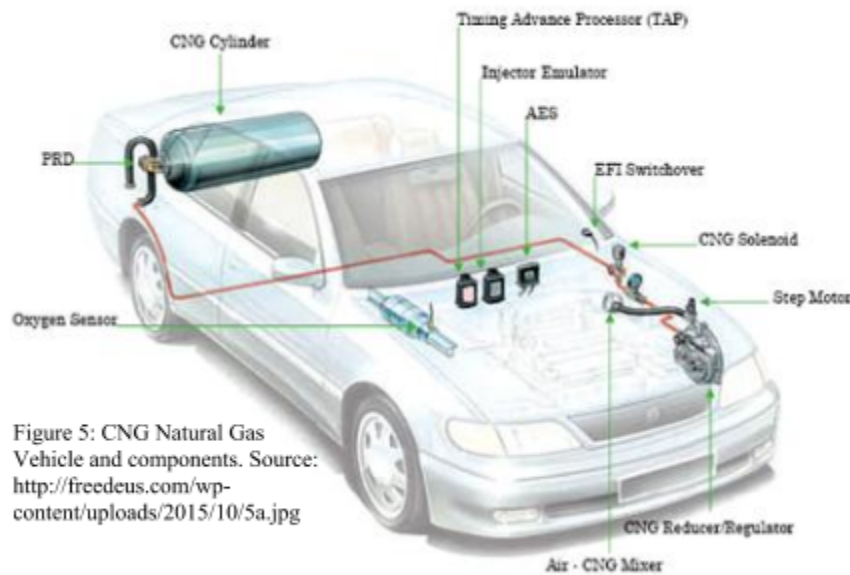


Figure 5: CNG Natural Gas Vehicle and components. Source: <http://freedeus.com/wp-content/uploads/2015/10/5a.jpg>

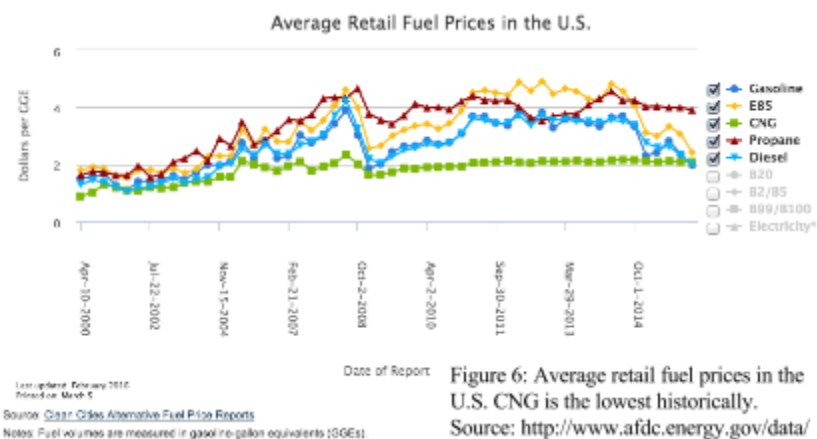
gallons of LNG is one GGE where 5.66 lbs of CNG is one GGE.¹⁸ There are three types of NGVs: dedicated, which are NGVs running solely on natural gas; Bi-fuel, which are hybrids between gasoline and natural gas; and dual-fuel, which are diesel-natural gas hybrids for larger vehicles. NGVs are split into several distinctions. Most notably are light-duty and heavy-duty vehicles. Light-duty vehicles usually operate in dedicated or bi-fuel modes while heavy-duty vehicles are dual-fuel or dedicated.¹⁹ In terms of vehicle performance, NGVs are “similar to gasoline or diesel vehicles with regard to power, acceleration, and cruising speed,” However, NGVs suffer a reduced driving range because less overall energy content can be stored in the same size tank as more energy dense gasoline or diesel fuels.²⁰ Another issue that Natural Gas

¹⁸ http://www.afdc.energy.gov/fuels/natural_gas_basics.html

¹⁹ http://www.afdc.energy.gov/vehicles/natural_gas.html

²⁰ http://www.afdc.energy.gov/fuels/natural_gas_benefits.html

faces today is its lack of infrastructure; however, there are many natural gas vehicles either in production or on the market. There is an “extensive natural gas distribution system in place” in the United States, yet its vehicle fueling infrastructure is lacking. This means that companies and fleets will have to pay for infrastructure, which can be costly due to the high initial costs of production and management of natural gas. One reason natural gas vehicles are limited in the U.S. is their “limited range, trunk space, higher initial costs, and lack of refueling infrastructure.”²¹ LNG stations deliver a liquid fuel to vehicles “at pressures of 30 to 120 psi.” However, in fueling, protective clothing, face



shield, and gloves are required when fueling a vehicle.²² LNG is usually delivered by tanker truck yet custom stations can be ordered. Small fueling units can cost \$10,000 yet LNG fueling sites can range from \$1 to \$4 million dollars.²³ It is important to note that there exists a renewable Natural Gas Source called RNG (biomethane) that produces much fewer GHGs. It is the product of organic matter decomposition and prevents methane release into the atmosphere if captured from landfills and farmlands. Importantly, it can be used in the existing natural gas distribution systems for transportation. Thus, no change in infrastructure is necessary for use.

V. Natural Gas as a Feasible Substitute for Gasoline

In 2013, the United States imported about 33% of the petroleum it consumed with nearly 70% of total petroleum consumption utilized for transportation. This put the U.S. in a position of dependency on foreign oil.²⁴ Much of this oil is located in “politically volatile” areas, which indicates vulnerability in its supply. However, Natural Gas, unlike gasoline, can be domestically produced in great quantity - reducing foreign dependence. Increasing dependence on domestic

²¹ <http://naturalgas.org/overview/uses-transportation/>

²² http://www.afdc.energy.gov/fuels/natural_gas_infrastructure.html

²³ http://www.afdc.energy.gov/uploads/publication/cng_infrastructure_costs.pdf

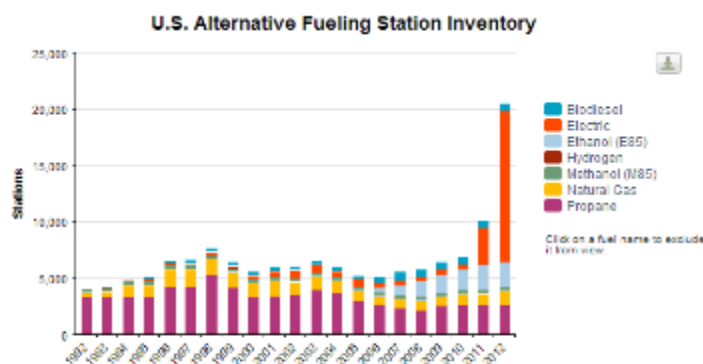
²⁴ http://www.afdc.energy.gov/fuels/natural_gas_benefits.html

production will help by lowering the trade deficit. Additionally, every “cubic foot of gas” domestically produced creates more jobs, raises national income, and increases growth.²⁵ From 2009 - 2013, around 35,000 jobs had been created due to oil and gas extraction alone. But what about the environmental impacts of using NGVs? Comparing a Honda Civic NGV to a normal Honda Civic (both 2013 models), given that both travel about 40 miles per day (average miles traveled per person per day)²⁶ with 3,484 miles per year for travel outside commute, we see that the annual fuel cost is about \$1.98 per gallon for gasoline and \$2.09 per GGE (gallon of gasoline equivalent). It’s important to notice, from Figure 6, that Natural Gas (CNG) has historically been cheaper than most forms of fuel, even if the average price for gasoline is currently cheaper than that of Natural Gas. We should note that the current average price of natural gas is higher (per GGE) than gallons of gasoline because of the plunging price of a barrel of oil. This is because of Saudi Arabia’s full-speed-ahead production of oil, oil companies’ stubbornness to halt production as long as prices cover

daily costs, and unexpected consumer habits.²⁷ We find some surprising results when analyzing GHG emissions of both vehicles: 9646 lbs of CO₂ for the normal Civic and 8243 lbs of CO₂ for the NGV annually.²⁸

To quantify this further, if everyone drove a 2013 Civic, 122.01 million cars²⁹ would be exerting 9646 lbs of

CO₂ per year (122,010,000 cars * 9646 lbs of CO₂/year = 1,176,908.46 million lbs of CO₂ annually). However, if everyone drove a 2013 Civic NGV, (122,010,000 cars * 8243 lbs of



Today's drivers can find thousands of fueling stations across the country that provide natural gas, electricity, ethanol, and other alternative fuels. Source: Alternative Fuels Data Center

Figure 7: Alternative fueling stations in the U.S.

Source: <https://www.washingtonpost.com/blogs/wonkblog/files/2013/04/US-alt-fuel-station-inventory-AFDC-via-CleanCities.png>

²⁵<https://www.whitehouse.gov/blog/2013/08/29/reducing-america-s-dependence-foreign-oil-strategy-increase-economic-growth-and-redu>

²⁶https://www.rita.dot.gov/bts/sites/rita.dot.gov/bts/files/subject_areas/national_household_travel_survey/daily_travel.html

²⁷<http://www.economist.com/news/leaders/21688854-low-energy-prices-ought-be-shot-arm-economy-think-again-whos-afraid-cheap>

²⁸ http://www.afdc.energy.gov/vehicles/natural_gas.html

²⁹ <http://www.eia.gov/forecasts/aeo/data/browser/#/?id=49-AEO2015>

CO₂/year) 1,005,728.43 million lbs of CO₂ would be produced, a significant difference of **171,180.03 million lbs of CO₂** annually. If this isn't a significant enough difference, one should note the assumptions that all cars driven are considered to be 2013 Honda Civics - a car with a 29 average mpg.³⁰ However, gasoline cars have mpgs that can be almost as low as 12 mpg. This

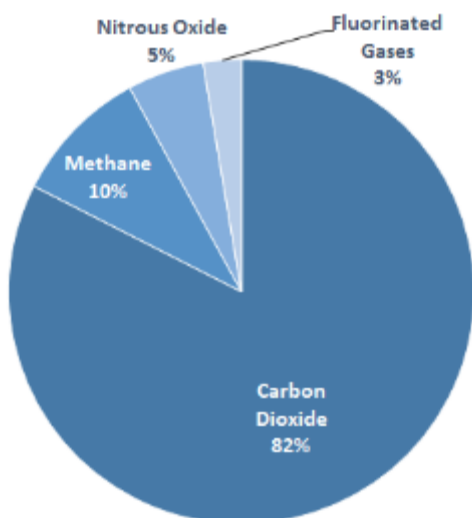


Figure 8: U.S. Greenhouse Gas Emissions in 2013.
Source: <http://www3.epa.gov/climatechange/ghgemissions/gases.html>

means that the calculations above greatly underestimate exactly how much CO₂ is produced by gasoline vehicles. This means the difference in CO₂ produced is greatly underestimated. Carbon Dioxide (CO₂) increases atmospheric concentrations of CO₂ that will last thousands of years, whereas methane produced by NGVs will last about a decade.³¹ Additionally, the emissions from gasoline vehicles are known to have detrimental health and environmental effects. CO₂ is considered the largest producer to greenhouse climate change. The emissions from gas vehicles cause several respiratory

issues, decrease air quality, and can lead to cardiovascular problems.³² Argonne National Laboratory's GREET model measures lifecycle petroleum use and GHG (greenhouse gas) emissions. It found that NGVs emit 6% - 11% lower levels of GHG than do gasoline in the fuel life cycle. The results were similar in a 2007 study for the California Energy Commission.³³ Although there aren't many refueling stations when compared to that of gasoline (only 1,500 in the U.S., half of which are public), the higher initial cost to create the infrastructure will be worth the benefits politically and environmentally. There exists hundreds of CNG and LNG (compressed and liquified) natural gas stations in the United States; however, there also exists

³⁰<https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=7&year=2013&make=Honda&model=Civic&srctype=ymm>

³¹ <http://www3.epa.gov/climatechange/ghgemissions/gwps.html>

³² <http://www.ehhi.org/reports/exhaust/exhaust06.pdf>

³³ http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html

options for NGV owners to get fueling appliances at home.³⁴ This will assist with the initial transition for the American public to use NGVs.

VI. Conclusion

The dependence of America on crude oil places it in a peculiar position. We have to reevaluate if America's relationship with oil is functional. The concerns for climate change are ever-rising. Additionally, political tensions in oil-producing nations reveal the constant economical risk that America is at every day. Thus, a gradual change from gasoline to LNG, CNG, and RNGs as fuel alternatives provide a solution to both these issues. With recent technology improvements and a change of infrastructure, the long-term benefits of using NGVs will make themselves apparent. Even if initial costs are high, the switch is economically and politically feasible. The option of NGVs for transportation isn't a novel concept. The infrastructure is in place. The sooner America can make the investment in NGVs and break its romance with oil, the better for everyone.

[2,321 words]

³⁴ http://www.afdc.energy.gov/fuels/natural_gas_stations.html