Utilizing new technologies and new opportunities keeps businesses lean and financially efficient. The United States' natural gas resources are changing, and some businesses can use this change to their advantage by converting their vehicle fleets to natural gas. In this paper, I will show that it is economically advantageous for localized fleets of light duty trucks to convert from vehicles fueled by gasoline to vehicles fueled by compressed natural gas.

I. U.S. Natural Gas Overview

Natural gas - often referred to simply as "gas" - is a mix of hydrocarbons, carbon dioxide, nitrogen, and hydrogen sulfide that is refined to leave only methane, a simple hydrocarbon that can be burned to release energy. Natural gas can be created by microscopic methanogenic organisms or by the compression of buried organic material at high temperatures underground. Most natural gas comes from fossil fuels, meaning that natural gas is generally considered a non-renewable resource. Natural gas is often discussed in units of thousand cubic feet. A thousand cubic feet of natural gas (at atmospheric pressure) very roughly costs ten dollars and can produce about 300 kilowatt hours of energy, which is enough to power an average U.S. home for one week.

a. Reservoirs and Extraction

Natural gas is found in gaseous form in natural gas fields and in oil fields underground. Until the 1990s, natural gas was usually a byproduct of oil extraction. Since then, it has commonly been extracted on its own. Natural gas can also be extracted from tiny pores in rocks buried in coal beds and shale formations. There are various methods for extracting natural gas, but they are all essentially drilling down into the reservoir of gas and utilizing its pressure to bring the gas to the surface for processing and distribution.

An innovative process to extract natural gas from shales is hydraulic fracturing, sometimes called "fracking." In this process, a pressurized liquid is forced into the gas shale, causing the reservoir to fracture and create pathways for the gas to reach the surface. While hydraulic fracturing has been in use since 1947, technological improvements to the process have made it much more profitable since 1998. Fracking makes the extraction of shale gas in particular more economically appealing. The process makes it technologically and economically feasible to extract gas from shales, which are a huge source of natural gas. One study estimates that the world's recoverable shale gas could double the

1 http://thebreakthrough.org/archive/shale_gas_fracking_history_and
world's total known gas reserves.\(^2\)

However, hydraulic fracturing can cause considerable environmental damage. The fracking fluid is a mixture of water, sand, and chemicals, some of which are carcinogens. This fluid can be forced into natural aquifers, including those used for residential water supplies, contaminating the water and causing environmental and human damage.\(^3\) Methane leaks caused by fracking can also contaminate the water and the air around the well.

On the other hand, fracking has some relative environmental benefits over the extraction of other fossil fuels. Natural gas production creates lower VOC (volatile organic compound) emissions than oil production. It also creates lower emissions of other air pollutants like SO\(_2\) and benzene than coal or oil production.\(^4\)

The overall message is that the process of fracking damages its surrounding environment, but the resulting increase in natural gas production helps the environment by displacing other fossil fuels that arguably cause even more damage. In any case, hydraulic fracturing greatly facilitates the extraction of shale gas and is playing an increasingly important role in the U.S. energy profile.

**b. Distribution**

The United States currently produces most of the natural gas it consumes. In 2011, net imports comprised only 8\% of U.S. natural gas consumption.\(^5\) The U.S. is projected to become a net exporter of natural gas by 2022, largely because of its increased shale gas production.\(^6\) Most of the current imported gas comes from Canada, and the U.S. exports gas to Mexico. Two-thirds of the United States' natural gas production comes from Texas, California, Louisiana, Florida, and New York.\(^7\)

Once extracted from the wellhead, natural gas has to be distributed to its end-users. Unlike liquid fuels like petroleum, natural gas is neither easy nor inexpensive to distribute because of its low energy density. Natural gas is distributed in three ways: through a pipeline, as compressed natural gas (CNG), or as liquefied natural gas (LNG). Natural gas produced and consumed in the continental United States is almost exclusively distributed through a series of pipelines, but gas is usually liquefied and shipped as LNG if its destination is overseas or farther than 2,500 miles from its source.\(^8\) Gas can be compressed into CNG and shipped via trucks and carriers on a smaller scale, often to

\(^2\) [http://www.nytimes.com/2009/10/10/business/energy-environment/10gas.html?_r=2&partner=rss&emc=rss&src=ig&]
\(^3\) [http://www.psehealthyenergy.org/data/Bamberger_Oswald_NS22_in_press.pdf]
\(^5\) [http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf p.183]
\(^6\) [http://www2.hmc.edu/~evans/AEO2012.pdf p.92]
\(^7\) [http://www.eia.gov/tools/faqs/faq.cfm?id=46&t=8]
\(^8\) [http://en.wikipedia.org/wiki/Natural_gas "Storage and transport"]
end-users.

This distribution system adds significant cost to the consumption of natural gas. The U.S. natural gas pipeline network has more than 200 natural gas pipeline systems, more than 1,400 compressor stations, and 400 underground natural gas storage facilities. Each of these components requires substantial resources to continue operating. The natural gas wellhead price, based in the U.S. off the price of gas at the Henry Hub pipeline in Louisiana, serves as the baseline for the various end-uses of natural gas. Increased transportation distance and lesser distribution networks increase the price of natural gas well beyond the wellhead price. Large-scale consumers located close to a natural gas distribution point - electric power, industry, and citygate (local gas companies) - pay roughly twice as much for natural gas as it costs at the wellhead. Commercial consumers pay another factor or two more, and residential consumers pay about four times as much as the wellhead price.

c. Uses

The electric power sector comprises 39% of the United States' natural gas consumption, followed by industry at 30%, the residential sector at 18%, the commercial sector at 13%, and vehicle fuel at less than one percent. Electric power plants burn natural gas to boil water in a steam turbine, which turns an electric generator to produce and sell electricity. Industry uses natural gas both for heat and as a feedstock for the production of chemicals and products. The residential sector uses natural gas to heat homes and power ovens and ranges. Natural gas is commonly used instead of electricity for these purposes despite its high distribution costs because it burns to produce heat so efficiently. The commercial sector uses natural gas for similar purposes to the residential sector, including space heating and water heating.

Natural gas is considered a relatively clean-burning fuel compared to other fossil fuels like coal and petroleum because it produces less carbon dioxide equivalent of greenhouse gases per kilowatt hour of energy produced. Since methane only has one carbon per molecule, its combustion produces less carbon dioxide per unit of energy than does the combustion of larger hydrocarbon molecules found in other fossil fuels. Some leaders, like President Obama, have encouraged the use of natural gas because they believe its use will displace the use of more highly polluting fuels.

---

10 http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm
11 http://www.naturalgas.org/overview/uses_electrical.asp
12 http://www.naturalgas.org/overview/uses_industry.asp
13 http://www.naturalgas.org/overview/uses_residential.asp
14 http://www.naturalgas.org/overview/uses_commercial.asp
d. Costs and Projections

The price of natural gas has historically followed the price of oil, since the two are substitute goods. Many consumers, like electric power plants, can switch their energy source between oil and natural gas if one is less expensive than the other. Since 2008, the global recession has decreased the demand for natural gas, driving down its price. In recent years, the United States' increased production of natural gas and increased dry natural gas proved reserves have further lowered the cost of natural gas. However, the EIA projects that the price of natural gas will soon start increasing steadily due to an increased cost of extracting gas. This increased cost is a result of the most easily accessible gas being quickly extracted, leaving only less profitable reserves. Right now, the United States' natural gas future is largely uncertain. Our natural gas future depends most strongly on our reserves of shale gas and our ability to extract it.

II. Natural Gas Vehicles

The United States' large reserves of shale gas create new opportunities for growth in different uses of natural gas, including natural gas vehicles. The U.S. has had natural gas vehicles for many decades, but they have become more important in the last fifteen years because of their low emissions compared to gasoline- or diesel-fueled vehicles. In addition to natural gas vehicles reducing dependence on foreign oil, the prospect of shale gas providing relatively cheap domestic natural gas has reinvigorated the appeal of natural gas vehicles.

a. Mechanics

Natural gas vehicles are simply vehicles that combust natural gas instead of conventional fuel. Because the combustion process is essentially the same for natural gas as it is for gasoline and diesel, the main difference between a conventional vehicle and a natural gas vehicle is how the fuel is stored and injected into the engine. Manufacturers produce vehicles designed to use natural gas, whether it's exclusively gas, either natural gas or gasoline, or a combination of gas and diesel. Alternatively, existing vehicles can be retrofitted to use natural gas. Light-duty vehicles, like mid-sized cars, can have natural gas conversion kits installed for only a few thousand dollars.

\[\text{References:}\]

16 [http://www.eia.gov/dnav/ng/hist/n9050us2m.htm](http://www.eia.gov/dnav/ng/hist/n9050us2m.htm)
17 [http://www.eia.gov/dnav/ng/hist/rngr11nus_1a.htm](http://www.eia.gov/dnav/ng/hist/rngr11nus_1a.htm)
Natural gas vehicles use either compressed natural gas or liquefied natural gas. In each case, the gas is stored in specialized cylindrical tanks on the vehicle and is combusted in the engine like conventional fuel. Compressed natural gas is stored and distributed at pressures around 200 times atmospheric pressure, while liquefied natural gas only has to be pressurized to about 15 times atmospheric pressure. In practice, the main distinction between CNG vehicles and LNG vehicles is vehicle size. Liquefied natural gas is more expensive to produce and more difficult to handle than compressed natural gas. Nonetheless, LNG is more desirable than CNG for vehicles that need to travel relatively long distances without refueling because of its higher volumetric energy density, meaning that more energy can be stored in a given volume of LNG than of CNG. Compressed natural gas’s volumetric energy density is only 42% of liquefied natural gas’s and 25% of diesel fuel’s. Whereas LNG has to be liquefied in large facilities and transferred to vehicles by trained personnel, CNG can be compressed relatively easily where it is used and safely pumped into a vehicle by anyone. There are even home refueling appliances available for a few thousand dollars that let users fill up their CNG vehicle in their home overnight.

b. Challenges in the United States

Natural gas vehicles comprise less than one percent of total vehicles in the United States. They are more common in other countries, most notably Iran, Pakistan, Argentina, Brazil, and India. In these countries, CNG vehicles are mostly used in taxicabs and bus fleets, and LNG vehicles only comprise a small portion of total natural gas vehicles. In the U.S., the only light-duty vehicle that is built to run on compressed natural gas is the Honda Civic GX. A larger portion of the U.S.’s natural gas vehicles are heavy-duty vehicles, like fleets of buses.

There are several reasons why there are so few natural gas vehicles in the U.S. One of the most important deterrents from consumers and companies purchasing natural gas vehicles is the country’s lack of refueling sites. While the U.S. has more than 157,000 stations that sell motor gasoline, it has only 1,047 CNG fueling stations and 53 LNG fueling stations, and these natural gas stations are not evenly distributed. This limited set of fueling stations helps explain why such a large portion of the United States' natural gas vehicles are part of a fleet. Fleets of vehicles that run consistent routes from a central hub can refuel every day at the central fueling station.

Another barrier to the use of natural gas vehicles is their increased upfront cost. Natural gas vehicles cost significantly more than their conventional fuel counterparts because of the need for larger, heavier fuel storage and electronics to monitor the gas use in the engine. For instance, the CNG-powered Honda Civic GX costs about $27,000 while the comparable gasoline-powered

23 http://www.ngvglobal.com/home-vehicle-refuelling-%E2%80%93-an-idea-whose-time-has-come-1005
25 http://www2.hmc.edu/~evans/AEO2012.pdf p.36
Honda Civic LX only costs about $18,000, meaning the natural gas version costs about 50% more.\textsuperscript{26} Similar comparisons are true for heavy-duty vehicles.

Additionally, natural gas vehicles have more limited range than conventional vehicles because of the low energy densities of CNG and LNG relative to gasoline and diesel. The process of refueling natural gas vehicles also usually takes longer than refueling conventional vehicles, and few natural gas vehicles are available for consumers.

c. Advantages

Despite these considerable shortcomings, natural gas vehicles have several advantages over conventional vehicles. Natural gas vehicles are quieter than conventional vehicles and wear the engine less because of methane's clean combustion, reducing expenses on vehicle maintenance. Natural gas vehicles are also safer than gasoline or diesel vehicles because natural gas is lighter than air and is only flammable in a small range of concentrations.\textsuperscript{27}

Natural gas vehicles produce less emissions than conventional vehicles do, putting them in a key position to reduce vehicle emissions.\textsuperscript{28} Natural gas vehicles do not need petroleum, which means their replacement of conventional vehicles reduces the United States' dependence on foreign energy, especially with the growth of domestic natural gas production resulting from the growth of shale gas. State and federal subsidies encourage the use of natural gas vehicles to reduce greenhouse gas emissions and to reduce our dependence on foreign oil.\textsuperscript{29}

The most important appeal of natural gas vehicles is the low cost of their fuel. CNG currently costs about two-thirds as much as gasoline and diesel per gasoline gallon equivalent (GGE). The average U.S. retail price of gasoline in October 2012 was $3.82 per gallon, while the average U.S. retail price of CNG was only $2.12 per gasoline gallon equivalent.\textsuperscript{30}

This large reduction in fuel cost eventually pays back the initial investment in a CNG vehicle. The payback period decreases with increased miles driven but is expected to be in the range of five to ten years for fairly high usage.\textsuperscript{31} Based on projections of shale gas and oil supply, the cost difference between natural gas and gasoline will likely become even larger in the next twenty-five years, decreasing the payback period.

\textsuperscript{26} http://www.consumerreports.org/cro/2012/03/the-natural-gas-alternative/index.htm
\textsuperscript{27} http://www.cleanvehicle.org/committee/technical/PDFs/Web-TC-TechBul2-Safety.pdf
\textsuperscript{28} http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html
\textsuperscript{29} http://www.nytimes.com/2012/06/22/business/natural-gas-vehicles-are-a-compelling-target-for-a-federal-program.html?pagewanted=all&_r=0
\textsuperscript{30} http://www.afdc.energy.gov/data/tab/fuels-infrastructure
\textsuperscript{31} http://www2.hmc.edu/~evans/AEO2012.pdf p.38
The use of natural gas vehicles in the near future depends greatly on the extent to which the necessary infrastructure is created. The problem is that consumers do not want to buy natural gas vehicles before they have reasonable access to refueling stations, while at the same time natural gas vehicle refueling stations are unlikely to be built unless they know there will be enough natural gas vehicles to pay back their capital investment. A possible solution to this apparent impasse is to implement a government policy that promotes the purchase and use of natural gas vehicles and the creation of natural gas refueling stations in such a way that aims to match their growth. If the United States can achieve this development, we will be able to greatly increase our use of natural gas vehicles, thereby saving money and reducing our emissions and our dependence on foreign oil.

III. Cost Analysis of A Model Fleet

Due to the United States' limited natural gas refueling infrastructure, natural gas vehicles realistically work best when they regularly travel the same route with known refueling stations or return to a central hub every day. The former is applicable to many trucking fleets, and the latter applies to many fleets of smaller vehicles. This analysis will address this second case. Several examples of vehicle fleets that travel throughout the day and return to a specific location at the end of the day are large delivery trucks, medium-sized mail trucks, and relatively small courier vans.

In this analysis, we will use the GMC 2013 Savana 2500 Cargo Regular Wheelbase Work Van RWD as our model vehicle. This Class 2 fleet vehicle is available for purchase with a conventional fuel system or with a compressed natural gas fuel system, and it is similar to many existing fleets' vans. For instance, AT&T has already purchased more than 1,000 CNG Chevrolet Express Cargo vans for their fleet - the Express and the Savana have similar fuel economy, practically identical dimensions, and the same gross vehicle weight rating (GVWR). This type of van can be used for a variety of tasks, including dispatching repairmen and delivering packages. Our hypothetical fleet will consist of 40 Savanas based in southern California used for, say, local package delivery.

32 http://www2.hmc.edu/~evans/AEO2012.pdf p.36
33 http://www2.hmc.edu/~evans/AEO2012.pdf p.38
34 http://www.wrcog.cog.ca.us/downloads/050205%20Truck%20Type%20Appendix.pdf
a. Fixed Cost of Each Type of Savana

The 2013 Savana Cargo 2500 with a gasoline fuel system and standard options costs $28,250 MSRP\(^{37}\). If the van is purchased in Los Angeles, it has total registration fees of $284 and total use/sales tax of $2,543\(^{38}\).

Gasoline-fueled van:

\[
\text{fixed cost} = \$28,250 + \$284 + \$2,543 = \$31,077
\]

Altogether, the gasoline-fueled vehicle's fixed cost is $31,077.

The 2013 Savana Cargo 2500 with a three-tank compressed natural gas fuel system and the subsequently required options costs $42,970 MSRP\(^{37}\). If it is purchased in Los Angeles, it has total registration fees of $379 and total use/sales tax of $3,867\(^{38}\). Rebates on natural gas vehicles are available in some areas to promote the relatively clean fuel, but rebates on individual vehicles will not be factored into this analysis.

Since our model requires a central refueling station at the fleet's hub, the cost of constructing and installing a CNG fueling station must also be factored into the vehicle's fixed cost. The two types of CNG fueling stations are fast fill stations and time fill stations. Fast fill stations can refill a twenty gasoline gallon equivalent tank in only five minutes, but they are expensive to build\(^{39}\). Time fill stations use lower pressure natural gas and take much longer to refuel vehicles, but they are significantly cheaper\(^{39}\). Since the fleet will already spend every night at the hub, it makes much more sense to use a time fill station. The component cost of a CNG time fill station that supports 40 vehicles refueling up to 33 GGE in a 10-hour period is around $375,000, and the installation cost is around $300,000\(^{40}\).

These costs can be subsidized by the federal government's Alternative Fuel Infrastructure Tax Credit by up to $30,000\(^{41}\). Adding these two costs together, subtracting the tax credit, and dividing by the number of vehicles, we see that each vehicle in the fleet needs to contribute about $16,125 of fixed cost for the fueling station.

\[
\text{fueling station cost per vehicle} = \frac{\$375,000 + \$300,000 - \$30,000}{40 \text{ vehicles}} = \$16,125
\]

\(^{38}\) https://www.dmv.ca.gov/wasapp/FeeCalculatorWeb/newVehicleFees.do
\(^{39}\) http://www.afdc.energy.gov/fuels/natural_gas_cng_stations.html
\(^{40}\) http://www.anga.us/media/content/F7D3861D-9ADE-7964-0C27B6F29D0A662B/files/11_1803_anga_module5_cng_dd10.pdf
\(^{41}\) http://www.afdc.energy.gov/laws/law/US/10513
Combining the CNG van's sticker price, registration fees, taxes, and contribution to fueling station cost, the natural gas vehicle's total fixed cost is $63,341, slightly more than double the gasoline vehicle's fixed cost.

CNG-fueled van:

\[
\text{fixed cost} = 42,970 + 379 + 3,867 + 16,125 = 63,341
\]

b. Operating Costs

Both types of vehicle have operating costs beyond their fixed costs. They both have to pay for insurance, maintenance, repairs, and their respective fuels. Additionally, the natural gas van has to pay its share of the fueling station's operating costs.

We will assume both vehicles have the same costs for insurance, maintenance, and repairs. Although these costs depend greatly on the location and use of the vehicles, a reasonable assumption is that they will cost $1,500 in insurance and $750 in maintenance and repairs each year\(^{42}\).

The vehicles' fuel costs vary directly with the amount they are driven. In our model of package delivery, we will assume that 90% of the fleet is in use for nine hours a day, five days a week, 52 weeks a year. We will simplify the routes by expecting each active van to drive at 30 miles per hour in a mix of city and highway driving conditions for 90% of the time it is out of the hub. In this model, each van drives:

\[
\text{mileage} = 0.9 \text{ use} \times 9 \frac{\text{hours}}{\text{day}} \times 5 \frac{\text{day}}{\text{week}} \times 52 \frac{\text{week}}{\text{year}} \times 30 \frac{\text{mile}}{\text{hour}} \times 0.9 \text{ driving} = 56,862 \frac{\text{mile}}{\text{year}}
\]

Accounting for the Savana's average fuel economy of 13.5 miles per gallon and 13.5 miles per GGE\(^{43,44}\), each van's annual gasoline/GGE usage is:

\[
\text{annual gasoline or CNG use} = 56,862 \frac{\text{mile}}{\text{year}} \times \frac{1}{13.5} \frac{\text{gal}}{\text{mile}} = 4,212 \frac{\text{gal}}{\text{GGE}} \text{ year}
\]

The cheaper cost of natural gas per gasoline gallon equivalent than gasoline is the primary advantage of the natural gas van over the conventional van. In calculating the two vehicles' annual fuel costs, projected prices of gasoline and natural gas are crucial. The model's gasoline-fueled van is expected to use publically available fueling stations and to pay the average cost for gasoline. In contrast, the model's CNG-fueled van is expected to use the fleet's fueling station, which is likely to pay prices for its natural gas similar to the prices paid by commercial facilities\(^{45}\). The natural gas fuel prices used below do not intrinsically account for the significant

\(^{42}\) http://www.edmunds.com/gmc/savana-cargo/2012/tco.html?style=101394122&zip=91711


\(^{45}\) http://www2.hmc.edu/~evans/AEO2012.pdf p.37
cost of compressing the natural gas into usable CNG - those costs are reflected in the CNG station's operating costs.

The EIA projects motor gasoline prices to rise from $3.34 per gallon to $4.95 per gallon (in nominal dollars, including taxes) over the next ten years\textsuperscript{46}. The EIA projects the price paid by the commercial sector for natural gas to increase from about $1.05 per GGE to $1.47 per GGE (in nominal dollars, excluding taxes) over the next ten years\textsuperscript{47}. Including the $0.69 per GGE tax from California and the federal government, these prices are $1.74 per GGE and $2.16 per GGE (in nominal dollars, including taxes)\textsuperscript{48}.

Assuming both fuels' prices rise steadily, the average cost over the next ten years is $4.15 per gallon of gasoline and $1.95 per GGE of fleet CNG. Using these values, we can calculate each vehicle's annual variable cost due to fuel consumption.

Gasoline-fueled van:

\[
\text{annual fuel cost} = \frac{4,212 \text{ gal}}{\text{year}} \times \frac{4.15 \text{ dollar}}{\text{gal}} = 17,480 \text{ dollar/ year}
\]

CNG-fueled van:

\[
\text{annual fuel cost} = \frac{4,212 \text{ GGE}}{\text{year}} \times \frac{1.95 \text{ dollar}}{\text{GGE}} = 8,213 \text{ dollar/ year}
\]

Taking the difference in these two annual costs shows that the CNG-fueled van's fuel costs are $9,267 per year less than the gasoline-fueled van's fuel costs.

We also have to take into account the CNG station's operating costs. The natural gas van's portion of the fueling station's operating costs is one-fortieth of the station's annual operating costs, which are primarily comprised of its maintenance costs and electricity costs to compress the incoming natural gas. The CNG station's annual maintenance cost can be expected to be around $96,000 per year, and its annual electricity costs can be expected to be around $24,000 per year\textsuperscript{49}. So, dividing the sum of these two costs by forty vans, each van's portion of the fueling station's annual operating costs is about $3,000 per year. This type of cost is incorporated into publically available natural gas fueling stations' prices for their CNG.

Adding up all these variable costs - insurance, maintenance, repairs, fuel, and, for the CNG van, fueling station operating costs - we can find each vehicle's annual operating cost.

Gasoline-fueled van:

\[
\text{annual operating cost} = \frac{1,500 \text{ / year}}{\text{ / year}} + \frac{750 \text{ / year}}{\text{ / year}} + \frac{17,480 \text{ / year}}{\text{ / year}} = 19,730 \text{ / year}
\]

CNG-fueled van:

\[
\text{annual operating cost} = \frac{1,500 \text{ / year}}{\text{ / year}} + \frac{750 \text{ / year}}{\text{ / year}} + \frac{8,213 \text{ / year}}{\text{ / year}} = 18,463 \text{ / year}
\]

\textsuperscript{46} http://www2.hmc.edu/~evans/AEO2012.pdf p.156
\textsuperscript{47} http://www2.hmc.edu/~evans/AEO2012.pdf p.137
\textsuperscript{48} http://www.gaspricewatch.com/web_gas_taxes.php
\textsuperscript{49} http://www.afdc.energy.gov/pdfs/47919.pdf p.6
annual operating cost = $1,500/yr + $750/yr + $8,213/yr + $3,000/yr = $13,463/yr

So, taking the difference between these two costs, we can see that a CNG-fueled van in this fleet costs $6,267 less per year in operating costs than a gasoline-fueled van.

c. Amortization and Total Annual Cost

To amortize each vehicle over its lifetime, we will estimate each vehicle to be used for ten years. Given the high annual mileage of each van, ten years is a generous estimate. However, given that the vans are a 2013 model that is designed for more rugged use than just deliveries, we can reasonably allow this long lifetime.

Given the gasoline-fueled van's fixed cost of $31,077 and the CNG-fueled van's fixed cost of $63,341 and assuming an annual discount rate of 6%, we can use the annuity formula to calculate each van's amortized cost.

Gasoline-fueled van:

\[
\text{variable annual cost (annual payment)} = \frac{($31,077)(1 + 0.06)^{10} - 1}{0.06} = \frac{($31,077)(1 + 0.06)^{10} - 1}{0.06} = $4,222 \text{ per year}
\]

CNG-fueled van:

\[
\text{variable annual cost (annual payment)} = \frac{($63,341)(1 + 0.06)^{10} - 1}{0.06} = \frac{($63,341)(1 + 0.06)^{10} - 1}{0.06} = $8,606 \text{ per year}
\]

So, subtracting the gasoline-fueled van's annual payment from that of the CNG-fueled van, we see that the amortized annual payment of the gasoline-fueled van is $4,384 cheaper than that of the CNG-fueled van.

To find each vehicle's total annual cost, we add its amortized annual payment to its annual variable cost.

Gasoline-fueled van:

\[
\text{total annual cost} = $4,222/\text{year} + $19,730/\text{year} = $23,952/\text{year}
\]

CNG-fueled van:

\[
\text{total annual cost} = $8,606/\text{year} + $13,463/\text{year} = $22,069/\text{year}
\]

With everything taken into account, the model gasoline-fueled van costs the fleet owner $23,952 per year, and the model CNG-fueled van costs the fleet owner $22,069 per year.

Dividing this total cost per year by the model vans' miles driven per year gives the total cost of each vehicle per mile driven:

Gasoline-fueled van:

\[
\frac{23,952 \text{ dollar/year}}{56,862 \text{ mile}} \times \frac{1 \text{ year}}{\text{56,862 mile}} = 42.1 \text{ cents per mile}
\]
CNG-fueled van:
\[
22,069 \text{ dollar/year} \times \frac{1 \text{ year}}{56,862 \text{ mile}} = 38.8 \text{ cents per mile}
\]

Using the previously calculated total annual costs, we can find the total savings for using compressed natural gas vehicles instead of gasoline vehicles:

\[
\text{total annual savings per vehicle} = \frac{23,952 \text{ year} \times \text{vehicle}}{22,069 \text{ year} \times \text{vehicle}} = \frac{1,883 \text{ year} \times \text{vehicle}}{}
\]

\[
\text{total ten-year savings per vehicle} = \frac{1,883 \text{ year} \times \text{vehicle}}{\times 10 \text{ years}} = \frac{18,830 \text{ year} \times \text{vehicle}}{}
\]

\[
\text{total annual savings for fleet} = \frac{1,883 \text{ year} \times \text{vehicle}}{\times 40 \text{ vehicles}} = \frac{75,320 \text{ year}}{}
\]

\[
\text{total ten-year savings for fleet} = \frac{75,320 \text{ year}}{\times 10 \text{ years}} = \frac{753,200 \text{ year}}{}
\]

To finally reach a simple, understandable result, we can see what portion of the total annual cost of a gasoline-fueled vehicle can be saved by using a CNG-fueled vehicle instead:

\[
\text{savings as portion of gasoline-fueled vehicle} = \frac{1,883 \text{ year} \times \text{vehicle}}{23,952 \text{ year}} = 7.9\%
\]

IV. Conclusion

As we have seen in this simplified model of a fleet of 40 vans, an investment in compressed natural gas vehicles and in a CNG fueling station brings a significant upfront cost but substantial savings in the long run. Furthermore, the fueling station can be used for subsequent sets of CNG fleet vehicles at only its operating cost, providing even greater savings in the following years.

The adoption of natural gas fleet vehicles also has less easily quantifiable benefits. Natural gas burns cleaner than gasoline and thereby helps the environment, and a company's public image can reflect this environmentally friendly change. Lastly, more natural gas vehicles will help spur the creation of more publically available natural gas refueling stations, helping to build out a much-needed natural gas refueling infrastructure in the United States.

[4,300 words]