Building a Business Case for Compressed Natural Gas in Fleet Applications

George Mitchell
National Renewable Energy Laboratory

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Technical Report
NREL/TP-5400-63707
March 2015

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All assumptions and inaccuracies are the responsibility of the author alone.

Table of Contents

List of Figures

List of Tables

1 Introduction

Natural gas is a clean-burning, abundant, and domestically produced source of energy. Compressed natural gas (CNG) has recently garnered interest as a transportation fuel because of these attributes and because of its cost savings and price stability compared to conventional petroleum fuels.

Many aspects of a CNG vehicle and fueling infrastructure project combine to determine overall profitability. The National Renewable Energy Laboratory developed the Vehicle Infrastructure and Cash-Flow Evaluation (VICE) model to help businesses and fleets evaluate the financial soundness of CNG vehicle and CNG fueling infrastructure projects. The VICE model demonstrates the relationship between the operational parameters of the vehicle fleet and financial profitability. The findings of the original VICE model were limited to municipal fleets (Johnson, 2010).[1]

The VICE model version 2.0 is an upgrade and expansion of the VICE model.

Enhancements to VICE 2.0, as reflected in the current business case, are significant. CNG projects may be categorized as vehicles and infrastructure or vehicle acquisitions only. Investments for vehicles and supporting infrastructure may now be staggered across a 20-year project timeline. Vehicle investment may be made independently, or decoupled, from infrastructure investment. And the vehicle fleet may now be composed of several common types of conventionally (gasoline and diesel) fueled heavy- and light-duty vehicles, including transit buses, school buses, trash trucks, delivery trucks, paratransit shuttles or “para shuttles,” and taxi cabs.

VICE 2.0 incorporates significant visual and reporting enhancements, including graphic images of return on investment, cumulative cash flow, and payback periods. The model calculates petroleum displacement (annual and cumulative) and annual greenhouse gas reductions, and displays them based on the selected fleet and attributes. This report describes how to use the VICE model.

This report is divided into two main sections. Section 2 is an overview of VICE 2.0 and establishes the default values for the base-case vehicles. These values attempt to represent the most applicable parameters affecting the financial performance of CNG projects for fleets of each vehicle type. Section 3 investigates how sensitive profitability is to different operational parameters, such as fuel cost and vehicle miles traveled (VMT).

This business case targets fleets that are well suited to using CNG, such as those that drive routes starting and ending in the same location and, thus, can refuel at a central location.

[1] http://www.afdc.energy.gov/pdfs/47919.pdf

2 General Overview

VICE 2.0 is the second generation of the VICE financial model developed by the National Renewable Energy Laboratory for fleet managers to assess the financial soundness of converting their fleets to run on CNG.

VICE 2.0 uses a number of variables for infrastructure and vehicles to estimate the business case for decision-makers when considering CNG as a vehicle fuel. Enhancements in version 2.0 include the ability to select the project type (vehicles and infrastructure or vehicle acquisitions only), and to decouple vehicle acquisition from the infrastructure investment, so the two investments may be made independently. Outputs now include graphical presentations of investment cash flow, payback period (simple and discounted), petroleum displacement (annual and cumulative), and annual greenhouse gas reductions. Also, the Vehicle Data are now built around several common conventionally fueled (gasoline and diesel) fleet vehicles.

Descriptions of the various model sections and available inputs follow. Each description includes default values for the base-case business model, which was created so economic sensitivities can be investigated by altering various project parameters one at a time.

2.1 Baseline Parameters

The inputs are divided into seven segments. The first five segments, 2.1.1 through 2.1.5, are included in Section 2 below: Project Type, Investment Type, Tax Exemption Status, Vehicle Data, and Infrastructure/Fuel/Operations/Incentives, respectively. The last two segments are described in 3.7, Fleet Composition, and 3.8.1 , Station Cost. Each inputs segment is described in detail.

2.1.1 Project Type

Two project types are available: (1) vehicles and fueling infrastructure; and (2) vehicle acquisitions only. Typically fleets require that infrastructure be acquired to support any vehicle acquisition, but occasionally fleets rely on fueling infrastructure that was developed by a second party. For the base case, a project that includes vehicles and fueling infrastructure is considered.

2.1.2 Investment Type

VICE 2.0 allows two types of investment strategies to be considered for a particular project type. Investments in vehicles and fueling infrastructure may be coupled or decoupled. These investments may be made at any time during the life of a program. VICE 2.0 defines the project life to the longest useful life of the vehicles selected and is capped at a maximum of 20 years. Selecting a coupled investment type "locks" infrastructure deployment to vehicle acquisition so the infrastructure is sized according to the vehicle requirements, and both investments are made in the same project year.

Selecting a decoupled investment strategy "unlocks" infrastructure deployment and vehicle acquisition so these capital investments can be made independently of each other at any time during the project life. Fleets that already use CNG may use this type of investment strategy as they increase their fleet size by first building additional capacity and then adding more vehicles. A decoupled investment strategy requires great care to ensure infrastructure throughput and vehicle fuel use are similar throughout the program life. It is very easy to develop an investment arrangement with a very short payback period in which the infrastructure is inadequate to meet the fueling needs of the vehicle rollout selected.

To avoid this, users should consult Figure 2 in Section 3. This visualization is provided to illustrate the growth of infrastructure capacity and fleet fuel use over the lifetime of the project.

2.1.3 Tax Exemption Status for Fuel

The federal and state governments tax fuel purchases and may provide incentives for the use of alternative fuels through tax credits. These credits are intended to reduce the overall cost of using natural gas—and other alternative fuels—as vehicle fuels. The alternative fuel tax credits are designed so that tax-exempt and tax-paying entities can capitalize on them (either directly or through fuel, vehicle, or equipment providers). Therefore, tax-exempt status has the primary effect of reducing the prices of diesel and gasoline.

To reflect a fleet operated by a state or local entity, tax-exempt fleet status is considered for the base case.

2.1.4 Vehicle Data

VICE 2.0 models seven vehicle types and includes comparison to gasoline as well as diesel. Default values for incremental cost, average annual VMT, average vehicle life, and expected fuel economy for each vehicle using its conventional fuel have been preloaded into the vehicle data section of the model. These default values come directly from the original VICE model and have been updated where appropriate. The vehicle data table allows tailoring of the vehicle data to more closely represent vehicles in the particular fleet under consideration. This can significantly enhance the accuracy of the business model prediction. Additional vehicle types may be modeled if these values are known. Entries in the vehicle data table that may be manipulated follow:

- **Vehicle Type.** Vehicle types range from light-duty passenger vehicles to medium-duty delivery vehicles to heavy-duty vehicles such as transit buses and garbage trucks.
- **Incremental Cost.** This represents the cost of equipping a vehicle to operate on CNG rather than on gasoline or diesel. This cost can include hardware and installation on an existing vehicle, but usually consists of the cost differential between a conventional and a CNG-fueled vehicle of the same or a similar model. Incremental costs were developed with the help of industry experts.
- **Average VMT.**[2,3] This is the average annual VMT. Data specific to your fleet may vary significantly, so real-world data reflecting your fleet will significantly improve fuel use estimates and the accuracy of overall economic performance.
- **Average Vehicle Life.**[4] This is the vehicle service life, or how long the vehicle is planned to be used. Adjusting average vehicle life to reflect the service life of vehicles in

[2] http://www.afdc.energy.gov/data/categories/vehicles--2#10310
[3] Public Transportation Fact Book 2011: http://www.apta.com/resources/statistics/Documents/FactBook/APTA_2011_Fact_Book.pdf
[4] Report &- State of the Industry: U.S. Classes 3-8 Used Trucks, http://www.actresearch.net/wp-content/uploads/2013/04/usedtruck12121.pdf

your fleet may significantly impact the net present value (NPV) as well as the expected time of the project payback period.

- **Fuel Economy Diesel.**[5,6] This is the average fuel economy in miles per diesel gallons. This value is used to estimate the CNG fuel use and required station size or throughput. If you have fuel use records for your fleet, you can input this value to improve the results of the model.
- **Fuel Economy Gasoline.**[7,8] This is the average fuel economy in miles per gasoline gallons. This value is used to estimate the CNG fuel use and required station size or throughput. If you have fuel use records for your fleet, you should be able to report this value to refine the results of the model.
- **Efficiency Differences/Loss.** This value represents the expected difference in fuel economy between similar vehicles operating on conventional fuels and CNG. Gaseous fuels like CNG have a lower energy density than do liquid fuels like gasoline and diesel. Engines that have been optimized to run exclusively on CNG (some dedicated OEM systems) can deliver fuel economy performance similar to that of gasoline vehicles, while engines that have been converted to run on CNG (or bi-fuel vehicles) generally experience reduced fuel economy when compared on a miles-per-gallon basis (or diesel gallon equivalent [DGE], or gasoline gallon equivalent [GGE] basis). This efficiency difference varies depending on engine type and vehicles being compared. Engines that use compression-ignition (e.g., diesels) are generally more efficient than those that use spark-ignition (e.g., gasoline and CNG engines). The VICE 2.0 model reflects these fuel economy differences in units of miles per gasoline gallon equivalent (mpGGE).
- **Hostlers or Attendants Needed.** Additional employees who refuel, clean, and maintain fleets are not considered an additional cost because they are required by conventionally fueled vehicles. So, the default value is zero. However, staff may need to be adjusted.

2.1.5 Infrastructure, Fuels, Operations, and Incentives

2.1.5.1 Compressed Natural Gas Station Cost

VICE 2.0 uses cost and throughput data gathered from U.S. Department of Energy-awarded CNG infrastructure projects from across the country. These data were then plotted and linear regression was performed. A best-fit trend line was determined, and this equation was then used in the model to predict station cost as a function of monthly capacity (see Figure 1). This methodology was seen as preferable to modeling the entire fueling station piecemeal and attempting to cover all foreseeable hardware combinations and site-specific costs. The data applied to hardware in the ground and final project costs. The baseline data for station cost can be modified as more data become available over time.

Between 2006 and 2014, the Federal Alternative Fuel Infrastructure Tax Credit was available for up to 30% of the cost of building a CNG station and was capped at $30,000. This tax credit has

[5] Transportation Energy Data Book, Edition 31, Table 5.1, Summary Statistics on Class 3-8 Single Unit Trucks
[6] Transportation Energy Data Book, Edition 31, Table 4.33, Summary Statistics on Demand Response Vehicles
[7] Transportation Energy Data Book, Edition 31, Table 4.3, Summary Statistics on Class 1, 2, 2b Trucks
[8] Transportation Energy Data Book, Edition 31, Table 4.1, Summary Statistics for Cars

expired; however, it has previously expired and been retroactively renewed.[9] Tax-exempt entities could pass this credit to the organization installing the station. VICE 2.0 assumes that the station constructor applies this tax credit to the purchase price to lower the overall financial liability, and users should input any tax credit available to them.

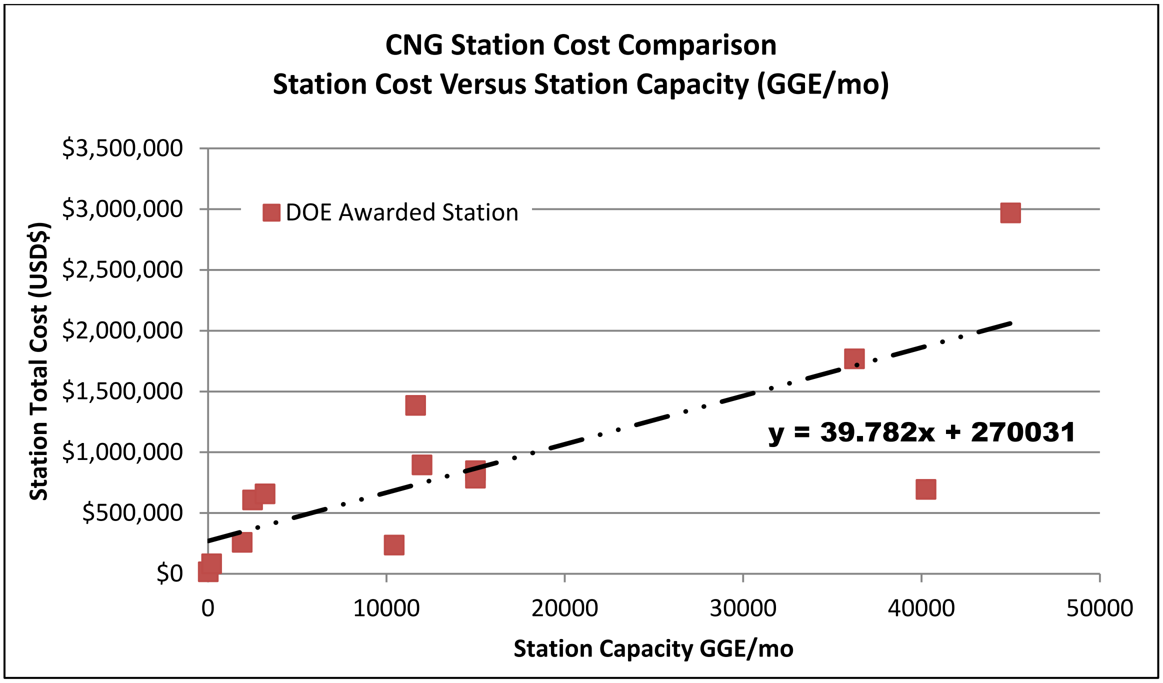

Figure 1. CNG station costs

2.1.5.2 Compressed Natural Gas Project Salvage Value

VICE 2.0 assumes that project life, or investment period, extends through the useful life of the last vehicle in service. This period can change depending on the vehicle types and timing of acquisition. If the useful life of the last vehicle in service extends beyond 20 years, the project life is capped at 20 years. All infrastructure is then assumed to be salvaged.

A CNG station infrastructure salvage value amounting to 20% of the total infrastructure investment is assigned at the termination of the project life. The 20% value is constant regardless of age, because salvage value is determined more by component demand than by component age. The value of 20% was carried over from the original VICE model and chosen after two CNG station technicians—who had overseen dozens of projects—were interviewed.

2.1.5.3 Fuel Pricing and Inflation

The default liquid fuel prices used in the VICE 2.0 model are national commercial retail averages and come from the U.S. Energy Information Administration (EIA) Gasoline and Diesel Fuel Update.[10] Fuel prices are updated weekly and provide national and regional retail averages for conventional fuels such as gasoline and diesel. The price of CNG was calculated based on the

[9] http://www.afdc.energy.gov/laws
[10] http://www.eia.gov/petroleum/gasdiesel/

EIA-reported 6-month national average price of commercially delivered natural gas.[11] This value is then converted from $/ft^3 to $/GGE using EIA conversion factors of 1,023 Btu/ft^3 and 124,238 Btu/gasoline gallon. Used in the base case, prices for gasoline, diesel, and CNG are $3.45/gallon, $3.91/gallon, and $1.18/GGE, respectively.

Fleet operators may take advantage of alternative purchasing methods for their natural gas, such as purchasing from a commodities market, a gas marketer in a deregulated market, or a vendor who purchases fuel from a third party and offers a contract for fuel and services over a fixed period. Because pricing in these methods is based on individual contracts, tracking fuel prices becomes extremely difficult. In any case, users of VICE 2.0 will obtain more accurate results by incorporating the fuel prices available in their particular location/situation.

Fuel price inflation rates for gasoline, diesel, and CNG were taken from EIA's 2014 Early Release Annual Energy Outlook[12] and are projected (in nominal dollars) for the 30-year period 2010–2040. The inflation rates used in the base case for gasoline, diesel, and CNG are 2.5%/year, 2.9%/year, and 1.8%/year, respectively.

2.1.5.4 Fuel Taxes

Fuel taxes used in the VICE model are taken from EIA's Gasoline and Diesel Fuel Update. VICE 2.0 adjusts the retail fuel price depending on the selected tax-exempt status. For the base case, all the fleets under consideration are assumed to be government owned and thus granted tax-exempt status.

VICE 2.0 allows for the Alternative Fuel Excise Tax Credit. When last implemented, a tax credit amounted to $0.50/GGE ($0.55/DGE) of CNG purchased. This credit was applicable to tax-exempt and tax-nonexempt fleets. Because this tax credit expired after December 31, 2014, for the base case it has been set to $0.00.

Users may customize the available tax inputs to more accurately reflect their situation. For example, some state/local fleets are exempt from state and local taxes, but not federal taxes. Likewise some federal fleets are exempt from federal taxes but are still required to pay state and local highway motor fuel taxes. These situations can be incorporated into the VICE model.

2.1.5.5 Operations

For vehicles, VICE 2.0 uses evidence gathered regarding maintenance and operation (M&O) through discussions with industry experts. The evidence supports both a cost decrease and a cost increase when switching from a vehicle's native fuel (diesel or gasoline) to CNG. It is unclear which factors most influence M&O costs. M&O parity is assumed across the line of vehicle types represented in VICE 2.0.

VICE 2.0 assumes that the fuel retailer wraps the M&O costs for a diesel or gasoline fueling station into the retail price of the conventional fuel. Natural gas prices do not normally include

[11] http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm
[12] http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014ER&subject=3-AEO2014ER&table=3-AEO2014ER&region=1-0&cases=ref2014er-d102413a,full2013-d102312a

CNG station costs because most natural gas is sold to the non-transportation market. Therefore, all M&O costs for the CNG station are added to the project cost.

M&O costs of a CNG station include parts, consumables, labor, breakdowns, and on-call staff to keep a station functioning properly. The labor is generally provided by a technician who is on call for a number of stations in a given area. The estimated annual M&O costs used in the model are 5% of the upfront cost of a large station and 8% of the upfront costs of a small station. This assumption came from Rob Adams (Marathon Technical Services). A rule-of-thumb estimate that takes most of these variations into account was needed because M&O costs vary so widely according to station. This estimation technique is based on the idea that when more money is spent on equipment, more money must be spent to keep up and replace the equipment. It also takes into account economies of scale.

The “8% to 5%” was distilled into an equation so it could be inserted into the model. As shown in Figure 2 (Section 3), a polynomial equation fit the line very well for the range from 0 to 300,000 DGE throughputs. After that, it was set to rise 0.06% per DGE. The polynomial equation used in the model is:

$$Y = -2.225*10^{-7}X^2 + 0.125X + 7{,}014.3$$

Rob Adams’ estimation technique was chosen because it averages the M&O estimates received from other sources. The three estimates are different because the contractors rely heavily on station-specific circumstances that were not available for these general estimates.

2.1.5.6 Financing and Incentives

The financial model used in VICE 2.0 assumes that CNG projects will be funded through the organizing entity’s annual budget. When gauging the financial soundness of any investment, it is prudent to consider the payback period, rate of return (ROR), and NPV of the project.

NPV is defined as the total present value of a project, including all capital costs present and future, and any cost savings accrued during the project lifetime. When calculating NPV, all future cash flows are discounted at a specific rate called the *discount rate* to compensate for the time value of money, i.e., the fact that money is worth more today because it may be used for other purposes that result in greater returns.

Determining the proper discount rate to be applied to any investment is often difficult. The higher the discount rate, the lower the present value of future money. Private sector investment generally uses 10%, because a discount rate as that is seen as the long-term average of the U.S. stock market. Municipal governments like to use 6% because that can typically be raised through bond sales. The default value in the model is 6%.

VICE 2.0 allows for vehicle tax incentives to be incorporated into the financial decision about any CNG fleet scenario..

2.1.5.7 Vehicle Maintenance and Operation

VICE 2.0 assumes that vehicle M&O costs between traditionally fueled vehicles and CNG-fueled vehicles are identical. Interviews with fleet operators and industry experts uncovered often contradictory evidence of operational costs between vehicles operated on each fuel.

2.1.5.8 Vehicle Acquisition and Infrastructure Investment

In a significant departure from the original VICE model, VICE 2.0 allows any of the seven vehicle types to be acquired at any time during the 20-year project timeline. Infrastructure investment may be made separately from vehicle acquisitions, as well, at any time during the project. This strategy allows incremental build-out to a different timeline than vehicle acquisitions.

3 Compressed Natural Gas Project Development

Each fleet is unique, which makes every business case unique. Fleet operators should look closely at the operating parameters of their fleets, because these parameters may deviate significantly from the base case. This section is intended to give fleet operators a starting point and show how changes to the operational parameters of the base case affect the profitability of the project.

3.1 Upfront Project Decisions

Caution should be exercised when making independent vehicle and infrastructure investments, even though a project shows potential with respect to the investment metrics, to ensure that fuel use does not exceed fuel availability. VICE 2.0 provides a quick graphical check for this situation.

Figure 2 shows incremental capacity (capacity built with each investment), total built capacity, and the capacity required for the vehicles in service. It also shows the drop-off in fuel requirement as vehicles are retired and the remaining overcapacity of the infrastructure. This plot is available on the results page of VICE 2.0.

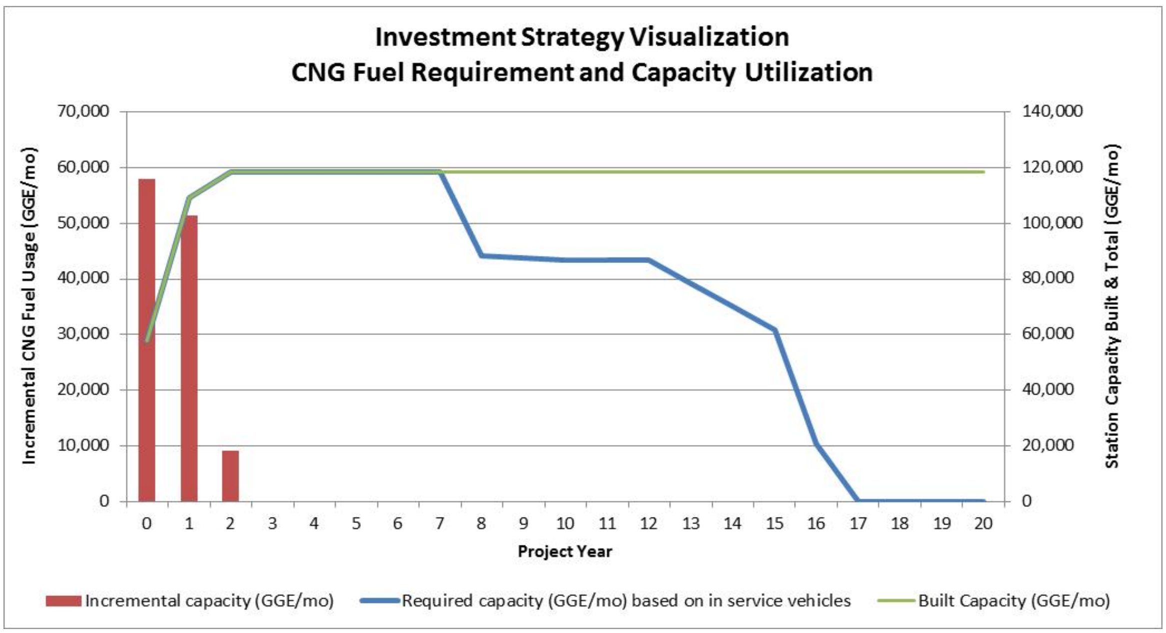

Figure 2. Investment strategy visualization—fuel use and availability

VICE 2.0 allows investments to be made at times other than the origination year (year 0) of the project. Figure 3 shows a simple example of how this affects the payback metric. Underlying this figure is a fleet of 200 vehicles (44 transit buses, 15 school buses, 80 refuse trucks, 5 shuttle buses, 10 delivery vans, 16 pickup trucks, and 30 taxis) with fueling infrastructure investment made simultaneously with vehicle investment. All vehicle types in the example are using the base-case default values. Three scenarios are illustrated: 100% investment in year 0; 33% investment in years 0, 1, 2; and 25% investment in years 0, 1, 2 , and 3. For this fleet, spreading the investment over 4 years increases the simple payback period by 2 years. This delay in return may make some investors nervous; others may accept it because they do not have the cash for the full investment in year 0.

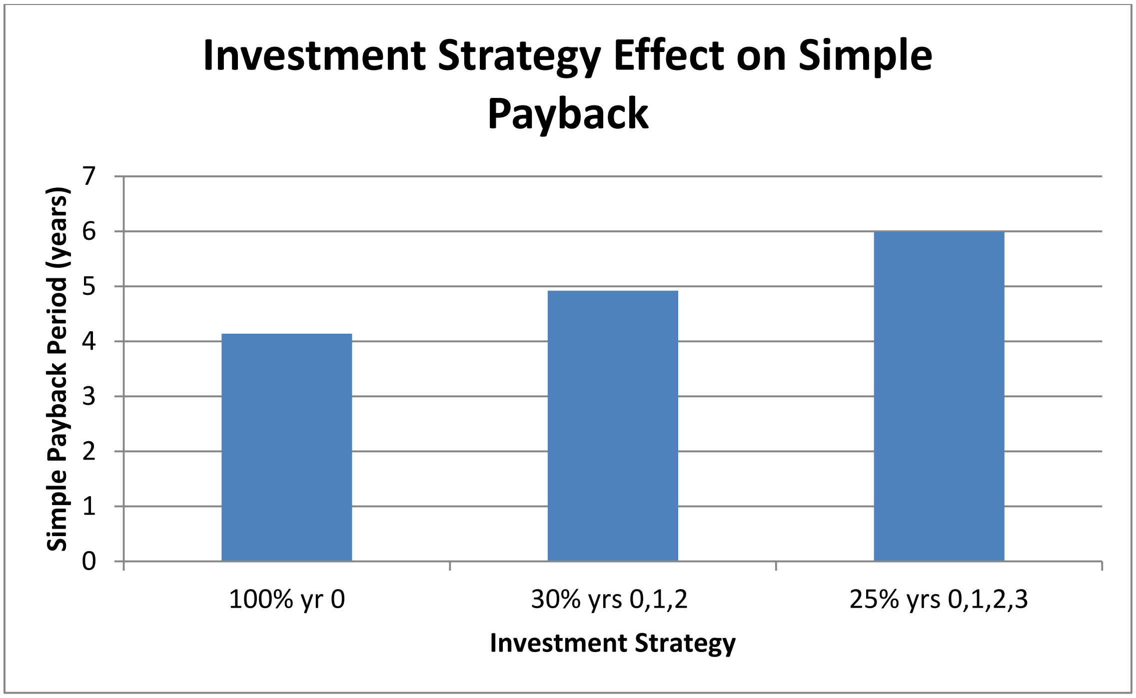

Figure 3. Investment timing effect

3.1.1 Understanding the Financial Soundness of a Compressed Natural Gas Project

Most financial projects are judged on the basis of NPV, ROR, and payback period. VICE 2.0 provides each indicator for your project. A short tutorial of each indicator follows:

- **NPV.** NPV is the total present value of any financial project. This includes capital cost of equipment purchased during the project lifetime as well as any savings from M&O and fuel. "Cash flow" is defined as the sum over time of these expenditures and savings. Positive cash flow is determined by savings; negative cash flow represents expenditures. Cash flows determined in VICE 2.0 are discounted at a specific rate called the discount rate, as mentioned earlier. When determining the financial soundness of a particular project, the NPV should be 0 or positive for the desired discount rate to achieve the needed financial outcome.

  Figure 4 represents the cash flow from another hypothetical CNG project. In this particular project, vehicle and infrastructure investments are made in years 0–2. The NPV of this project in Figure 2 is $14.2 million in year 15. An interesting feature of the project depicted in Figure 4 is that the investments are greater than the cumulative savings in years 0–1.5, as shown by the negative slope of the discounted cumulative cash flow.

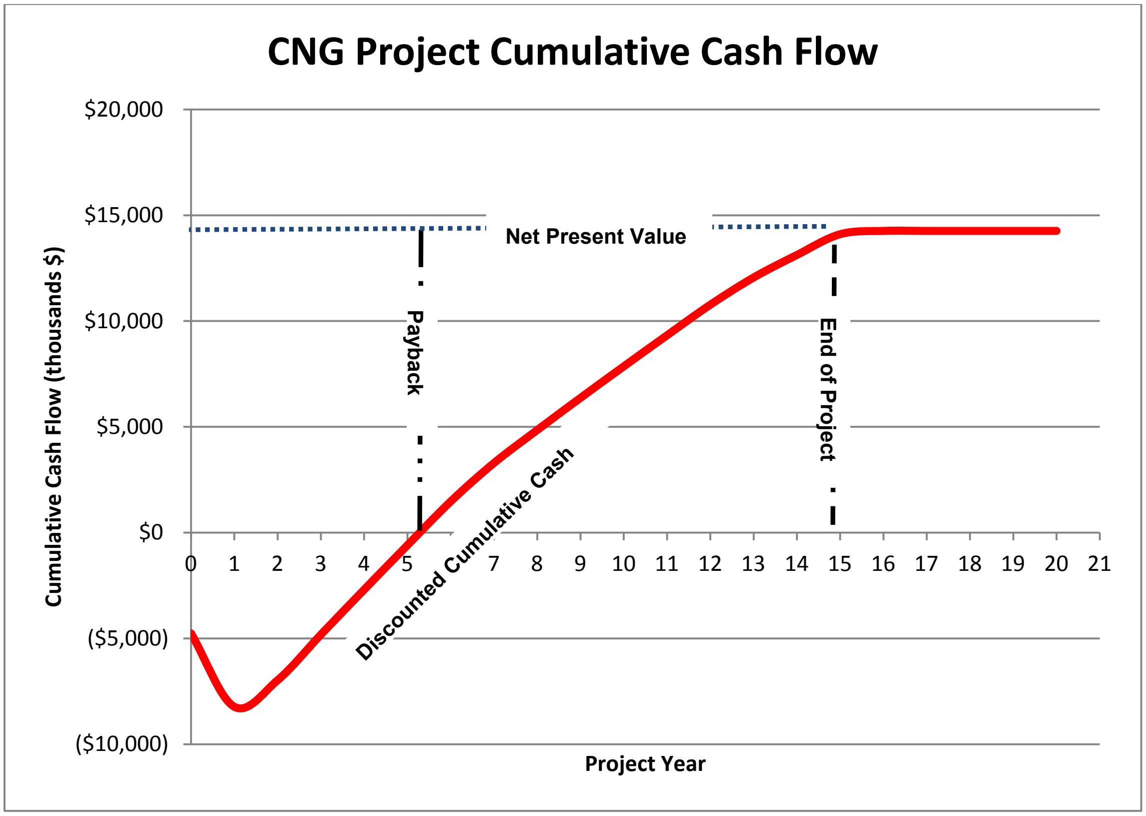

Figure 4. Example of cumulative cash flow, by year

- **ROR.** ROR is defined as the annual return on investment. For comparison purposes some investors chose a target ROR to be what they could make by investing their money elsewhere in a project of similar risk. When an ROR is selected in this manner, it can then be used as the discount rate in the NPV calculation of the proposed project.
- **Payback Period.** Payback period is defined as the point where the investment or project has begun to turn a profit. Once a project reaches the break-even point, the likelihood that the investment will lose money diminishes. VICE 2.0 calculates two types of payback periods: discounted and simple. Discounted payback uses discounted cash flow calculated with the same discount rate used to calculate the project's NPV. Discounted payback includes the time value of money. Simple payback does not include the time value of money and looks strictly at the cost of the project and the undiscounted annual cash flows. Simple payback is typically used to "screen the rocks" with regard to possible payback scenarios when laying out a potential project. Because cash flows are not discounted, simple payback is shorter than discounted payback. Figure 4 illustrates a discounted payback period of 5.6 years. The same project would have a simple payback period of 5.1 years.

3.2 Results From the Base Case

The model was run using the most probable values for fleets, which are outlined in segments 1 through 4 of the model inputs. For the base-case comparison, single vehicle type fleets were chosen for simplicity and to illustrate the differences in fleet financial performance based on the physical characteristics of each vehicle type. VICE 2.0 does allow for fleets of varying compositions in vehicle types and quantities.

3.3 Simple Payback

Figure 5 illustrates the dependency of the simple payback period on fleet vehicle type and quantity.

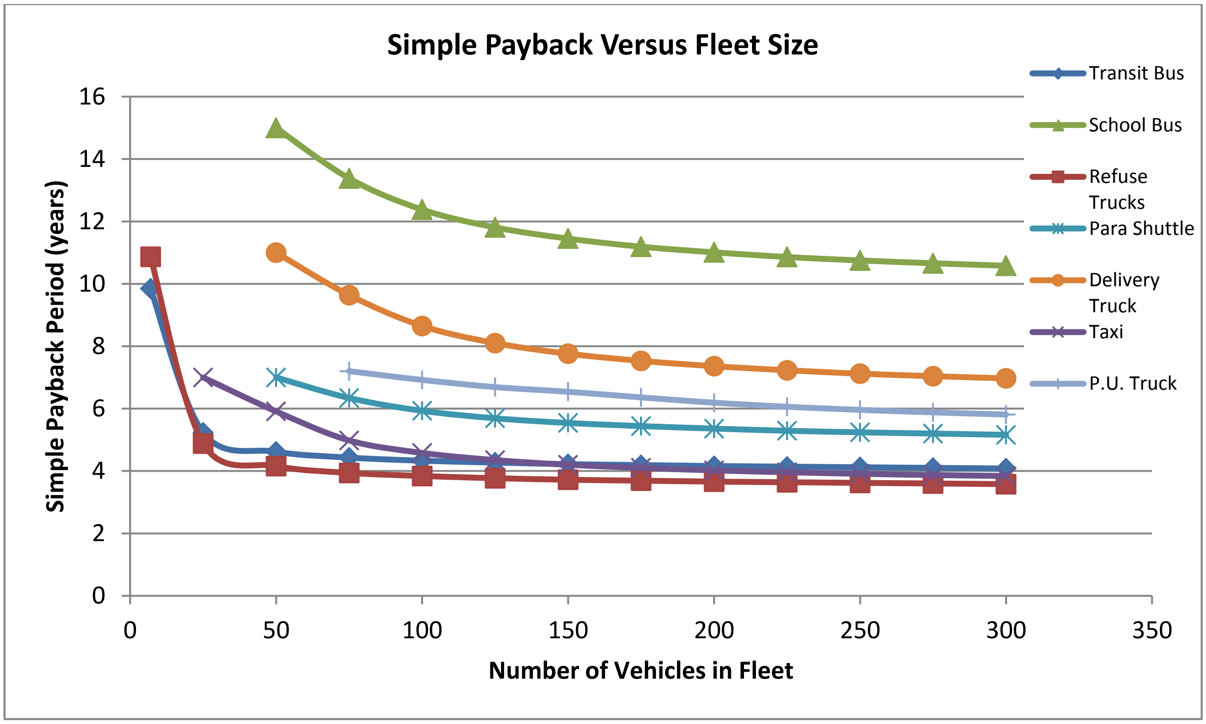

Figure 5. Relationship between fleet size and simple payback period

Regardless of vehicle type, simple payback is relatively flat with regard to the number of vehicles in the fleet. This is especially the case with transit buses and refuse trucks, which tend to have higher VMT and lower fuel economy than the other types. Thus, transit buses and refuse trucks may present themselves as favorable from a business case standpoint with a relatively small (fewer than 50) fleet size. For the other types of vehicles shown in Figure 5, fuel efficiency tends to be higher and yearly VMT tends to be lower. Singularly or in combination, these two variables significantly lower fuel use, which slows the cash flow from fuel savings. In the case of school buses, para shuttles, delivery trucks, pickup trucks, and taxis, the maximum payback period is limited to the vehicle service life when small fleets are considered.

3.4 Rate of Return

Project ROR, similar to simple payback, is significantly influenced by the amount of fuel a fleet uses. Transit buses and refuse trucks exhibit an acceptable ROR at very small fleet sizes. Figure 6 shows that this is also the case for taxi fleets, although to a lesser degree than for refuse and transit fleets.

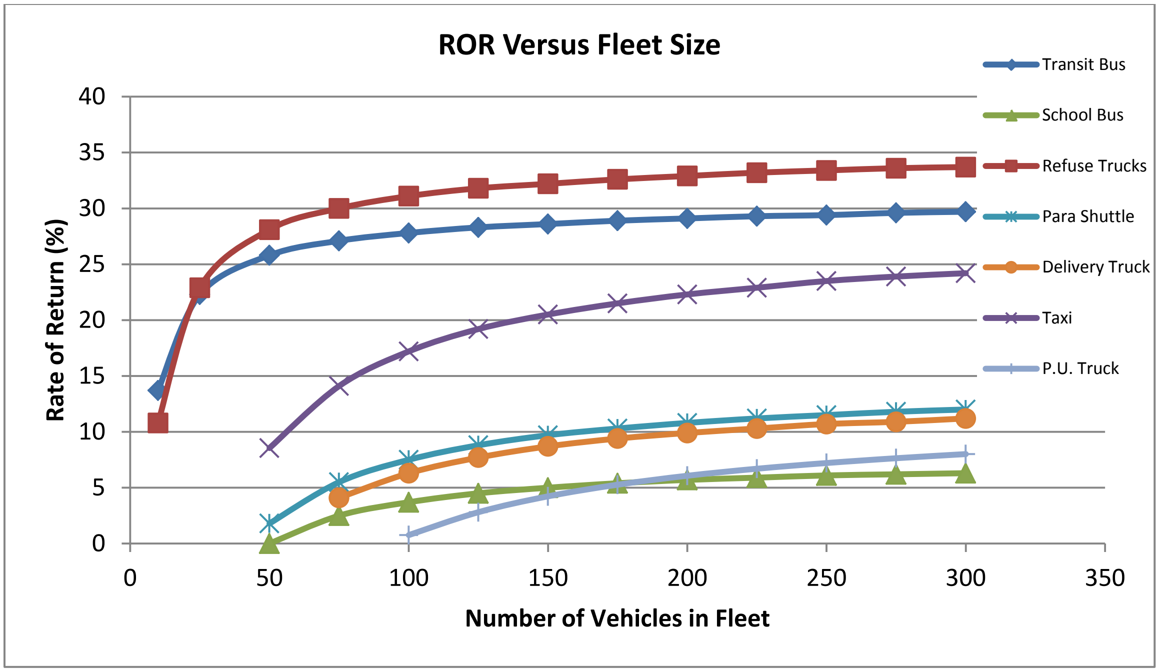

Figure 6. Effect of fleet size on the project ROR

Fleets containing vehicles with lower VMTs or higher fuel efficiency have lower RORs and require larger numbers to generate an acceptable ROR level. This is especially the case in a fleet made up entirely of gasoline pickup trucks. In this case, 150–200 vehicles are needed to generate an ROR of 5%. As mentioned earlier, this is a result of good fuel efficiency and low VMT.

Figure 6 also illustrates the difficulty faced by some school bus fleets. High incremental cost plus low VMT and relatively good fuel efficiency combine to result in very low RORs on fleets with fewer than 125 vehicles. Even above this number the ROR never exceeds 7%.

3.5 Project Net Present Value

Figure 7 compares the NPV of each fleet type by the number of vehicles in each. Fleets consisting of transit buses or refuse trucks show superior NPV results compared to the others. As with the metrics discussed above, fuel efficiency and VMT drive fuel use. Transit buses and refuse trucks will therefore have a significantly higher fuel savings at project termination, which will drive the project's NPV.

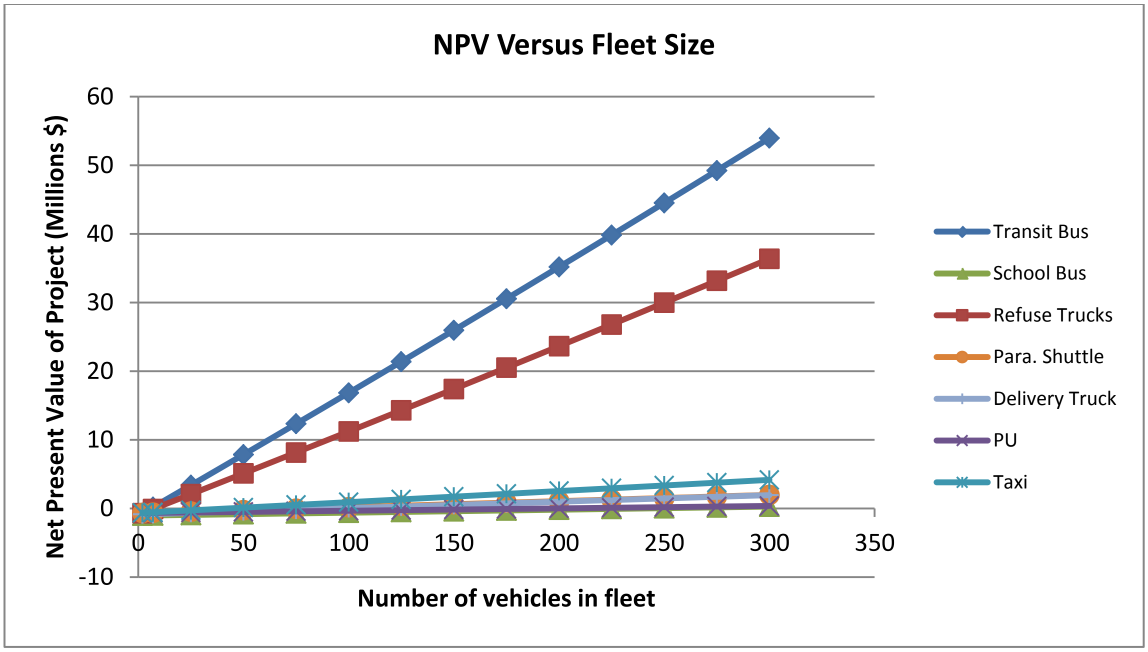

Figure 7. Fleet size effect on project NPV, discount rate = 6%

Table 1 looks at fleet composition, initial investment, NPV, and the number of vehicles required to break even. The initial investment in Table 1 combines total incremental cost for vehicles as well as infrastructure investment for a fleet of 300 vehicles. The NPVs for each fleet reflect the recuperated cost from fuel savings over the life of each project. Typically, projects with high fuel consumption (higher vehicle numbers, lower fuel efficiency, higher VMT) have better NPVs.

Table 1. Project Investment, NPV, and Break-Even Point

Fleet Vehicles	300 Vehicle Investment ($)	300 Vehicle NPV ($)	6% ROR Break Even (no. of vehicles)
Transit Buses	$26,616,545	$53,961,110	7
School Buses	$11,635,745	$265,706	230
Trash Trucks	$19,302,665	$36,382,820	25
Para Shuttles	$9,456,069	$1,973,544	100
Delivery Trucks	$6,918,106	$1,934,299	100
Pickup Trucks	$5,299,631	$363,594	200
Taxis	$6,282,000	$4,163,049	50

Another way of looking at this is to determine when the NPV of the project crosses zero, or the cash flow is positive. This point is also where the ROR of the project is 6%.

Transit buses, refuse trucks, and taxis all require relatively modest fleets to provide a 6% ROR (the discount rate assumed for municipal governments), because these vocations have a high throughput of fuel.

A secondary observation from Figure 7 in combination with Table 1 is that infrastructure sharing could result in greater station throughput, increased vehicle diversity in the fleet, and fewer specific types of vehicles needed to break even. This is investigated in Section 3.8.

3.6 Fuel Consumption and Cost

As illustrated in the analysis of simple payback, ROR, and NPV, fuel use is a driving variable behind project profitability. Fuel consumption and fuel cost combine to provide the profit or loss of any CNG fleet project. Figure 8 illustrates the relationship between average VMT per vehicle and fleet size for each vehicle to break even or pay off the investment of the project.

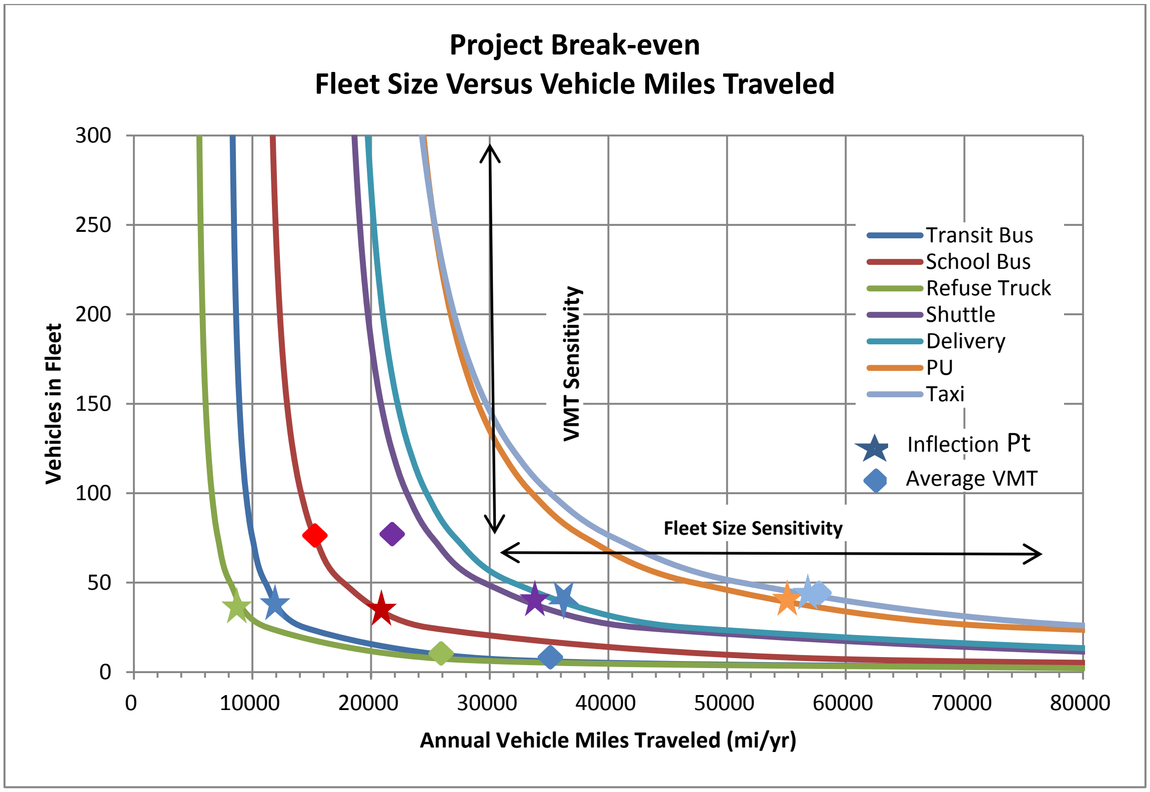

Figure 8. Fleet size and VMT sensitivity

Figure 8 was labeled for each fleet at the point of inflection. This point represents the transition between vehicle number and VMT dominance for each vehicle fleet. Each curve moving to the left of the inflection point is where profitability is more VMT driven; moving to the right of the inflection point, profitability is more dependent on the number of vehicles in the fleet. For any fleet, the area above the curve represents a profitable project; any point below the curve is unprofitable.

The average VMT is shown for most fleets in Figure 8. For projects such as transit buses and refuse trucks, their average VMT is to the right of their respective inflection points, suggesting a higher sensitivity to vehicle numbers rather than to VMT. Conversely, the remaining fleet projects in Figure 8 have their average VMT to the left of the inflection point, suggesting sensitivity to the number of vehicles in the fleet.

The cost differential between conventional liquid fuels (diesel and gasoline) and CNG determine the major component of payback. Figure 9 illuminates the effect this cost differential can have on the simple payback period of a CNG project. For this comparison, four fleets were chosen to illustrate the effects of conventional fuel choice and sensitivities to VMT and fleet size.

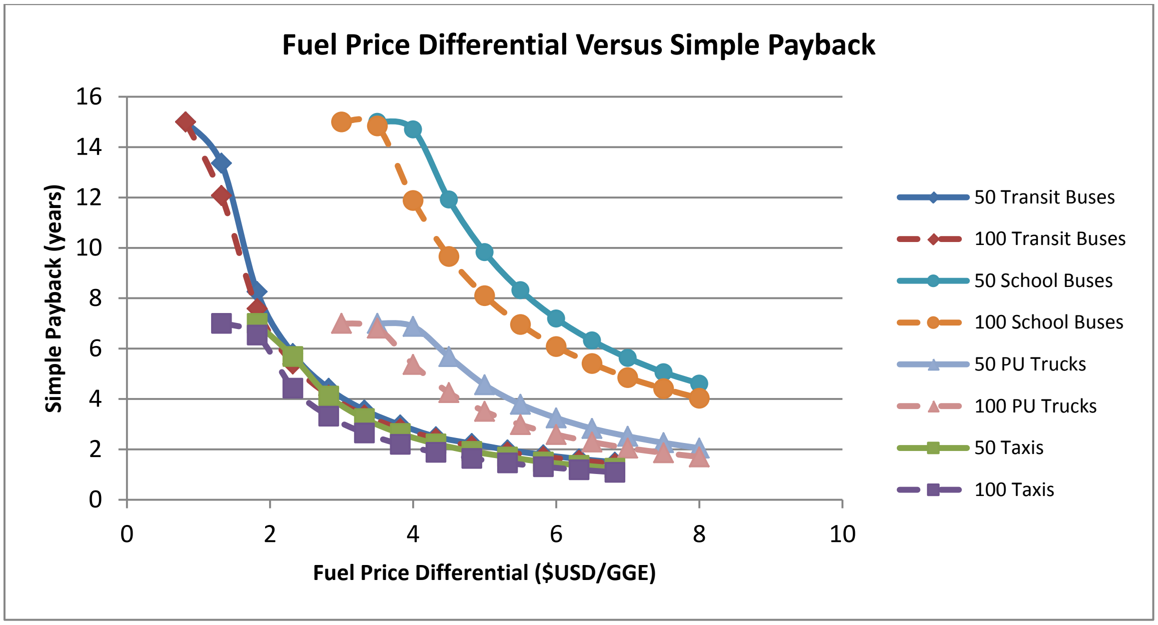

Figure 9. Fuel price differential effect on simple payback

Transit buses (diesel) and taxis (gasoline) represent two fleets that have been previously shown to have a relative insensitivity to fleet size (Figure 8). These fleets are relatively insensitive (3- to 6-month reduction in simple payback) between vehicle fleet sizes of 50–100 vehicles, but are very sensitive to the price differential of fuel. In both examples a $2.00 differential in the cost of the fuels reduces the simple payback period by about 4 years.

In contrast, the marginal fleets such as school buses and pickup trucks have a significant sensitivity to the vehicle fleet size in addition to the fuel price differential. The pickup truck fleet and the school bus fleet exhibit similar sensitivities to fuel price differential as do the previous fleets. They also exhibit a significant reduction, in some cases more than 1 year, in simple payback by increasing the fleet size from 50 to 100 vehicles.

3.7 Fleet Composition

Fleet composition (the number and type of vehicles) can have a striking effect on project economics. Until now this analysis has been of homogeneous fleets and their profitability. Many potential projects will surround a single vehicle type; however, some fleets have marginal economics, even with a large number of vehicles.

Table 2 compares the economics of the seven homogenous fleets investigated previously and two mixed vehicle fleets. VICE 2.0 allows any number of each type of vehicle to be selected for inclusion in the analysis. Each fleet consists of 100 vehicles total: Mixed Fleet A leans toward heavy vehicles and Mixed Fleet B leans toward the marginal fleet vehicles identified earlier. In each mixed vehicle fleet the economic performance was better than four of seven homogeneous fleets when compared on the basis of ROR. The lowest performing (Mixed Fleet B) yielded an

ROR of nearly 14%. Mixed Fleet A returned a 20.4% ROR, performing better than all others except transit buses and trash trucks. Simple payback for both mixed fleets was shorter than 6 ½ years.

Table 2. 100 Vehicle Mixed Fleet Comparison

Fleet Vehicles	100 Vehicle Investment ($)	100 Vehicle NPV ($)	ROR (%)	Simple Payback (years)
Transit Buses	9,052,202	16,844,379	27.8	4.3
School Buses	4,058,602	(625,349)	3.7	12.4
Trash Trucks	6,614,242	11,210,428	31.1	3.8
Para Shuttles	3,332,044	176,691	7.5	5.9
Delivery Trucks	2,486,056	41,226	6.3	8.7
Pickup Trucks	1,946,564	(338,495)	<1.0	6.9
Taxis	2,274,768	911,142	17.2	4.6
Mixed Fleet A	4,784,768	4,777,465	20.4	5.2
Mixed Fleet B	3,676,227	1,743,290	13.6	6.4

When developing a CNG business case, Table 2 suggests that looking beyond a single strategic vehicle may be advantageous by increasing fuel use with a minimum increase in investment and payback.

3.8 Additional Considerations Affecting Project Profitability

3.8.1 Station Cost

Investment profitability also depends on the initial or upfront costs, because these are typically of significant magnitude and are directly related to NPV, return on investment, and payback periods. Each parameter is important to fleet or project managers when evaluating a specific project.

The capital cost of a CNG station can vary widely depending on many fleet- or installation-specific factors. See *Costs Associated with Compressed Natural Gas Vehicle Fueling Infrastructure*[13] for an overview of factors that contribute to the total cost of an installed station.

Varying the station cost ± X% has a symmetrical effect on the length of simple payback. This means that any cost increase has an equal but opposite effect on simple payback years as decreasing the cost an equivalent amount. Figure 10 shows the effects of varying the cost of the CNG filling station ± 50%. These nearly symmetrical results change simple payback by less than 1 year for diesel fleets. The same 50% swing in station cost has a larger impact on the payback for gasoline-based fleets, largely because the CNG station represents a greater fraction of the upfront cost.

[13] http://www.nrel.gov/docs/fy14osti/62421.pdf

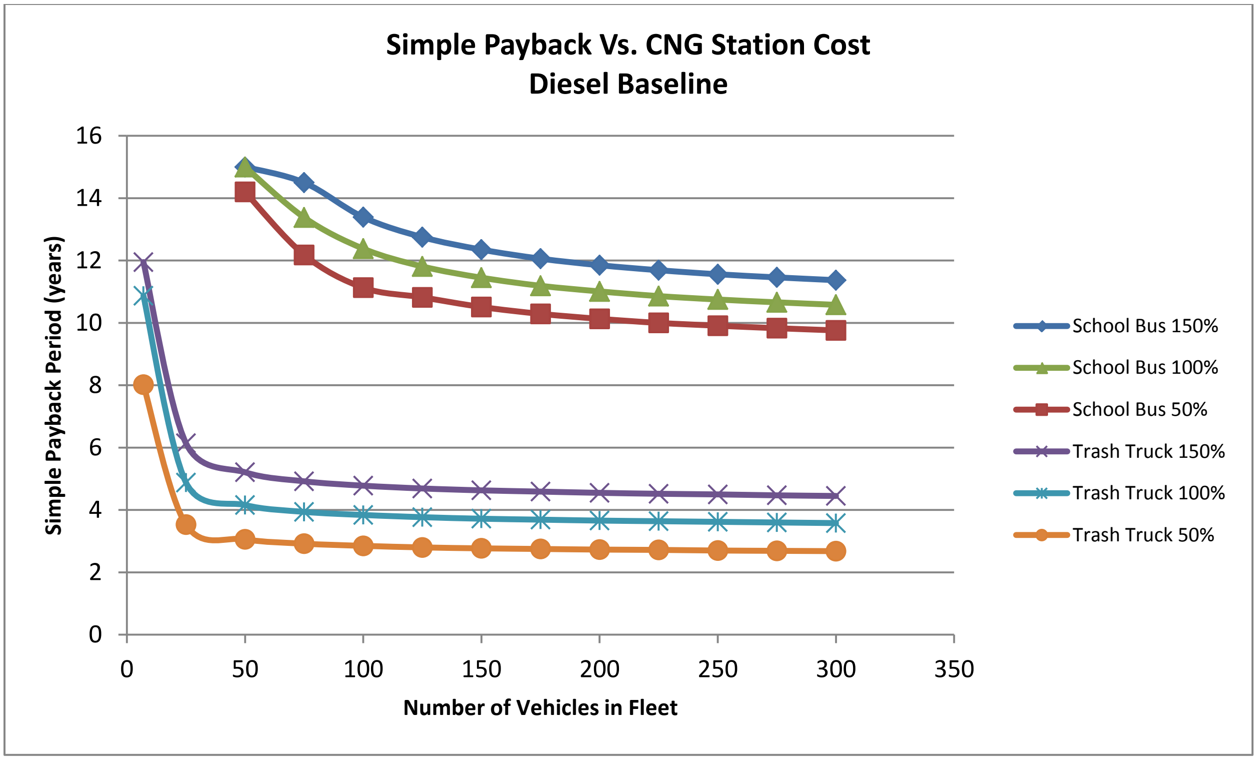

Figure 10. Effects of CNG station cost on simple payback (diesel)

Figure 11 illustrates the same effect on two fleets of gasoline vehicles. In the same fashion as Figure 10, the cost of the CNG filling station was varied ± 50% with essentially the same results.

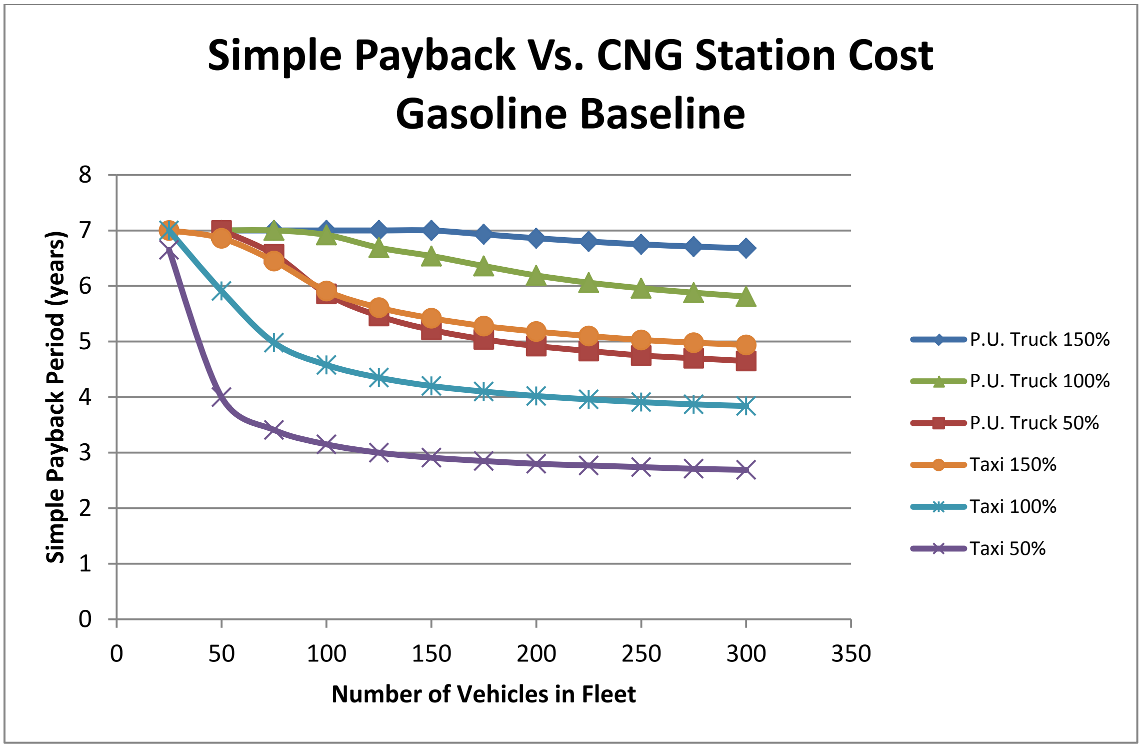

Figure 11. Effects of CNG station cost on simple payback (gasoline)

3.8.2 Incremental Vehicle Cost

Vehicle costs may vary for a number of reasons, including economies of scale, level of customization, and the cost of regulation compliance. Figures 12 and 13 demonstrate the effects of changes in incremental cost for diesel and gasoline vehicle fleets. Incremental costs vary between vehicle type and manufacturer and can run from a few thousand dollars to $50,000 or more. For this investigation, the incremental cost for each vehicle type was first doubled from the base incremental cost and then set to zero. For both examples, the fleets chosen represent good and marginal financial performers.

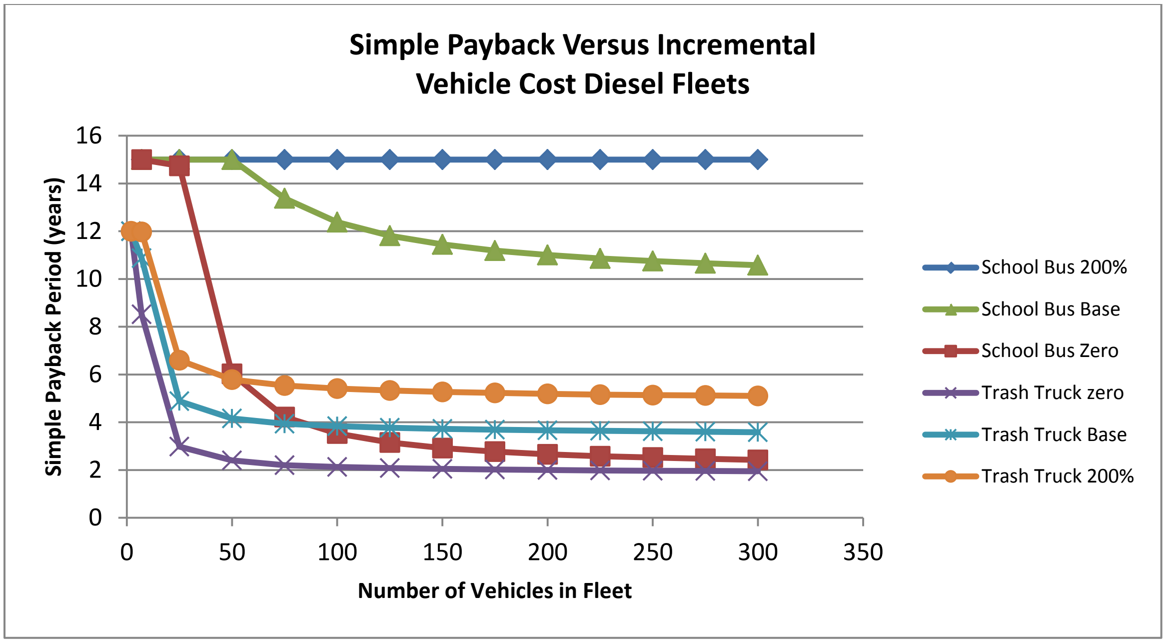

Figure 12. Effects of vehicle incremental cost on simple payback (diesel)

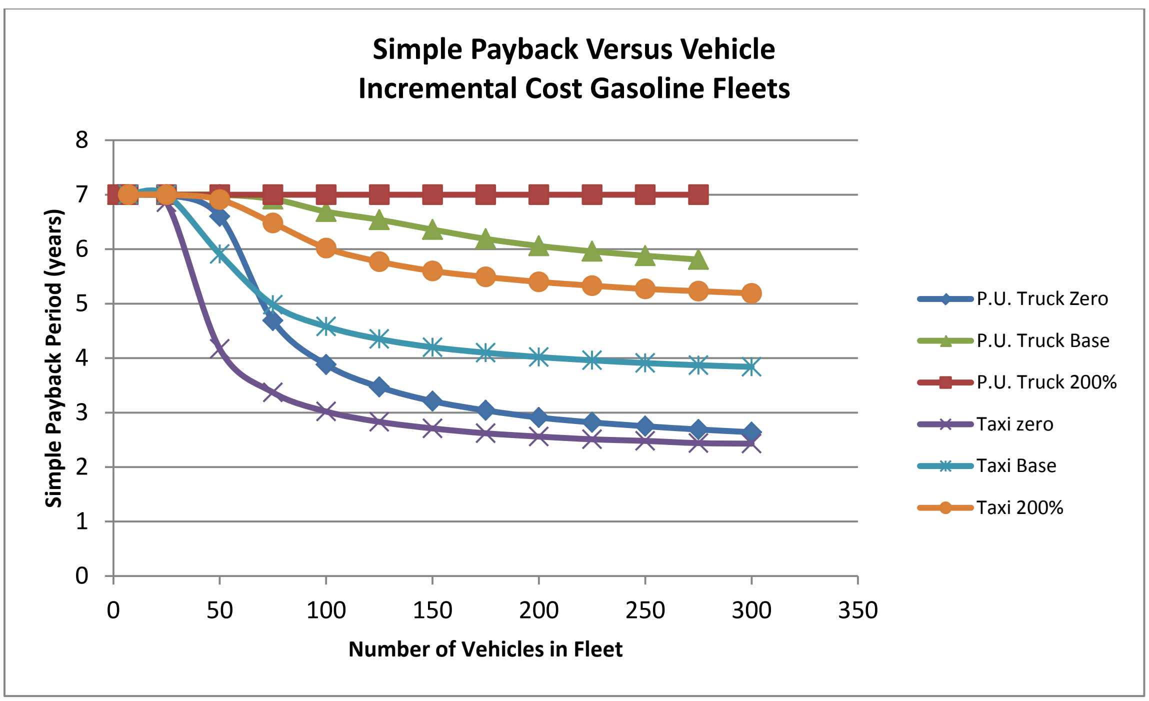

Figure 13. Effects of vehicle incremental cost on simple payback (gasoline)

Regardless of fuel type, two interesting effects should be noted:

- When a fleet performs well, the effect of varying the vehicles' incremental cost ± X% has symmetrical effect on the length of simple payback. This means that any cost increase has an equal but opposite effect on simple payback period as decreasing the cost an equivalent amount.

- Doubling the incremental cost of a vehicle in a marginally performing fleet has a devastating effect on the simple payback period for that project, because it never pays back. Conversely, incentives or grants that lower the incremental cost of the vehicle in a marginal project may shorten the simple payback period significantly (in at least one case by nearly 8 years), increasing the attractiveness of investment.

3.8.3 Vehicle Maintenance Costs

Vehicle M&O costs can have a significant impact on the simple payback period of any fleet. Figure 14 illustrates this effect on school bus and trash truck fleets. These fleets were chosen because they represent examples of a well-performing fleet and a fleet with marginal to poor performance. For this comparison the vehicle M&O costs were set 50% above and below the baseline costs. The trends shown here are consistent with the financial performance of the fleet regardless of original fuel type.

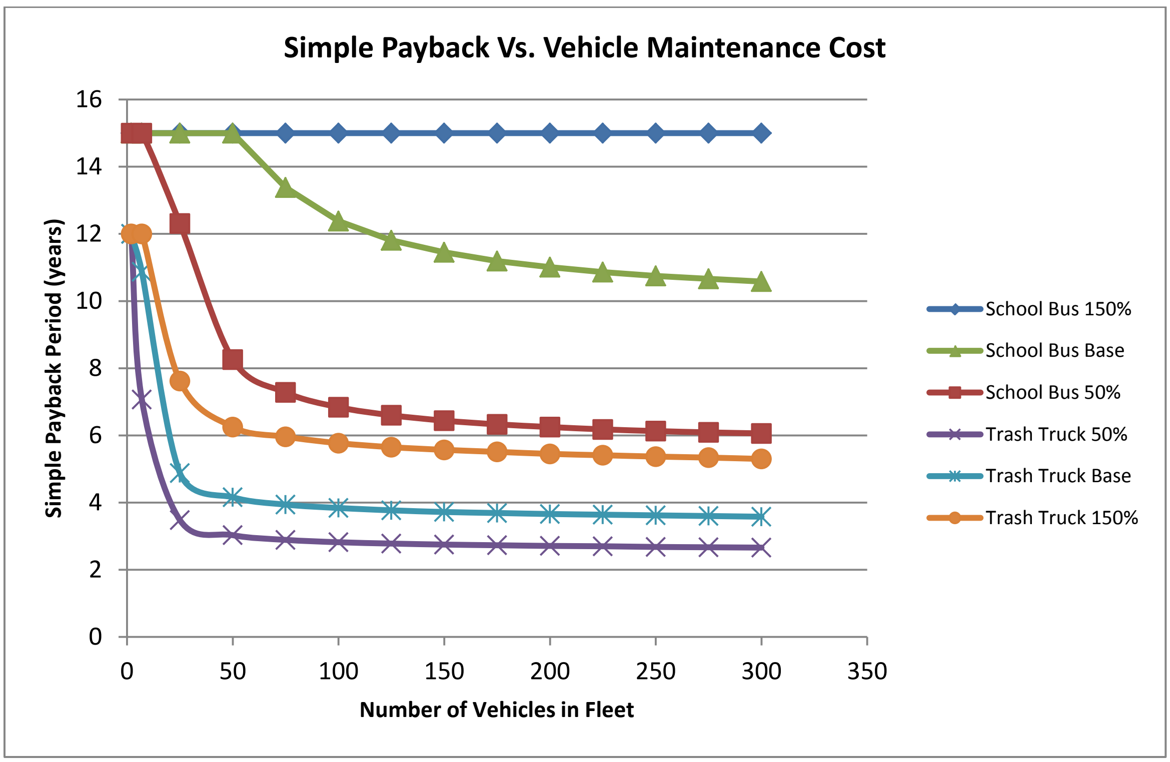

Figure 14. Vehicle M&O cost effects on simple payback

Vehicle M&O costs can have a significant impact on a marginally performing fleet, both positively and negatively. In this case decreasing the vehicle M&O costs by 50% decreases the simple payback period by nearly 6 ½ years (not quite 50%). For a marginally performing fleet the effects of lower M&O costs are particularly evident at low vehicle volumes, hence low fuel use, where the fuel cost differential can go into paying the capital costs of vehicle and station investment instead of vehicle M&O costs.

For a well-performing fleet—trash trucks in this example—the trends are similar but significantly less pronounced. Fleets using large quantities of fuel achieve more of their investment payback from fuel savings and are therefore less sensitive to changes in their M&O costs.

3.8.4 Compressed Natural Gas Station Electricity and Maintenance Costs

Maintenance and electricity costs for running a CNG station can be highly variable between projects. Both can be driven by changes in use, such as making the station publically available or, in the case of electricity costs, changing the price of the fuel used in generating the electricity. Figure 15 shows the effects on the simple payback of the two fleets, well and marginally performing, of increasing and decreasing the monthly M&O costs of the station by 50%.

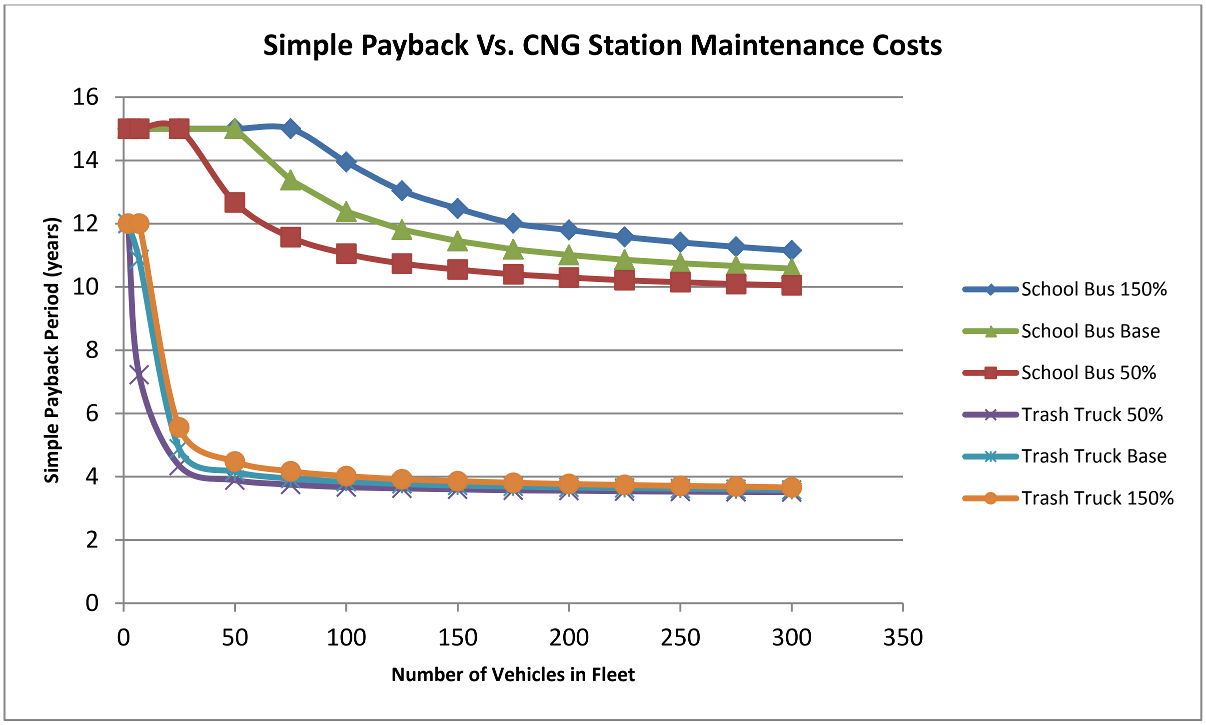

Figure 15. CNG station M&O cost effects on simple payback

Similar trends can be seen between the two fleets. However, the effect of these cost swings on a marginally performing fleet—in this case school buses—is significantly more pronounced at lower fleet volumes. For reasons similar to vehicle M&O costs, lower station M&O costs allow the fuel differential savings to be put toward repaying the investment. This effect is more clearly seen at lower fleet volumes.

CNG station electricity costs have a relatively small in effect on payback. For the example illustrated in Figure 16, monthly electricity costs were increased and decreased 50%. The figure shows a greater effect on the marginally performing school bus fleet that was symmetrical and less than 3 months in payback length.

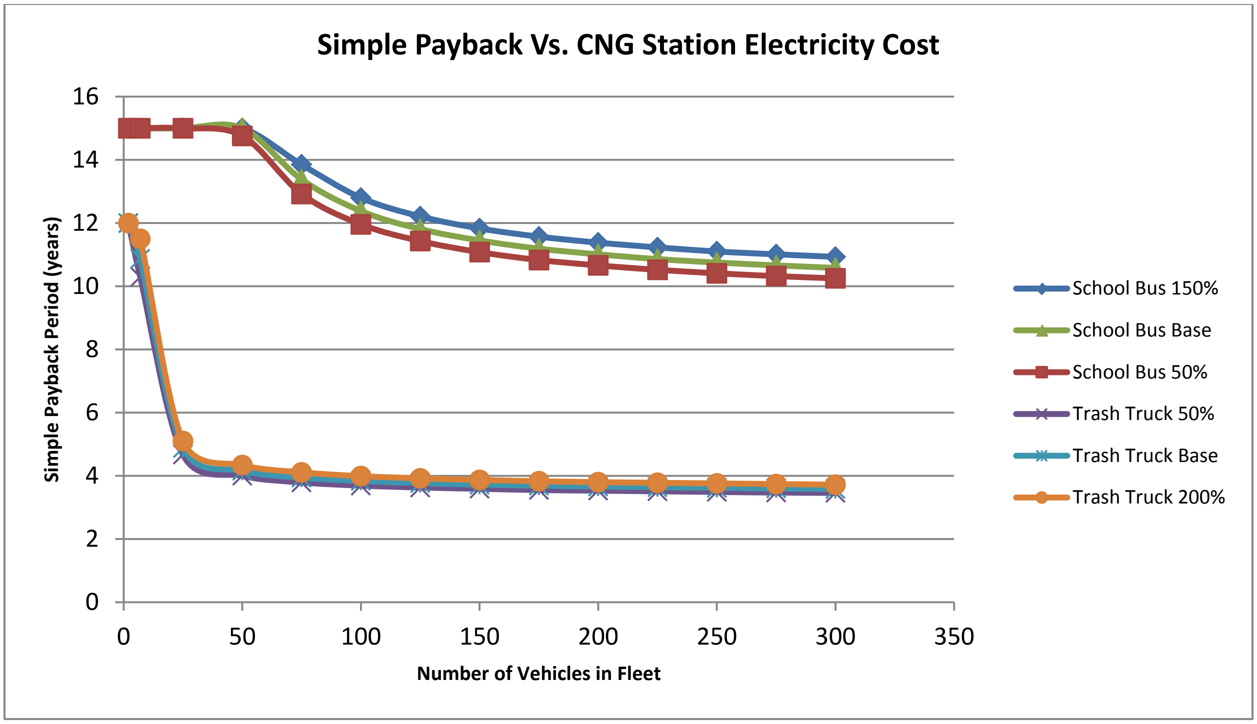

Figure 16. CNG station electricity cost effects on simple payback

3.8.5 Subsidies and Tax Credits

In the past the government has made available a number of incentives to encourage the use of CNG. These included an excise tax credit for the purchase of CNG as a fuel ($0.50/GGE or $0.55/DGE), a tax credit to cover 80% of the incremental cost of a CNG vehicle purchase, and a tax credit for the installation of a CNG filling station (up to $30,000). These tax credits were to be made available to tax-exempt entities through certificates and pass-alongs. At the time of this report, none of these subsidies were available. The default values used in the base case of VICE 2.0 reflect this. However, provisions have been made in the model to accommodate any one of them should they be reinstated. There is a chance of these being reinstated because they have expired and been reinstated in the past.[14]

Table 3 demonstrates the effects on simple payback period of these particular subsidies. For this demonstration, a fleet size of 100 vehicles was used. Column 1 is the simple payback period for the base case. Each column shows the effects of the individual credit on the projects' simple payback period. The final column shows the combined effects of all the subsidies applied to the particular fleet.

[14] http://www.afdc.energy.gov/laws/

Table 3. Effect of Tax Credits on Simple Payback

	Simple Payback (years)				
100-Vehicle Fleet	No Credits (Baseline)	Station Credit Only	Vehicle Credit Only	Fuel Credit Only	All Credits Combined
Transit Buses	4.33	4.32	2.87	3.26	2.1
School Buses	12.38	12.31	5.68	9.41	3.9
Trash Trucks	3.84	3.82	2.49	2.82	1.8
Para Shuttles	5.93	5.88	3.57	4.14	2.4
Delivery Trucks	8.65	8.56	4.84	6.0	3.1
Pickup Trucks	≥ 7	6.87	4.66	5.08	3.0
Taxis	4.58	4.52	3.34	3.13	2.2
Mixed Fleet A	5.16	5.13	3.14	3.78	2.2
Mixed Fleet B	6.36	6.31	3.62	4.61	2.5

The two most effective tax credits were for vehicle purchase and fuel purchase. Individually, either could take a marginally profitable project such as school buses, delivery trucks, or pickup trucks and bring it into the realm of acceptable payback periods of 6 years or shorter. Essentially, subsidies have the same effects on simple payback as fuel prices, station costs, and incremental vehicle costs. Simply stated, the effects of subsidies can be quite dramatic.

4 Conclusions

Determining the financial soundness of any investment project is vital. Many aspects of a CNG vehicle and fueling infrastructure project combine to define overall profitability. The National Renewable Energy Laboratory developed the VICE model to help businesses and fleets evaluate the financial soundness of CNG vehicle and fueling infrastructure projects. The VICE 2.0 model demonstrates the relationship between the operational parameters of the vehicle fleet and financial profitability.

The model does this by providing NPV, return on investment, and payback period (simple and discounted). It is not the intent of the author to define the profitability of the individual fleet types available to the user of VICE 2.0, but to outline the operational parameters that may add to or subtract from any project's profitability.

4.1 Most Influential Parameters

In an effort to identify the most influential fleet parameters, the input values for three mixed vehicle fleets were varied ±50% from the baseline and the change in NPV was noted. The parameters were then ranked from most to least influential based on the magnitude of the associated swing in NPV. Table 4 illustrates the comparative ranking of the sensitivity to baseline parameter changes between the three fleets. The different parameters shown in Table 4 are color coded to indicate the type of input each represents: green = vehicle parameters; orange = CNG vehicle O&M; grey = fuel cost parameters; blue = RoR or discount rate and infrastructure O&M parameters. Within each fleet, the baseline parameters are ranked from high to low as previously noted.

Table 4. Project NPV Sensitivity to 50% Swing in Input Parameters

Ranked from most to least influential

Mixed Fleet A[a]	Mixed Fleet B[b]	Mixed Fleet C[c]
Diesel Fuel Price	Diesel Fuel Price	Gasoline Fuel Price
Fuel Economy	Fuel Economy	Fuel Economy
VMT	VMT	CNG Vehicle M&O Costs
Vehicle Life	Vehicle Life	Required ROR/Nominal Discount Rate
CNG Vehicle M&O Costs	CNG Vehicle M&O Costs	Diesel Fuel Price
Price of CNG (per GGE)	Price of CNG (per GGE)	VMT
Vehicle Number	Required ROR/Nominal Discount Rate	Vehicle Life
Monthly Station M&O Cost	Gasoline Fuel Price	Price of CNG (per GGE)
Required ROR/Nominal Discount Rate	Vehicle Number	Vehicle Number
Diesel Price Increase	Incremental Cost	Incremental Cost
Gasoline Fuel Price	Diesel Price Increase	Monthly Station M&O Cost
Incremental Cost	Monthly Station M&O Cost	Diesel Price Increase
Realized Diesel Excise Tax Exemption	Monthly Electricity Costs	Realized Gasoline Excise Tax Exemption
Monthly Electricity Costs	Realized Diesel Excise Tax Exemption	Gasoline Price Increase
CNG Price Increase	Light-Duty Vehicle CNG Vehicle M&O Costs	Light-Duty Vehicle CNG Vehicle M&O Costs
Light-Duty Vehicle CNG Vehicle M&O Costs	CNG Price Increase	Realized Diesel Excise Tax Exemption
Realized Gasoline Excise Tax Exemption	Realized Gasoline Excise Tax Exemption	Monthly Electricity Costs
Gasoline Price Increase	Gasoline Price Increase	CNG Price Increase
CNG Station Salvage Value	CNG Station Salvage Value	CNG Station Salvage Value

Color key: green = vehicle parameters; orange = CNG vehicle O&M; grey = fuel cost parameters; blue = RoR or discount rate and infrastructure O&M parameters

[a] 20 Transit, 20 School, 15 Trash, 15 Shuttle, 10 Delivery, 10 Pickup, 10 Taxi
[b] 8 Transit, 30 School, 8 Trash, 5 Delivery, 36 Pickup, 5 Taxi
[c] 5 Transit, 5 school, 2 Trash, 22 Shuttle, 22 Delivery, 22 Pickup, 22 Taxi

As shown in Table 4, fuel price and fuel economy for the dominant vehicle type are the most influential parameters. VMT and vehicle life show strong effects as well. Simply put, the more traditional fuel replaced with CNG and the larger the price differential, the better the investment. Conversely, fleets that have lower fuel consumption make for a less desirable CNG investment by having longer simple payback periods, lower ROR, and very low NPV.

Upfront costs such as CNG station cost or vehicle incremental cost can also have a significant impact on financial performance. CNG station cost is extremely volatile and is driven by a number of site- and fleet-specific variables. In this study, reducing the cost of the CNG station by 50% reduced the simple payback period by 0.9–1.1 years. This modest reduction may mean the difference between a go and a no-go decision for a fleet with a baseline simple payback of 4–7 years.

Vehicle incremental cost can have a dramatic effect on a project's simple payback period. Incremental cost may be influenced by variables such as technological innovation or economies of scale. Similar to CNG station cost, incremental vehicle cost has a direct impact on the overall capital investment of the project. Reducing the upfront capital investment allows the cash flow generated through the fuel savings to pay off the project and become profitable more quickly. Reducing the incremental vehicle cost has an especially dramatic effect on fleets that require a relatively high per-vehicle incremental cost and a low per-vehicle VMT.

Vehicle M&O costs can also have a significant impact on a marginally performing fleet, both positively and negatively. For a marginally performing fleet the effects of lower M&O costs are particularly evident at low vehicle volumes (hence low fuel use) where the fuel cost differential can go into paying the capital costs of vehicle and station investment instead of vehicle M&O costs. For a well-performing fleet the trends are similar but significantly less pronounced. Fleets using large quantities of fuel can more easily cover the fluctuation in M&O costs.

CNG station electricity and M&O costs have relatively little effect on project financial performance. The exception is station M&O cost of the marginally performing fleet. In this case the effect on simple payback period is significantly more pronounced at lower fleet volumes. Much like lowered vehicle M&O costs, lower station M&O costs allow the fuel differential savings to be put back into paying the capital costs of vehicle and station investment. This effect is more clearly seen at lower fleet volumes.

As illustrated throughout this report, the economic environment for any particular fleet brought about by subsidies and tax credits can have a tremendous impact on project profitability, especially those projects that involve vehicle and fuel purchasing. Significant synergies result when tax credits are used in combination. When combined, the tax credits for station cost, vehicle purchase, and fuel purchase result in payback periods shorter than 4 years for each fleet considered with VICE 2.0. Unfortunately, no federal credits are currently available. The availability of incentives related to the use of CNG may be tracked through Alternative Fuels Data Center or by contacting your local Clean Cities coordinator.[15]

[15] http://www.afdc.energy.gov/laws/

VICE 2.0 was developed to aid fleet managers in the financial assessment of proposed CNG projects. The trends and effects in this report are the results of modeling with what the National Renewable Energy Laboratory considers average operational values for the types of vehicles contained in VICE 2.0. Numerous interactions between variables were not considered or tested. To increase the accuracy of VICE 2.0, the individual operating parameters of the fleet under consideration should be used when available.

Glossary

Compressed natural gas (CNG)—A gas, consisting primarily of methane, that is compressed for storage.

Demand response vehicles— (also called paratransits, para shuttles, and dial-a-rides) are widely used by transit agencies. The vehicles do not operate over fixed routes or on fixed schedules. They may be dispatched to pick up several passengers at different pickup points before taking them to their respective destinations and may even be interrupted en route to pick up other passengers. Demand response service is provided primarily by vans.

Diesel-gallon equivalent (DGE)—The amount of energy in 1 gallon of diesel fuel. This is 10% greater than a gasoline-gallon equivalent (GGE).

Discount rate—The interest rate used in discounted cash flow analysis to determine the present value of future cash flows. The discount rate takes into account the time value of money (the idea that money available now is worth more than the same amount of money available in the future, because it could be earning interest) and the risk or uncertainty of the anticipated future cash flows (which may be less than expected).

Gasoline-gallon equivalent (GGE)—The amount of alternative fuel required to equal the energy content of one liquid gallon of gasoline.

Hostler—A person who refuels, cleans, and performs regular maintenance for a fleet of buses or trucks at the end of the day.

Maintenance and operation (M&O) costs—The monetary cost associated with the care and operation of vehicles and facilities. The categories of M&O include inspection, cleaning, servicing, and adjusting as necessary.

Net present value (NPV)—The difference between the present value of cash inflows and the present value of cash outflows. All cash flows have been discounted so that recent flows are worth more than future flows, to account for the time value of money.

Rate of return (ROR)—The gain or loss on an investment over a specified period expressed as a percentage increase over the initial investment cost.

Refueling window—The period of time in which vehicles are available to refuel.

U.S. Energy Information Administration (EIA)—A U.S. government agency that collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment.

Vehicle-miles traveled (VMT)—The number of miles traveled by one vehicle in 1 year.

Vehicle Infrastructure and Cash-Flow Evaluation (VICE)—A computer model that is designed to help businesses and fleets evaluate the financial soundness of CNG vehicle and CNG fueling infrastructure projects.