U.S. and Canadian Natural Gas Vehicle Market Analysis:

Light- and Medium-Duty Vehicle Ownership and Production

Final Report

Legal Disclaimer

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Abbreviations

AFV	Alternative Fuel Vehicle
AGA	American Gas Association
ANGA	America's Natural Gas Alliance
BEV	Battery Electric Vehicle
BoM	Bill of Materials
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
CNG	Compressed Natural Gas
E85	Ethanol (85% ethanol blended with 15% gasoline)
ECM/ECU	Engine Control Module/Unit
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
EV	Electric Vehicle
FMVSS	Federal Motor Vehicles Safety Standards
GGE	Gasoline Gallon Equivalent (=115.6 cubic feet of natural gas)
NFPA	National Fire Protection Association
OBD II	Onboard Diagnostic System
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
psi	Pounds per square inch
QAFMV	Qualified Alternative Fuel Motor Vehicle
QSR	Qualified System Retrofitter
SUV	Sport Utility Vehicle
SVM	Small Volume Manufacturer
ZEV	Zero Emissions Vehicle

Lower Heating Value Energy Content Conversion Factors

Diesel	129,488 BTU/gal
Gasoline	113,602 BTU/gal
Natural gas	983 BTU/cubic foot (=131.4 BTU/gal of volume)

Source: Argonne National Laboratory, "Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation," 1.8c

Natural Gas Properties Comparison

Property	Natural Gas	Gasoline	Diesel
Physical State	Vapor	Liquid	Liquid
Ignition Temperature	1,080 °F	540 °F	410 °F
Density	22 Grams/Cubic Foot (Lighter Than Air)	2,800 Grams/Gallon (lighter than water)	3,200 Grams/Gallon (lighter than water)
Spill Behavior	Evaporates and Disperses	Pools on Surface	Pools on Surface
Storage Temperature	CNG: Ambient Temperature LNG: Below –200 °F	Ambient Temperature	Ambient Temperature
Strong Pressure	CNG: 3,000–3,600 psi LNG: Varies	Ambient Pressure	Ambient Pressure

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Preface

Identifying the most productive and effective means to increase the use of natural gas vehicles

With the primary objective of identifying the most productive and effective means to increase the use of natural gas vehicles (NGVs) in the U.S. and Canada, the TIAX team has conducted a thorough and independent assessment of the NGV market. To identify the major market development and expansion opportunities, this assessment examines key technical, economic, regulatory, social, and political drivers and challenges that shape this market. TIAX has partnered with The CARLAB, Clean Fuels Consulting, the Clean Vehicle Education Foundation, Jack Faucett Associates, the Natural Gas Vehicle Institute, and St. Croix Research to provide perspective and insights into the development of the future NGV market.

TIAX's overall approach relies on six key stages

- Segmentation of the vehicle market
- Identification of market decision drivers
- Assessment of market development actions
- Analysis of competing technologies
- Analysis of market scenarios
- Integration of overall market development opportunities

The market perspectives for which decision drivers and opportunities have been identified and assessed are: light- and medium-duty vehicle ownership and production; heavy-duty vehicle ownership and production; compressed natural gas infrastructure; liquefied natural gas infrastructure; and government.

Drawing on the respective expertise of each team member, TIAX presents an integrated assessment of the U.S. and Canadian NGV market in a collection of eight reports. Each report is capable of standing alone while integrating the data, ideas, and themes of the other seven reports. The collection of reports in this TIAX analysis of the NGV market is supported by America's Natural Gas Alliance and is intended to be transparent and accessible to a broad audience.

Executive Summary

Bi-fuel NGVs offer the greatest potential for expanding the use of natural gas in light- and medium-duty vehicles.

For the last 25 years, the top-selling vehicles in every light- and medium-duty vehicle segment collectively had one characteristic in common: fuel economy was virtually unchanged over that time period, indicating that the market is driven by other priorities. Private and fleet consumers in North America, absent absolute regulations to the contrary, have consistently demanded larger, safer, and higher performing vehicles with a driving range of 350 to 400 miles, regardless of fuel type or vehicle segment.

As a variety of battery electric vehicles and hybrids join the North American market, consumers are becoming conditioned to calculate payback period when considering any alternative fuel vehicle. To achieve favorable payback relative to traditional gasoline and competing alternative fuel vehicles, such as ethanol flex-fuel and biodiesel vehicles, natural gas vehicles (NGVs) may require incentives that are on an equal playing field. In the past, these incentives have been applied inequitably to the various alternatively fueled vehicles.

Bi-fuel NGVs offer the greatest potential for expanding the use of natural gas in light- and medium-duty vehicles (Figure ES-1). The benefits of low natural gas capacity bi-fuel NGVs over their dedicated NGV counterparts include: **1)** no range anxiety for the consumer, **2)** the ability to run the predominant majority of daily use miles on natural gas, **3)** superior packaging, and **4)** lower cost. For bi-fuel personal use vehicles, natural gas capacity of approximately 3 gasoline gallons equivalent (GGE) may offer the best return on investment for the purchaser based on typical personal use vehicle range and driving characteristics. For bi-fuel commercial fleet vehicles, depending on unique fleet operation, incentives may not be required at all.

Expansion of the NGV industry will need to focus on original equipment manufacturers (OEMs) rather than NGV converters, as OEMs continue to be the key to mass-market NGV adoption. OEMs should have incentives, such as generous Corporate Average Fuel Economy (CAFE) credits to support NGVs and to level the playing field with other alternative fuel technologies. Research and development cost offsets, loans, or direct involvement by NGV stakeholders will help focus OEMs on viable solutions and overcome internal hurdles and resource constraints. Overall, dramatic growth in the NGV market can be accomplished through four actions:

1. Focus on bi-fuel NGVs and shift away from dedicated NGVs for the light-duty market

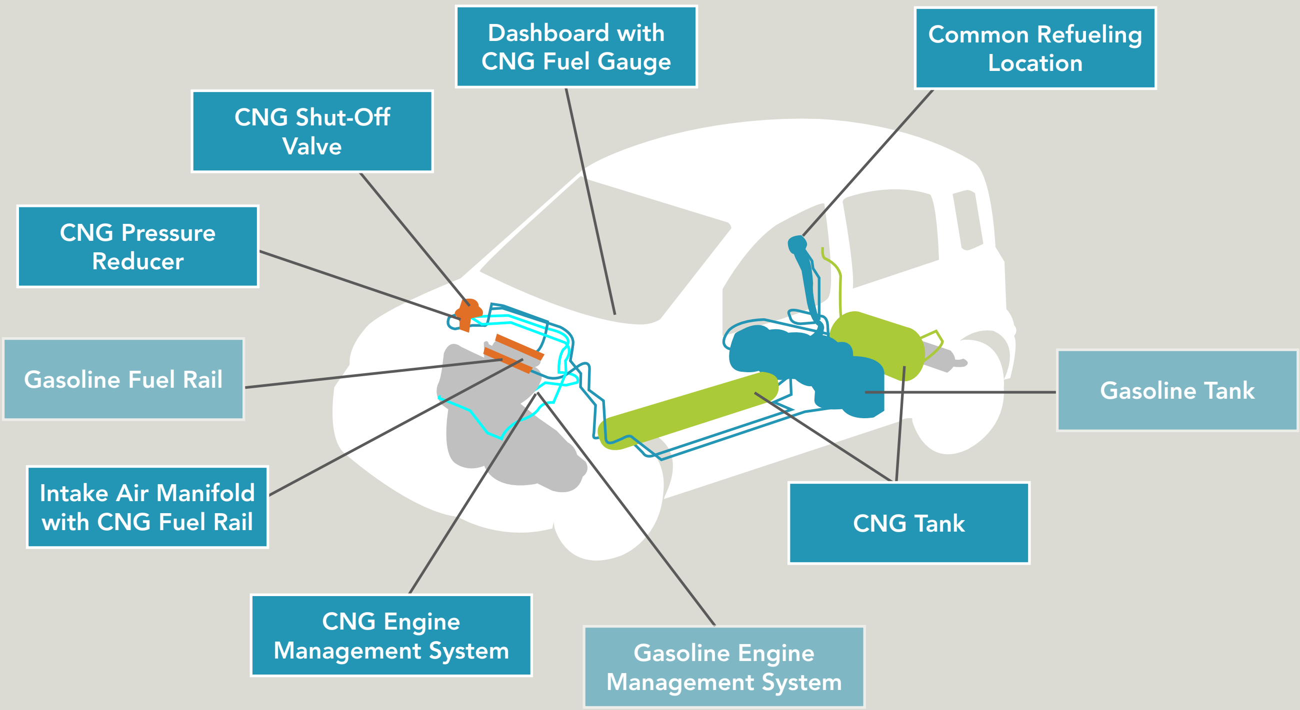
2. Support incentive policies that ensure a level playing field for all alternative fuels.

3. Provide regulatory assistance for OEMs (such as CAFE credits)

4. Become directly involved with development and promotion of bi-fuel NGVs as a way to drive the above actions

Figure ES-1

Bi-fuel NGVs offer greater opportunities than dedicated NGVs for expanding the light- and medium-duty NGV market.



Source: Fiat Powertrain

1 Introduction

This report focuses on assessing the drivers of and opportunities for development of light- and medium-duty NGV ownership and production.

The CARLAB, as part of the TIAX team, has detailed the key decision drivers and actions that will have the greatest impact on light- and medium-duty natural gas vehicle (NGV) growth. Vehicles that are analyzed in this report are "light-duty" (weighing less than 10,000 pounds and including passenger cars, SUVs, and light trucks) and "medium-duty" (weighing between 10,000 and 19,500 pounds, including slightly larger trucks and vans that are used in work applications, such as package delivery and utility services). Within this range of vehicle weights, the natural gas fuel being considered is compressed natural gas (CNG). Two perspectives within the light and medium-duty vehicle market are assessed: 1) personal and fleet vehicle owners and 2) NGV suppliers. Within the NGV supplier perspective, both original equipment manufacturers (OEMs), such as Ford, GM, Toyota, and Chrysler, and NGV converters (also known as small volume manufacturers or SVMs) are considered.

The methodology used for identifying key NGV opportunities for personal vehicle buyers, fleets, OEMs, and SVMs relies on:

- The team's industry expertise and contacts
- Interviews with key constituents (Figure 1-1)
- VHAS – The CARLAB's long-term study of characteristics of best-selling vehicles
- Government-published data

In particular, The CARLAB is an advanced automotive consulting firm specializing in product planning, forecasting, and consumer research. The company's specific alternative fuel technology research spans electric vehicles, hybrids, diesel, diesel-electric, natural gas, ethanol, and exotic-material construction, with clients including:

AAA	**Kia**
AM General	**Magna**
Audi	**Mitsubishi**
AAA	**Fisker**
Bentley	**Nissan**
BTO	**Plasan**
Chrysler	**PRC**
Comaq	**PRTM**
Connaught	**SDGandE**
Continental	**Subaru**
DCX	**Suzuki**
Disney	**THX**
Ferrari	**Ticona**
Ford	**Toyota**
GE	**Triad Services**
General Motors	**Visteon**
Global Auto	**VW**
Honda	**Volvo**
Hyundai	**VPG**
Isuzu	**Yamaha**

Leveraging The CARLAB's deep automotive industry expertise, this assessment combines direct input from light- and medium-duty vehicle manufacturers and end users with The CARLAB's specific insights into this market. The report is divided into four main sections: personal vehicle use; commercial fleet use; OEMs; and SVMs, installers, and repair professionals. The requirements, decision drivers, challenges, and opportunities from each perspective are discussed in the context of developing the light- and medium-duty NGV market.

Figure 1-1

Current and former members of these organizations were interviewed to provide insights in this analysis.

Alfred Gobar Associated	Ford	Natural Drive
Alt. Fuel Technologies	FuelTek	Nissan
AT&T	GE Capital	San Jose Police Department
BAF Technologies	GM	San Jose Unified School District
Baker	Honda	South Coast AQMD
Carmenita Truck Center	Hyundai/Kia	Suzuki
Chrysler	Magna	Toyota
EPA	Metropolitan Transit Authority	VW/AUDI
	Yellow Cab	

2 Personal Vehicle Use

2.1 Consumer Behavior

2.1.1 Range Requirements

Acceptable vehicle range of 350 to 400 miles is historically consistent across vehicle segments and inextricably tied to users' expectations of fueling approximately once weekly.

Driving distance range of personal use vehicles is today mostly a non-issue for both original equipment manufacturers (OEMs) and customers of gasoline powered vehicles, as distance needs are essentially met by the vast majority of vehicles offered in the North American market. Range requirements are clearly manifested in high volume selling vehicles across many key market classes. The summary of ranges in Figure 2.1.1-1 consistently depicts an acceptable window of around 350 to 400 miles for vehicles in all established market segments over the last 25 years of sales in the U.S. market.

In the general arrangement of a vehicle, fuel tanks, which dictate vehicle range, are placed around rear axle lines, a location that tends to be driven by weight distribution and safety concerns; alternative placement is rarely considered due to these critical factors. With the location of fuel storage effectively fixed around the crowded rear area, pressure on vehicle planners to reduce the size of the tank is ever-present. However, fuel capacity has not declined, despite such pressure, because OEMs who fail to deliver acceptable range often come under harsh criticism. For example, the Subaru Impreza GD platform (15.9 gallons) saw a tank volume expansion at the next major model change in the Impreza GE platform (16.9 gallons).

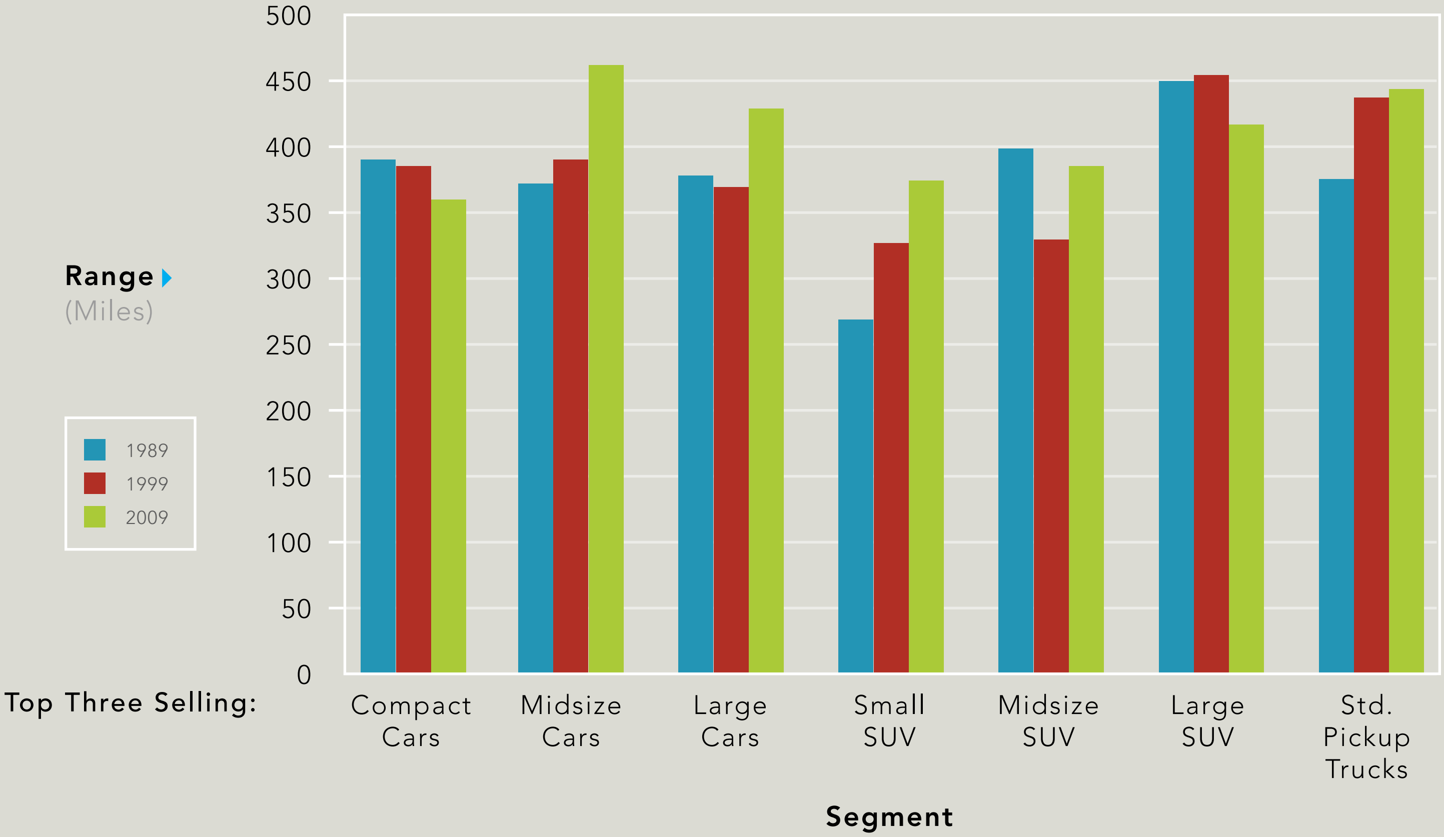
While publicized statistics show predominant daily driving distances of fewer than fifty miles, buyers want ranges far exceeding these distances. With the average driver logging approximately 29 miles daily,[1] 350 to 400 mile ranges conveniently separate fill-ups by about a week, a common planning target for OEMs. Furthermore, shoppers of personal use vehicles think in terms of potential exceptional distances associated with infrequent, recreational driving trips. In the case of continuous, long-distance highway travel, consumers' expressed ideal ranges tend to also fall between 350 and 400 miles, coinciding with approximately five hours of driving time between rest stops at typical open-road highway speeds.

However, vehicle range remains a topic of intense study for alternative fuel vehicle (AFV) makers. There is ongoing debate as to whether current personal vehicle ranges are truly required. Such debate often misses a critical point: for consumers and automakers, there is almost no direct cost for higher driving range in gasoline vehicles. Conventional fuel tanks are relatively cheap stamped steel or molded plastic items, often with a BoM (bill of materials) cost of around $20. The monetary difference between providing a 15 and 25 gallon gasoline tank is therefore almost negligible. Packaging implications are minor since gasoline tanks can be shaped in nearly any manner to fit around other vehicle components, and the weight impact on dynamic performance of a vehicle over 3,000 pounds is very slight. As a result, few inherent challenges currently exist for gasoline vehicle ranges of over 350 miles, and the North American fueling infrastructure continues to evolve around such ranges.

1 U.S. Department of Transportation Federal Highway Administration. "2009 National Household Travel Survey." http://nhts.ornl.gov. Accessed August 2012.

Figure 2.1.1-1

Consumer requirements for vehicle range (as reflected in the top three selling vehicles in each segment) have generally increased over the last 3 decades.[2]



2 Data from The CARLAB's long-term study of vehicle specifications, 2010.

2 Personal Vehicle Use

2.1 Consumer Behavior

2.1.2 Daily Use and Driving Patterns

Personal vehicle travel is very consistent across segments in terms of day-of-week, speed, distance, and other dynamics measures, varying mostly in occupants and payload.

Generally, most characteristics of regular vehicle use by private, mass market vehicle operators are remarkably uniform. Purpose, time of day, distance, and average speed are very consistent across vehicle classes and price ranges. National Household Travel Survey data confirm that the major destinations for which OEMs design most vehicles – work/school, errands, and social/recreation – dominate total vehicle usage at 29 miles per day,[3] equivalent to total vehicle usage of about 200 miles per week. Other recent studies of miles traveled support this planning assumption, with the average vehicle logging 11,853 miles annually,[4] or 228 vehicle miles per week. An examination of the daily miles driven in the U.S. reveals that the vast majority of trips driven in the U.S. are fewer than 40 miles (Figure 2.1.2-1).

Examinations by carmakers in which vehicles are instrumented and monitored in use confirm little variance in actual driving dynamics. In key measures, such as velocity and lateral and linear acceleration, most light- and medium-duty vehicle usage looks surprisingly similar, a fact illustrated daily by the collection of vehicle types (e.g., Toyota Camrys, Chevrolet Silverados, and BMW M5s) on a metropolitan highway or suburban arterial road. Such driving consistency between personal use vehicles continues with the distribution of daily trips within a week, with all seven days accounting for between 12.9 percent (Sunday) and 15.6 percent (Friday) of total trips per week. These trips tend to originate from households most often based in suburban and rural areas, as described further in Section 2.2.3.

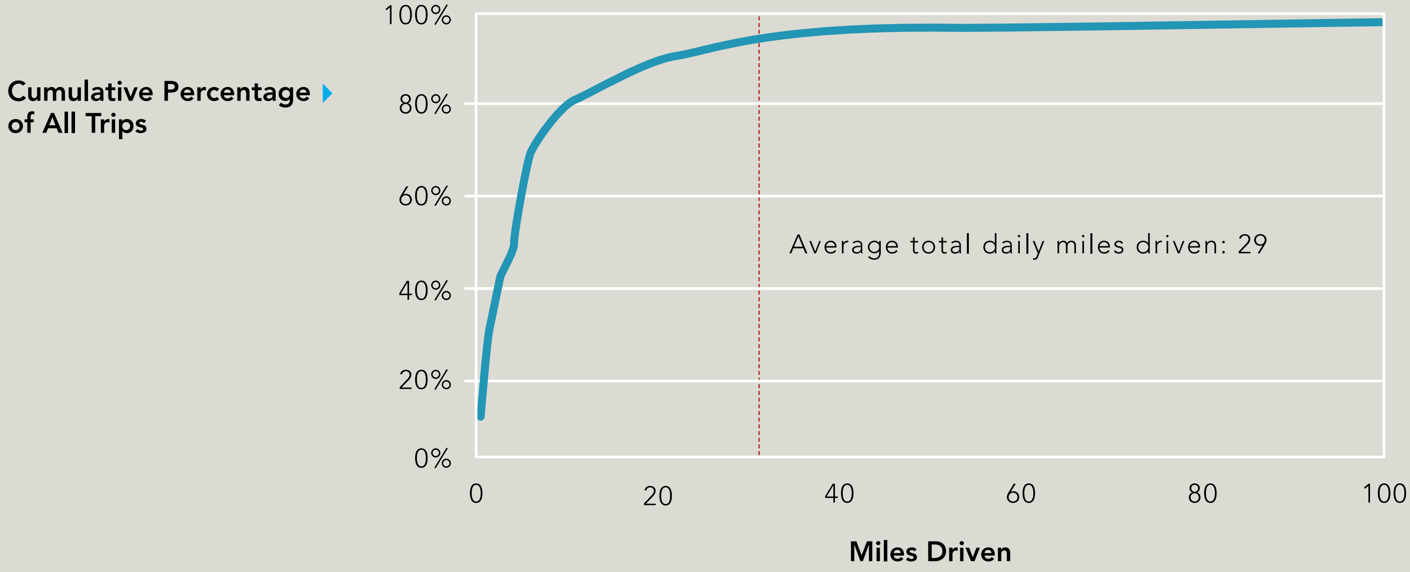
Infrequent private vehicle use for longer distances tends to average about 220 miles in each direction, and trips of this length account for approximately 90 percent of all long distance trips made by personal vehicles in the U.S;[5] longer distance trips tend to fall to other modes of transportation, such as aircraft. Consumers have these occasional trips in mind when seeking long ranges for their vehicles.

While general driving patterns across private vehicle owners tend to be similar, they belie very real differences in how vehicles of different segments are used, if not driven. Key among these usage variances are occupants and payload, both of which are particular to vehicle segment and bear on chassis, fuel and engine/power system planning during vehicle engineering, research, and development.

3 U.S. Department of Transportation Federal Highway Administration. "2009 National Household Travel Survey." http://nhts.ornl.gov. Accessed August 2012.
4 Oak Ridge National Laboratory. "Transportation Energy Data Book." Edition 31. 2012.
5 U.S. Department of Transportation, 2001.

Figure 2.1.2-1

A consideration when designing alternative fuel tank capacities is that the vast majority of trips driven in the U.S. are fewer than 40 miles, and the average total daily range is 29 miles.[6]



6 U.S. Department of Transportation Federal Highway Administration. "2009 National Household Travel Survey." http://nhts.ornl.gov. Accessed August 2012.

2 Personal Vehicle Use

2.1 Consumer Behavior
2.1.3 Vehicle Turnover Rate

Due to mandated and technological improvements in light- and medium-duty vehicle durability, turnover of the North American fleet is lengthening.

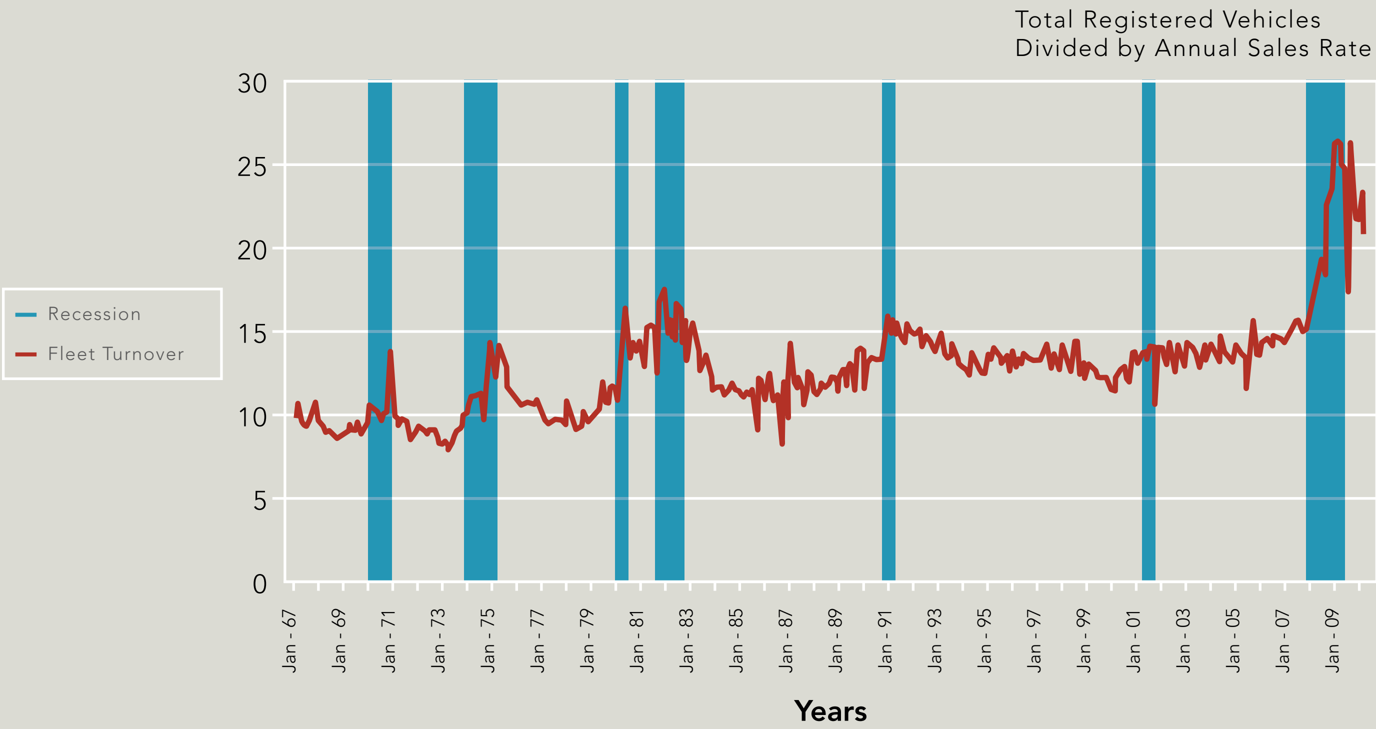
Vehicle turnover rate is a function of both sales and scrappage, the former being transitory to the extent it is heavily tied to economic conditions and consumer confidence (Figure 2.1.3-1). Scrappage, on the other hand, is heavily influenced by a less volatile factor, vehicle reliability. Long term durability, quality, and reliability of vehicles sold in North America continue to increase, along with the length of most OEM warranties and of regulated emission control lifespan (which keeps vehicles "smog legal" longer than previously). Absent artificial inducements such as the Cash for Clunkers program, average vehicle life has increased, impacted by real improvement in vehicle durability and by the relative household demand and purchase rates for new and used vehicles.

As reported by Polk, the average vehicle in the total U.S. fleet is now more than ten years old. This average is up from only 5.6 years in 1977 and 7.7 in 1990,[7] precisely for the reasons stated above. By age, the distribution of vehicles in the national fleet has traditionally fallen dramatically at ten years or older, but fully 23.4 percent of all vehicles are now ten to fifteen years old.[8] This trend toward longer lifespan of vehicles, subsequent aging, and resulting longer turnover of the national fleet has challenging implications for policymakers and others desiring to effect change in the composition of that fleet.

7 U.S. Department of Transportation. "Nationwide Personal Travel Survey." 1998.
8 U.S. Department of Transportation. "National Household Travel Survey." 2009.

Figure 2.1.3-1

Vehicle turnover is a function of sales and scrappage, and the lifetime of vehicles in the U.S. fleet has increased significantly.



2 Personal Vehicle Use

2.1 Consumer Behavior

2.1.4 Repair Service Availability and Financing Requirements

Repair service availability and financing requirements of NGVs are similar to those of gasoline vehicles when manufactured and distributed by OEMs in volume.

For OEMs and dealers alike, private AFVs are treated without prejudice in terms of repair service and part availability. The Civic Natural Gas, for instance, carries essentially the same warranty as the gasoline-powered Civic. Some differences in service schedule apply to NGVs (valve adjustments every 30,000 miles for the GX vs. 120,000 miles for the gasoline vehicle, and CNG tank inspections every three years or 36,000 miles), but such differences are a normal part of vehicle maintenance for dealers of multiple vehicle lines. Diesel vehicles, for instance, also require different service intervals than gasoline vehicles, for refilling of urea injection systems (e.g., Mercedes Benz's BlueTEC) and other fuel specific components. Because natural gas is a cleaner-burning fuel than gasoline, NGVs have an advantage over gasoline vehicles in that fewer oil changes are needed. For private repair facilities, natural gas is currently an unfamiliar technology as a result of its rarity. Like all nascent service needs, natural gas repair capabilities outside of dealerships would advance directly with market penetration of NGVs. Training and equipment advances are routinely absorbed by private garages whenever new technologies such as fuel injection, variable valve control, and continuously variable transmissions have surfaced in mass-produced cars.

Financing of new vehicle acquisition sees more variance, as dealers and consumers are free to choose from a wide variety of captive (e.g., Ford Motor Credit or GMAC), dealer (e.g., Chase) and buyer-accessed (e.g., credit unions) sources. Each source may have unique underwriting requirements, but OEM produced cars are typically treated similarly, regardless of fuel type (Figure 2.1.4-1), except to the extent it impacts residual value for leases. Residual values for alternative fuel vehicles, whether higher or lower than their gasoline-fueled counterparts, factor into the cost of leasing. In markets with small numbers of NGVs, the low number of transactions may hinder the establishment of accurate residual values. However, as the market expands, this concern diminishes. As shown in Table 2.1.4-1, three-year residual values for several alternative fuel vehicles exceed those of their gasoline counterparts, in part reflecting the higher initial cost of these vehicles. In any case, post-dealership modification, including natural gas conversion, of vehicles typically does not enjoy OEM captive financing or dealership-provided third party financing.

Figure 2.1.4-1

When produced and sold by OEMs at significant volume, repair service availability and financing requirements for NGVs are expected to be similar to those of gasoline vehicles.

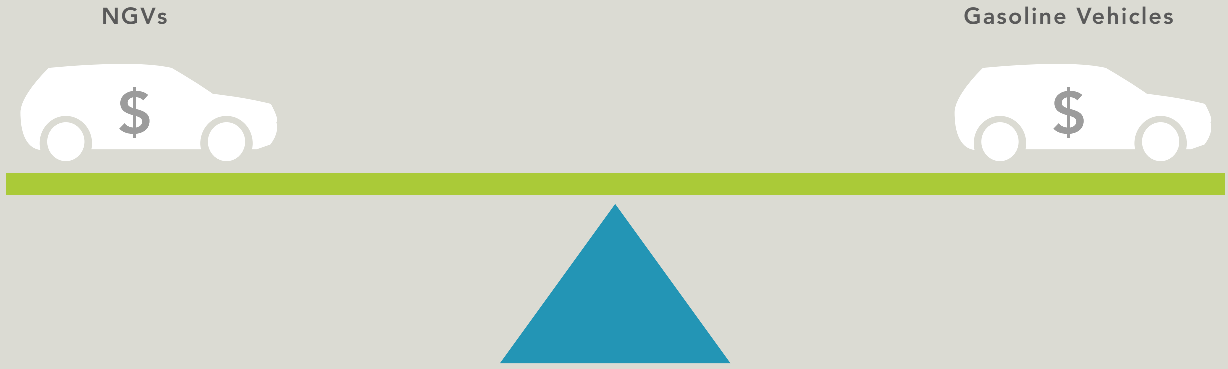


Table 2.1.4-1

These comparisons show that for several alternative fuel vehicles, residual values 3 years after purchase may exceed those of their corresponding gasoline-fueled models.

Vehicle	Residual Value After 3 Years
Honda Civic	$13,728
Honda Civic, Hybrid	$16,204
Honda Civic, Natural Gas	$16,257
Ford F-250	$18,454
Ford F-250, Diesel	$24,449
Ford F-350	$19,186
Ford F-350, Diesel	$25,564

Sources: Edmunds, Kelly Blue Book, and Intellichoice; values adjusted to reflect equal equipment levels.

2 Personal Vehicle Use

2.2 Consumer Preferences of Vehicle Attributes

2.2.1 Fuel Economy

Fuel economy has not been a primary motivator of consumers' vehicle choices within segments or of long-term segment migration in the North American market.

Personal use vehicle buyers are consistent in their demand for improved vehicle dynamic performance, but not fuel economy, over time, as evidenced by a recent study of the top selling personal use vehicles in the U.S. over the last 25 years (Figure 2.2.1-1). This figure presents the average combined fuel economy for seven major segments of personal use vehicles, examining the best-selling three models in each. While consumers' stated importance of fuel economy varies with pump prices and the geopolitical environment, their vehicle purchase behavior reveals a pattern to the contrary: a relatively constant fuel economy in the top selling vehicles, which essentially establishes a level of expected and accepted fuel economy for each segment.

Furthermore, despite assumptions widely reported by media during times of increased fuel prices, purchases of personal use vehicles across segments appear to be uninfluenced by fuel economy. That is, segment switching toward smaller vehicles in order to attain higher fuel economy has been historically absent. In fact, steady growth of the sport utility vehicle (SUV) segment suggests consumer behavior to the opposite effect. Figure 2.2.1-2 illustrates that segment sales since 1985 have been remarkably stable, moving mostly in sync with macroeconomic forces.

Figure 2.2.1-1

Average combined fuel economy has remained relatively unchanged over the last 25 years.

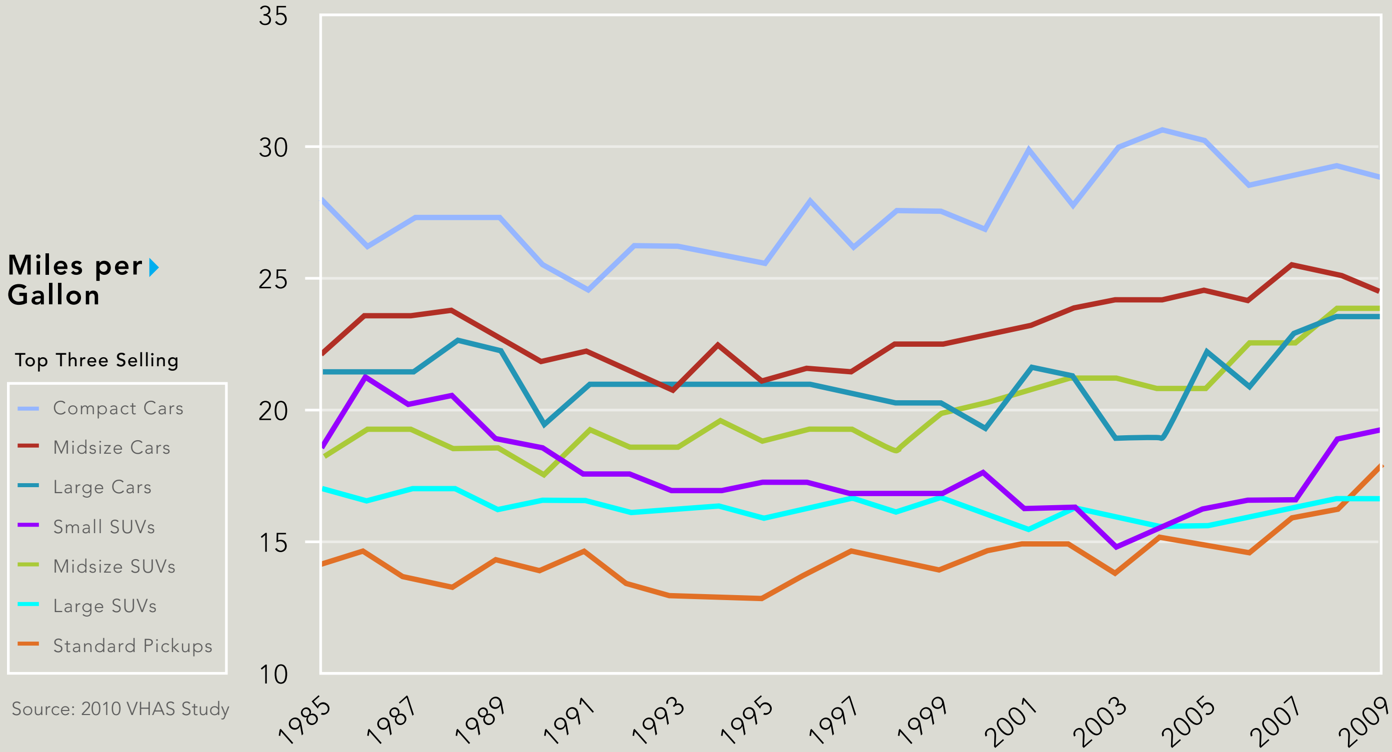
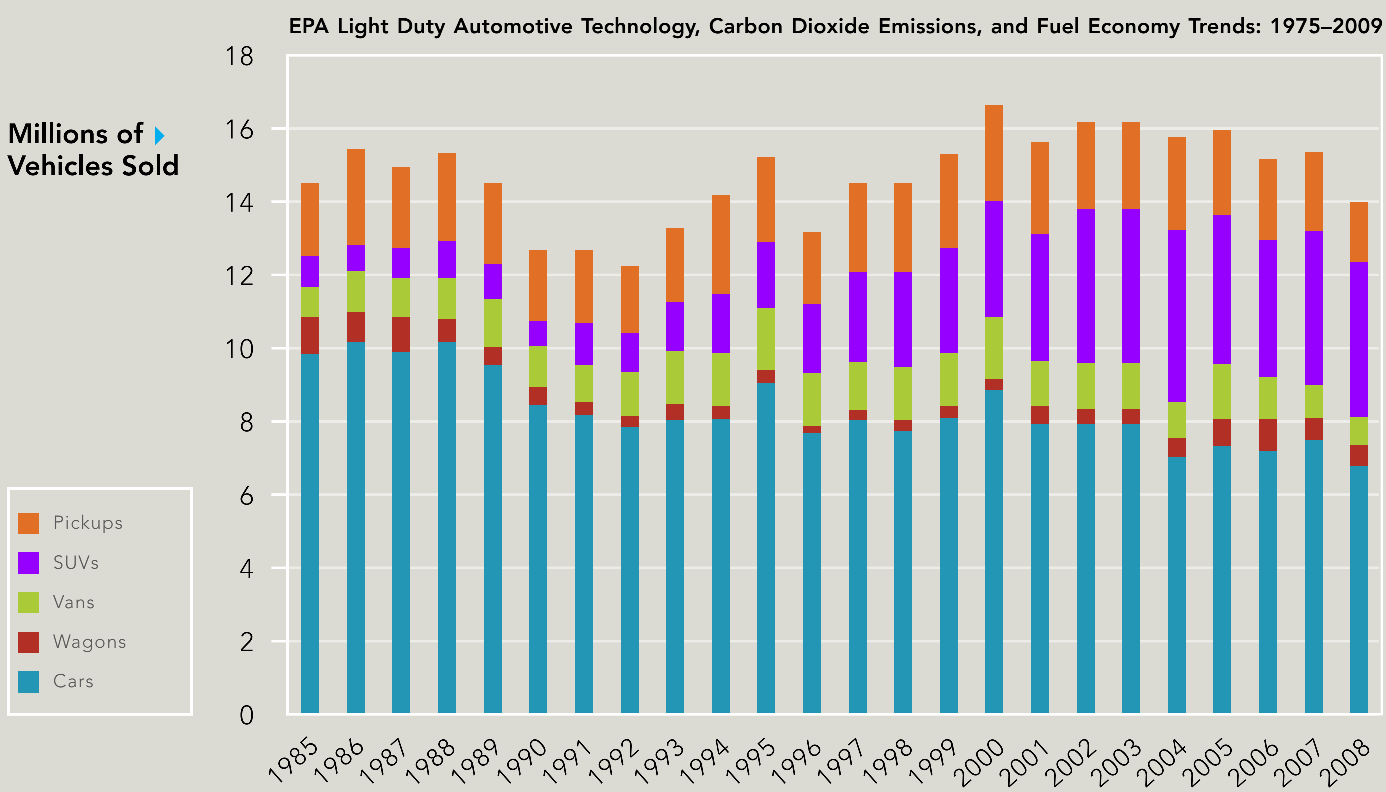


Figure 2.2.1-2

U.S. market segment shares have been largely stable, with gradual shifts toward SUVs.



2 Personal Vehicle Use

2.2 Consumer Preferences of Vehicle Attributes

2.2.2 Vehicle Power and Weight

Across all sizes, vehicles have increased in engine power, torque, and weight for 25 years. Consumer demand, safety regulations, and economics will tend to perpetuate these trends.

If cross-segment relationships and fuel efficiency within segment have been mostly stable for 25 years, the question remains as to what motivates light vehicle buyers from a hardware perspective. Figure 2.2.2-1 depicts horsepower and torque from 1985 to 2009, again as an average of the top three sellers in each major segment. What is clear from these related findings is that marked advances in engine technology have been used to yield dramatic power increases across all classes of light vehicles. This consistent increase in engine performance is a result of both consumer demand for better performance and OEM response to regulatory requirements (equal or better performance despite necessarily increased vehicle weight to meet increased safety standards).

For consumers in most vehicle classes, features once considered optional, such as air conditioning and power windows, are now rarely missing on any vehicle or any trim level. In fact, most OEMs participating in the North American market plan new vehicle programs with no roll-up windows at all. The same applies to manual gearboxes, which have been almost completely supplanted by heavier automatic transmissions on all but a few vehicles.

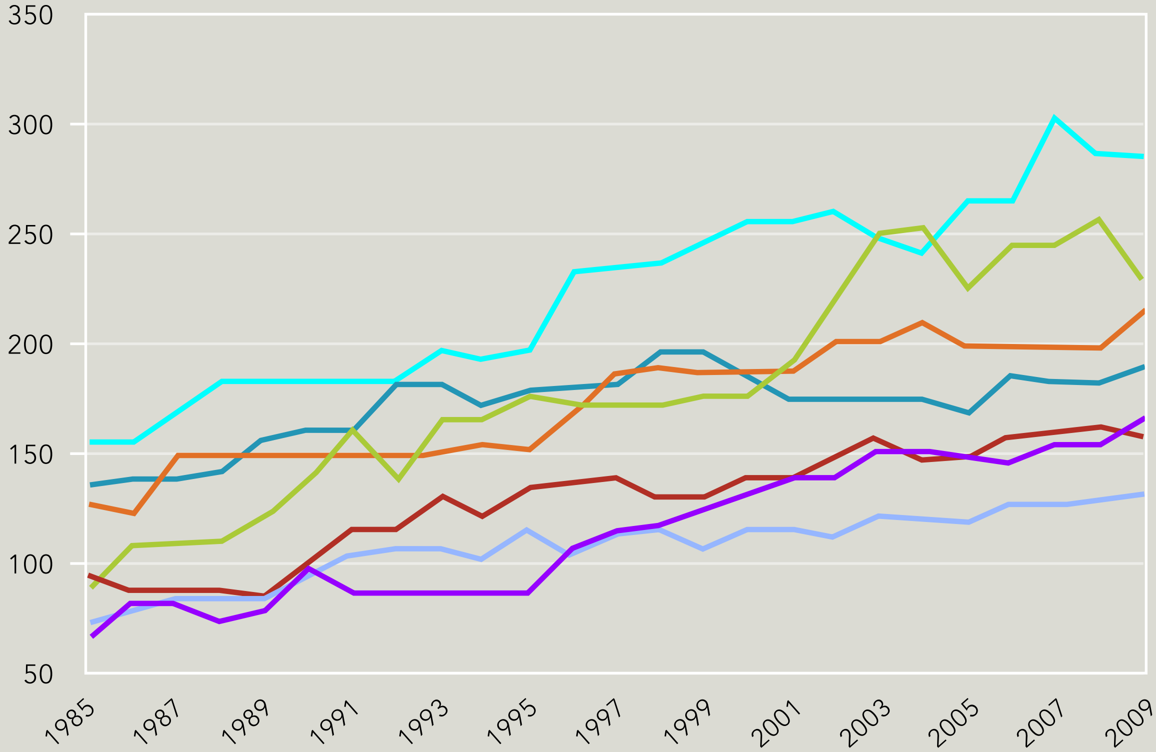
As vehicle feature content has burgeoned, OEMs are simultaneously challenged to meet dramatically increased crash standards, inevitably resulting in increasing amounts of sheet and tubular steel in vehicle's construction. While lightweight alloys and composites exist and are perennially touted as challengers to steel's dominance in vehicle body and frame systems, few price classes of vehicle support their substitution for steel from an economic standpoint. Even in times of relatively high gasoline prices such as those experienced in 2008 and 2009, the generally accepted rule by OEM vehicle line planners is that the cost per pound of mass saved cannot exceed about one dollar for most models and segments. This cost challenge eliminates exotic materials such as carbon fiber and aluminum alloys from most body systems for all mass-market vehicles.

The low value planners place on mass elimination is not arbitrary but rather speaks to the fact that consumers themselves, as evidenced by their purchase behaviors, find no explicit benefit in such efficiencies. To the extent increased mass results in cars with more comfort, amenities, and safety and less noise, buyers actually reward increased vehicle weight, both in terms of volume and price paid. These externally counterintuitive findings are routinely borne out by OEM studies showing correlation between price and mass for most U.S. segments.

Figure 2.2.2-1

While fuel economy has remained relatively unchanged, average horsepower and torque have increased over time, indicating that changes to engines have been motivated by performance improvements.

Horsepower ▸

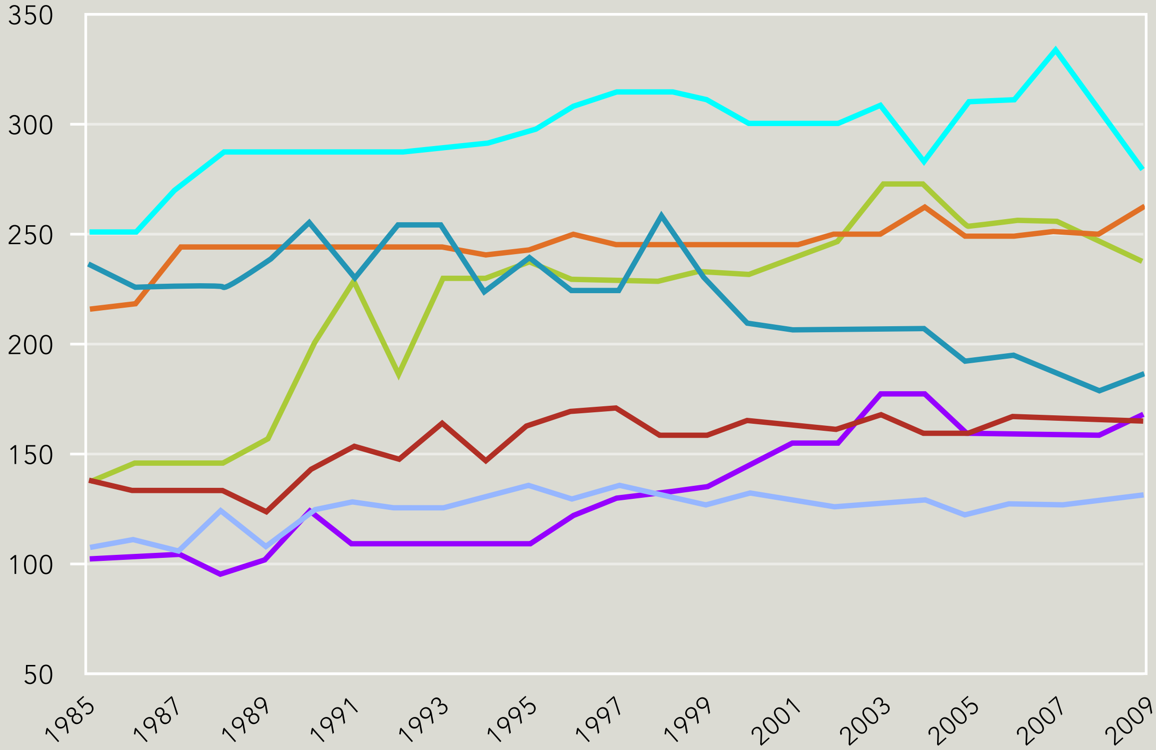


Top Three Selling

- Compact Cars
- Midsize Cars
- Large Cars
- Small SUVs
- Midsize SUVs
- Large SUVs
- Standard Pickups

Source: 2010 VHAS Study

Torque ▸
(foot-pounds)



Top Three Selling

- Compact Cars
- Midsize Cars
- Large Cars
- Small SUVs
- Midsize SUVs
- Large SUVs
- Standard Pickups

Source: 2010 VHAS Study

2.2 Consumer Preferences of Vehicle Attributes
2.2.2 Vehicle Power and Weight (Concluded)

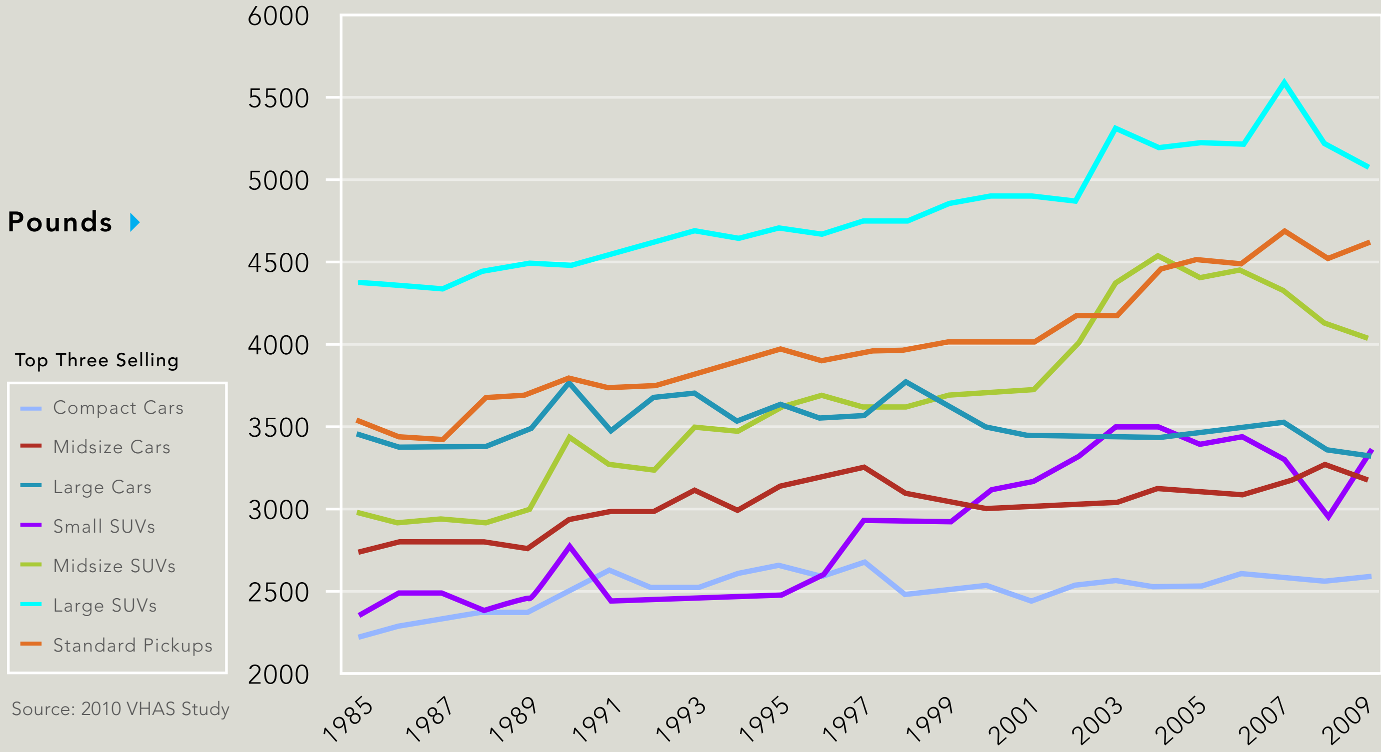
Such realities of both demand and regulation result, for instance, in the weight of a Ford F-series base pickup moving from 3,412 pounds in 1985 to 4,743 pounds in 2009. Examination of this vehicle reveals massive increases in frame rail section and the addition of boron steel beams to reinforce the upper cab structure to meet upgraded Federal Motor Vehicle Safety Standards (FMVSS) thresholds and tests.

Figure 2.2.2-3 shows that curb weight has increased for 25 years nearly as rapidly as have horsepower and torque, but such large mass gains have been offset by the aforementioned rise in engine output. Regardless of fuel type, light-duty vehicle weight in North America may reasonably be expected to continue to rise for the next several generations, or for at least ten to twenty years. While increasing Corporate Average Fuel Economy (CAFE) standards have long been predicted to result in lower vehicle mass, to date they have not. CODA Automotive, an electric vehicle manufacturer, provides a recent example. For the company's first electric vehicle, CODA placed a large emphasis on weight reduction to improve the vehicle's battery power range, yet the company added 200 kg of steel to its Chinese-made vehicle to meet U.S. crash standards.[9] It is less certain if engine and transmission performance gains can continue to outstrip the rise in weight required by safety and consumer demands. As unprecedented CAFE greenhouse gas standards come into effect, however, new requirements for automakers may reverse this trend.

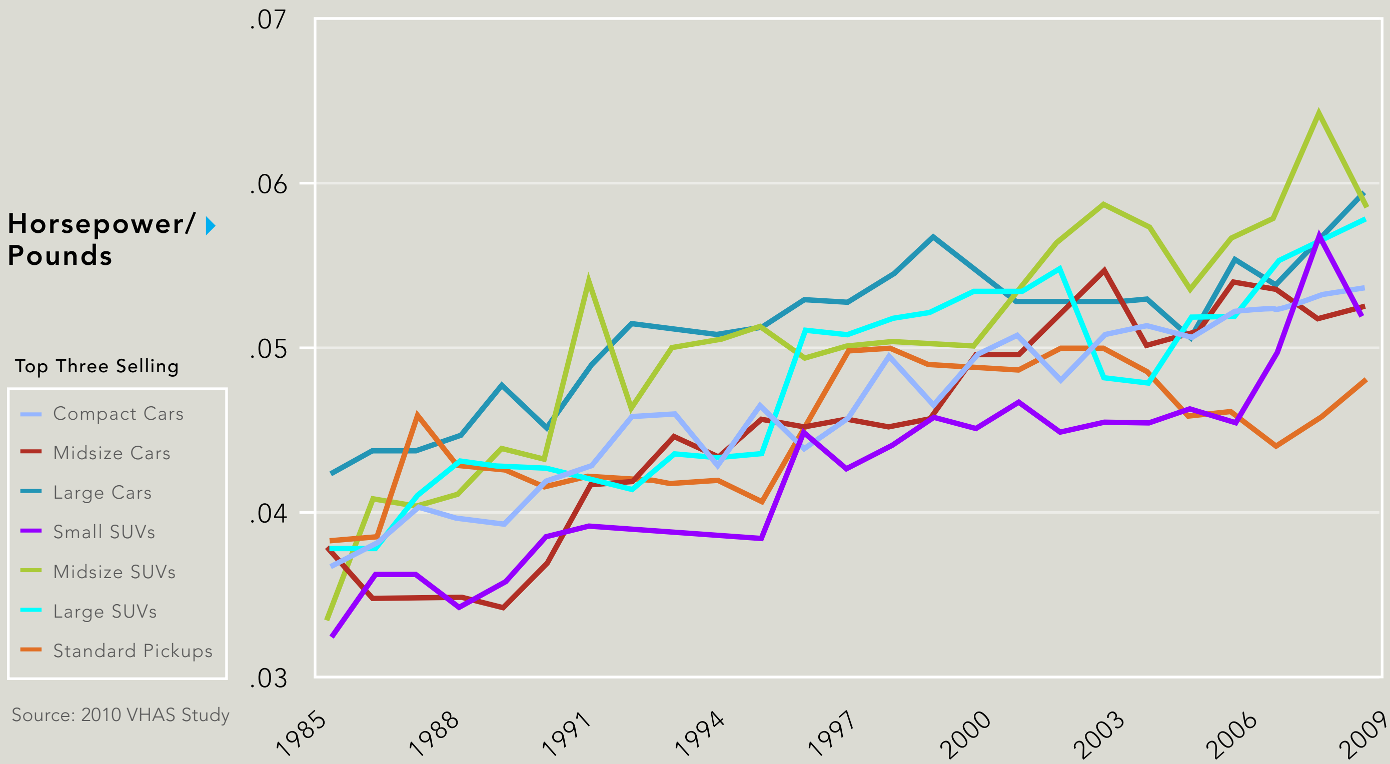
9 CODA Automotive Media conference call, September 21, 2010.

Figure 2.2.2-3

Increases in vehicle power to weight ratios have enabled vehicles to become heavier despite increases in CAFE standards.



Source: 2010 VHAS Study



Source: 2010 VHAS Study

2 Personal Vehicle Use

2.2 Consumer Preferences of Vehicle Attributes

2.2.3 Suburban Growth and Infrastructure Implications

Suburban land use planning continues to place most private home garages thirty minutes away from workplaces, subsequently resulting in relatively sparse distribution of fueling stations.

Modern suburban growth, famously beginning in 1947 with Levittown in the postwar Nassau County, New York area, together with America's rapid expansion of the interstate highway and freeway systems beginning in the same period, places most new vehicle consumers in suburban or formerly rural, not urban, areas. Re-urbanization, and attendant relocation of the new vehicle buyer, has so far failed to materialize in North America, a fact demonstrated by the relatively consistent failure of a number of "urban car" market entrants, from the 1954 to 1962 Nash Metropolitan with peak sales of 22,209 in 1959 (the same year in which 525,461 Chevrolet sedans were sold) to the current Smart Fortwo, sales of which had fallen to only 560 units in July 2010, from an already modest 1,418 for the same month in 2009.

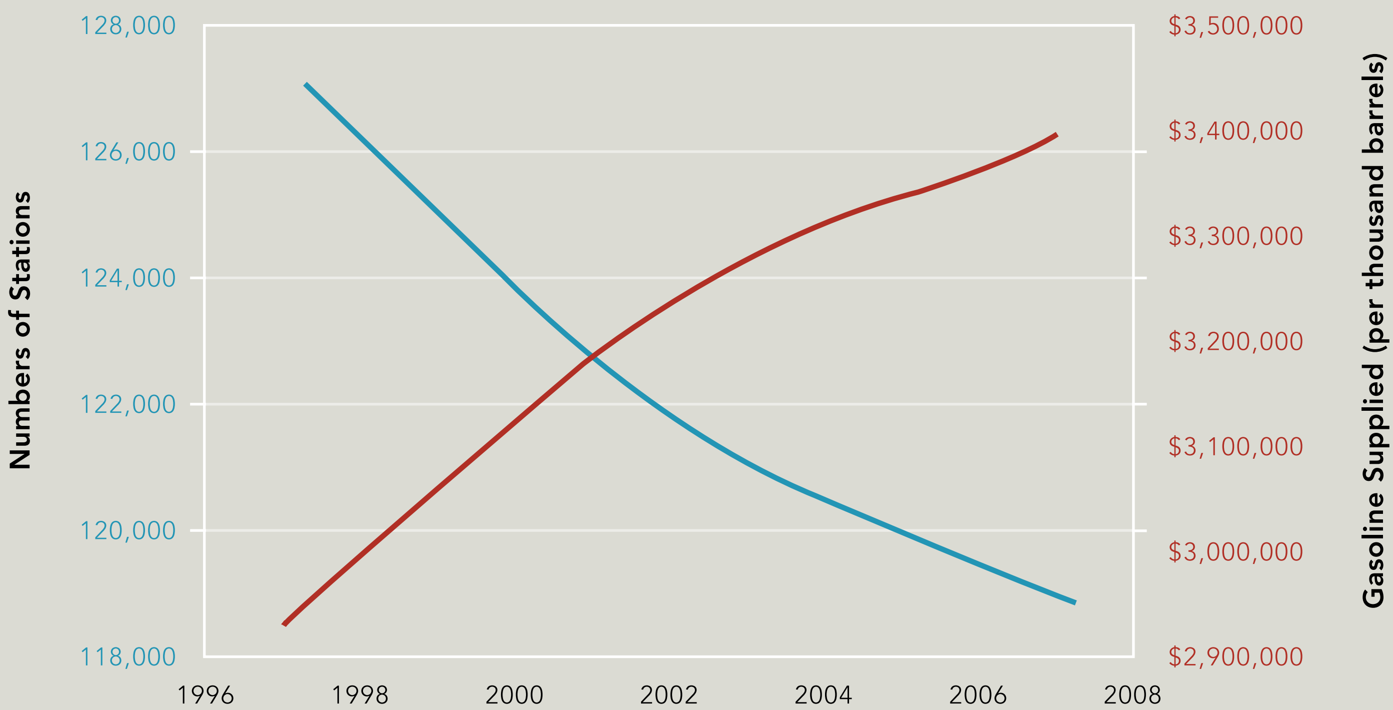
Current land use planning further mirrors this trend, with highly publicized "infill" urban development accounting for a small share of new housing construction. In contrast, massive suburban sprawl continues with the approval of regulating agencies. Double digit growth was seen in Kendall County, Illinois; Rockwall County, Texas; and Loudoun County, Virginia, three commuter suburbs typifying residential distribution in major metropolitan areas (in this case, Chicago, Dallas, and the District of Columbia, respectively) throughout the country.

While such suburban developments require commuting to workplaces by nearly all residents, very little emphasis is currently placed on zoning for new fuel filling installations, which may be an opportunity for the NGV market. The average American commute is approximately 14 miles each way,[10] consistent with the thirty minute drive time planners generally assume jobs can be from new housing developments. Implicitly, planners intend for most vehicle fueling to occur in employment areas. Thus, much new development and vehicle population shift in the first decade of the 21st century remains supported by the same 118,756 gasoline stations existing in 2007,[11] a number already down from the 126,889 stations in 1997.[12] As the total number of stations decreased, the throughput per station increased, suggesting overall consolidation of retail fueling stations (Figure 2.2.3-1). The majority of suburban housing zoning and development actions, as relevant to retail fueling infrastructure, continue to reinforce vehicle ranges at current levels and apply pressure for higher ranges. This has resulted in a thin distribution of fueling stations across the country, with 0.034 gasoline stations per square mile or 1 station for every 30 square miles.

10 U.S. Department of Transportation. "National Household Travel Survey." 2009.
11 U.S. Census Bureau. "Economic Census." 2007.
12 U.S. Census Bureau. "NAICS 4471." 1997.

Figure 2.2.3-1

While the total number of retail gasoline stations in the U.S. is declining, increasing volumes of gasoline supplied indicates increasing throughput per station and consolidation of fueling infrastructure as a whole.[13,14,15]



13 U.S. Census Bureau. "Economic Census." 2007
14 U.S. Census Bureau. "NAICS 4471." 1997.
15 U.S. Energy Information Administration. "U.S. Product Supplied of Finished Motor Gasoline." http://www.eia.gov/dnav/pet/pet_cons_top.asp. Accessed October 2010.

2 Personal Vehicle Use

2.3 Consumer Perceptions of Fuel Types

2.3.1 Overview

American consumers dislike gasoline for its perceived geopolitical and security costs, giving an advantage to all potential vehicle fuels, including natural gas, which does not appear to be associated by consumers with oil.

Due to the periodic conflicts around fuel extraction, import, cartels, pricing, and even availability, North American consumers have been conditioned to see fuels derived from crude oil as suboptimal environmentally, politically, and economically. Natural gas does not currently appear to suffer from association with oil among U.S consumers, who are relatively unaware of the two fuels' close association in extraction and providers.

Most proprietary research by the auto industry reveals a car buying public eager to see gasoline supplanted as the predominant fuel for their vehicles, whether for reasons of environmental sensitivity or nationalism (energy independence). Such disloyalty to fuel source is hardly new, as the early twentieth century saw massive shifts by drivers away from electric vehicles and into the then newly advanced gasoline powered vehicles.

Like other alternative fuels for vehicles, natural gas is far from new. For most consumers, NGVs are associated with municipal buses, along with residential water heaters, furnaces, and appliances – reassuring associations, with the types of occasional, publicized setbacks that befall all energies. Auto industry research respondents, when prompted, express familiarity with and little reservation to natural gas as a source of vehicle power yet have little experience with it in such an application. Results of Kelley Blue Book's 2008 Eco Watch study ranked natural gas among the top three alternative fuels in which new vehicle shoppers were interested (Table 2.3.1-1). In the study, which has been updated monthly since its debut, 22 percent of total respondents were "very interested" in natural gas, while another 38 percent were "interested but have questions." As gasoline prices have declined over the period, however, monthly measures for both interest levels have trended slightly downward from 22 to 18 percent and 39 to 35 percent, respectively. Similar waning demand for all alternative fuels typifies times of declining, low, or stable gasoline prices.

Table 2.3.1-1

Kelley Blue Book's Eco Watch Study demonstrates a waning consumer interest in alternative fuels as gasoline prices stabilize.

For the Following Technology, Please Indicate Your Level of Interest Technology: Natural Gas (A Mixture of Hydrocarbons–Mainly Methane)				
	2008 (All Months)		June 2010	
Base Number of Respondents	15,001	100%	1,704	100%
Definitely Interested	3,281	22%	304	18%
Interested but Have Questions	5,737	38%	603	35%
Skeptical	5,367	36%	717	42%
Never Heard of It	616	4%	80	5%

2 Personal Vehicle Use

2.3 Consumer Perceptions of Fuel Types

2.3.2 Safety Concerns

Consumers make little distinction among safety perceptions of various fuel types – all are seen as mostly safe and occasionally dangerous.

There is little variance in consumer perception of safety between vehicle fuel types. Significantly, gasoline vehicles, the overwhelming norm, continue to have occasional, spectacular fuel fires covered by media. Toyota's recent negative coverage regarding claims of unintended acceleration has been instructive to all OEMs participating in North America: if quality champion Toyota is subject to safety crisis in the minds of buyers, then so are all automakers. The topic of perceived safety since the recent Toyota events has been extensively researched throughout the industry with very similar results. Consumers view all vehicles as potentially dangerous to an extent but are philosophical about the risks over the long term. Gasoline and diesel fires will continue to occur, and electric vehicle (EV) batteries will doubtless eventually be involved in dramatic spills, accidents, and conflagrations as well.

Concurrently, natural gas has been used at some volume in the North American vehicle fleet for many years, so consumers are unlikely to be faced with the specter of dramatic new, unforeseen dangers from the fuel if market penetration increases. Indeed, the U.S. Environmental Protection Agency (EPA) has established natural gas as a very safe vehicle fuel (Figure 2.3.2-1). As with conventional fuel vehicles, NGVs have experienced accidents, but they have also been credited with increasing the safety of vehicles for drivers. For example, in an accident involving a New York State Department of Transportation Honda Civic Natural Gas, the vehicle's CNG tank was cited by the accident investigator as the reason the driver was protected from the impact of the fully load tanker truck (Figure 2.3.2-2). As for SVMs, whether or not their products, conversions, and service are compliant with FMVSS and OEM standards, mainstream consumers appear to simply not consider them.

Figure 2.3.2-1

The U.S. Environmental Protection Agency regards natural gas as a very safe fuel for use in vehicles.[16]

Safety

Although CNG is a flammable gas, it has a narrow flammability range, making it an inherently safe fuel. Strict safety standards make CNG vehicles as safe as gasoline powered vehicles. In the event of a spill or accidental release, CNG poses no threat to land or water, it is nontoxic. CNG also disperses rapidly, minimizing ignition risk relative to gasoline. Natural gas is lighter than air and will not pool as a liquid or vapor on the ground. Nevertheless, leaks indoors may form flammable mixture in the vicinity of an ignition source. CNG is primarily methane, however, which is a greenhouse gas that could contribute to global climate change if leaked. Methane is slightly soluble in water and under certain environmental conditions (anaerobic) does not biodegrade; if excess amounts accumulate, the gas can bubble from the water, possibly creating a risk of fire or explosion.

Reported incidences of bus fires are related to engine failures, not the use of natural gas. Natural gas buses have onboard gas detectors and other safety devices, such as tank safety valves that allow fuel flow only when the engine is keyed on. Also, the tanks must be inspected and approved by the U.S. Department of Transportation after certain periods of use.

There are some different safety concerns with CNG buses than diesel fuel buses, such as greater breaking distance due to increased fuel storage system weight. This is a relatively small concern, however, because the fuel system is a small fraction of a bus' total weight. CNG buses also might accelerate slower than their diesel counterparts.

Figure 2.3.2-2

In an accident in which a Honda Civic Natural Gas owned by the New York State Department of Transportation was struck from behind by a fully loaded gasoline tanker, the strength provided by the CNG fuel tank was credited with saving the driver's life.

16 U.S. Environmental Protection Agency. "Clean Alternative Fuels: Compressed Natural Gas." http://eerc.ra.utk.edu/etcfc/docs/EPAFactSheet-cng.pdf. March 2002.

2 Personal Vehicle Use

2.3 Consumer Perceptions of Fuel Types

2.3.3 Consumer Consideration of Alternative Fuel Vehicles

Customers tend to financially compare alternative fuel vehicles of all types to similar gasoline powered competitors. Annual fuel costs are relatively low in personal vehicle use, and AFV acquisition costs are high, so such comparisons are rarely favorable for AFVs.

The recent ascent of some hybrid vehicles to sales success across North America and the globe has created a general expectation among consumers that vehicle fuel efficiency is a premium feature in price. U.S. consumers have learned to quickly consider, in financial measure, whether such premium powertrain systems make sense within their expected ownership term. Critically, such calculation is nearly always performed at some level in consideration of alternative fuel or alternative powertrain systems and vehicles.

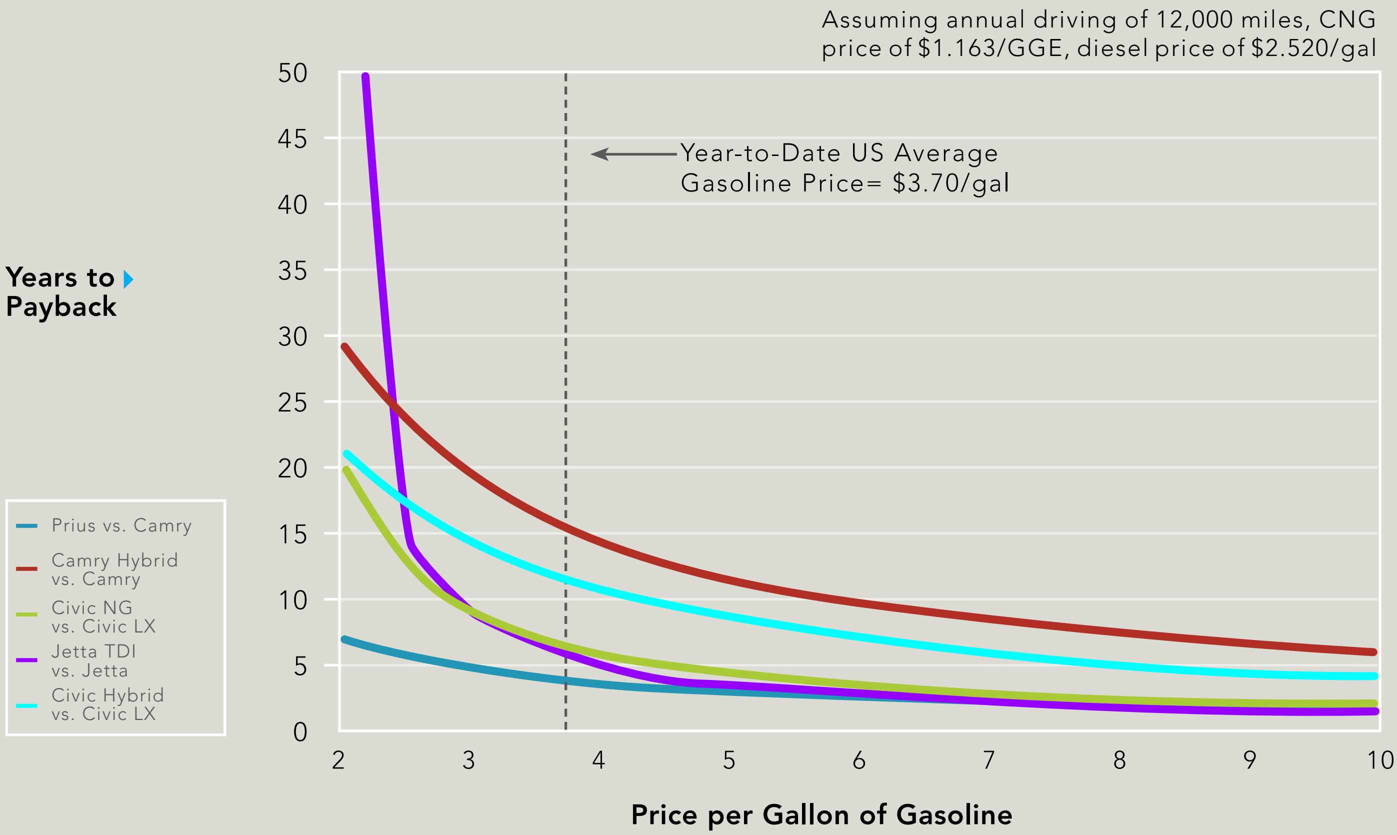
Figure 2.3.3-1 depicts a version of such analysis in a format familiar to that of carmakers and their suppliers. In this "payback analysis," the price difference (premium) for the alternative fuel/powertrain trim or model versus its closest equivalent gasoline trim or model is amortized by lower fuel costs over annual expected miles driven and years of ownership. What is apparent from these curves, and all variations of the same analysis, is that annual fuel cost for light vehicles is relatively insignificant when compared with the cost premium for most alternative fuel systems/vehicles. This leaves most alternative fuel/powertrain vehicles with payback curves unpalatable to the majority of personal use buyers.

At current gasoline prices, for instance, only the Prius (when compared with the Camry) has a premium payback of less than five years if driven 10,000 miles annually. While such an analysis is more sophisticated than what might be used by average vehicle shoppers, the basic relationship it depicts is not lost on them. The best-selling hybrid in history, the Toyota Prius, has by far the best payback curve of any hybrid vehicle in the North American market – one that promises many users full payback of premium paid to acquire a Prius well within the window of their likely ownership. This is one of the key reasons sales of the Prius have been so strong relative to all other gas/electric hybrids to date.

Additional comparisons of light- and medium-duty NGVs with other alternative fuel technologies can be found in the Comparative Analysis report of the overall TIAX assessment.

Figure 2.3.3-1

The Toyota Prius is currently the only vehicle with a reasonable payback period of just under 5 years.



Assumptions: Vehicle Make and Model	MSRP	MPG
Honda Civic Natural Gas	$25,280	28
Honda Civic Hybrid	$23,800	42
Honda Civic LX	$18,360	29
Toyota Camry	$19,720	26
Toyota Camry Hybrid	$26,150	34
Toyota Prius	$22,800	50
Volkswagen Jetta	$17,735	25
Volkswagen Jetta TDI	$22,830	34

1. No discount rate is included in this payback analysis to more closely approximate the decision making process of most consumers.
2. All MSRPs are provided by their respective manufacturers as of October 2010.

2.3 Consumer Perceptions of Fuel Types
2.3.4 Bi-fuel Vehicles

Because of their inherent flexibility, bi-fuel vehicles in general enjoy far more demand with light vehicle users than do dedicated AFVs, especially when one of the two fuels is gasoline, with its range and distribution advantages.

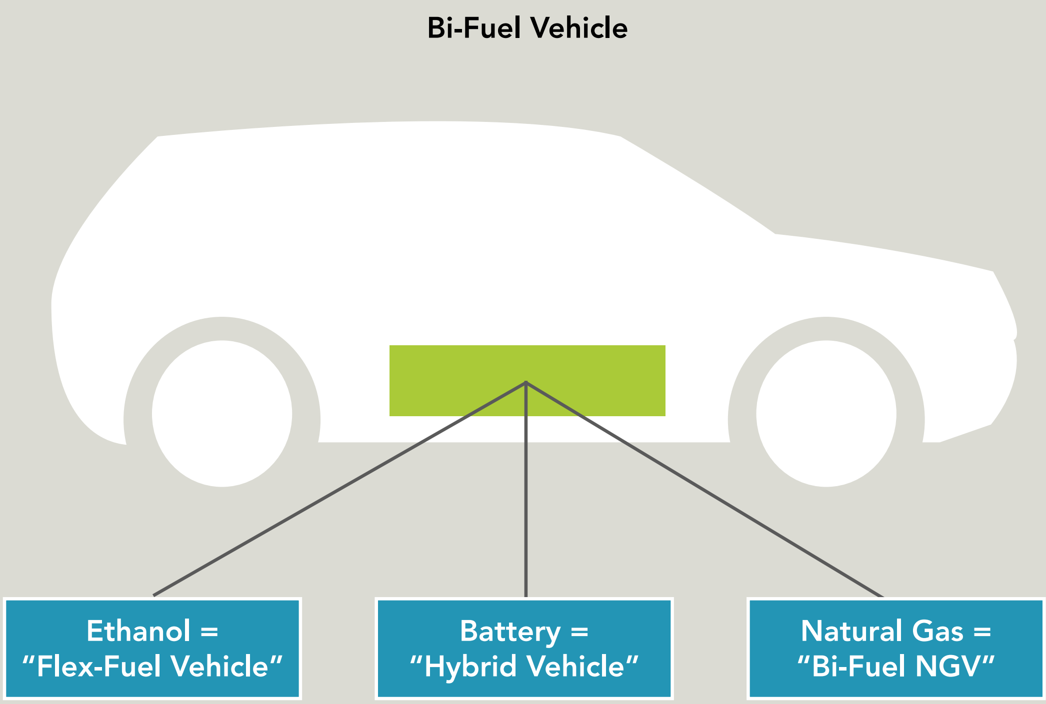
The relative success of hybrid electric vehicles (HEVs) for personal consumer use strongly illustrates the advantage of leveraging gasoline's extensive and familiar distribution system to lower consumer objections to alternative powertrains. The recent sales volume of "FlexFuel" gasoline/ethanol vehicles (FFVs) also illustrates this point, even if few buyers actually use the intended ethanol capability. Both vehicle types have outsold other alternative fuels/powertrains precisely because consumers are not asked to change their behavior. In the case of FFVs, the case to adopt these vehicles is driven by the fact that the buyer incurs zero incremental vehicle costs. Fundamentally, FFVs, hybrids, and bi-fuel NGVs are essentially equivalent, differing only in the form of alternative energy storage—ethanol, battery, and natural gas, respectively—that accompanies gasoline (Figure 2.3.4-1).

Ethanol flex-fuel capability was essentially provided without incremental cost to consumers because OEMs had to do very little in terms of BoM to allow the vehicles to run on alcohol. Millions of such vehicles were sold, as consumers effectively faced no real trade-off relative to the gasoline-only version. HEVs, however, have significant BoM cost (for batteries, controllers, motors, and other components) that ultimately must be recovered by OEMs from consumers. In comparison to dedicated EVs, though, HEVs have a cost advantage principally because the volume of battery they must contain is far lower than required for dedicated EVs, and these batteries are by far the highest cost item in the vehicles' build. Hybrids are therefore much less expensive to build and buy than full EVs, which, when combined with their easy use of existing fueling infrastructure, make them much more rational options for consumers than dedicated EVs. Therefore, while HEVs have outsold pure battery electric vehicles (BEVs), their cost premium continues to be a constraint on their success over gasoline vehicles.

In contrast, the BoM cost of a bi-fuel NGV (detailed in Section 4.3 below) is nearly the same as that for a dedicated NGV, which means actual cost or purchase price does not affect a comparison of the two. Instead, the relative advantages of each must be compared from the perspective of the end user. Here again, bi-fuel has the clear advantage precisely because the buyer is not forced to change behavior, especially in cases where range or resultant drive routes might be impacted. Instead, drivers of such vehicles can selectively take advantage of the lower operating cost and greener footprint of natural gas, knowing that there is no "walk home" factor that threatens their convenience or safety should travel take them beyond natural gas pumps. Drivers of such vehicles simply have more choice when the fuel range and availability issues that plague EVs, hydrogen vehicles, and dedicated NGVs are removed. As HEVs (the equivalent of bi-fuel EVs) are to dedicated EVs, bi-fuel NGVs are potential fatal competitors to dedicated NGVs. As it is with HEVs, the cost premium of bi-fuel NGVs is a natural constraint on their success over gasoline vehicles.

Figure 2.3.4-1

Fundamentally, FFVs, hybrids, and bi-fuel NGVs are essentially equivalent, differing only in the form of alternative energy storage—ethanol, battery, and natural gas, respectively.



2 Personal Vehicle Use

2.4 Opportunities and Actions

2.4.1 Range

NGVs can be made dramatically more attractive to private users by offering a range approaching 350 to 400 miles, which can be achieved with bi-fuel NGVs.

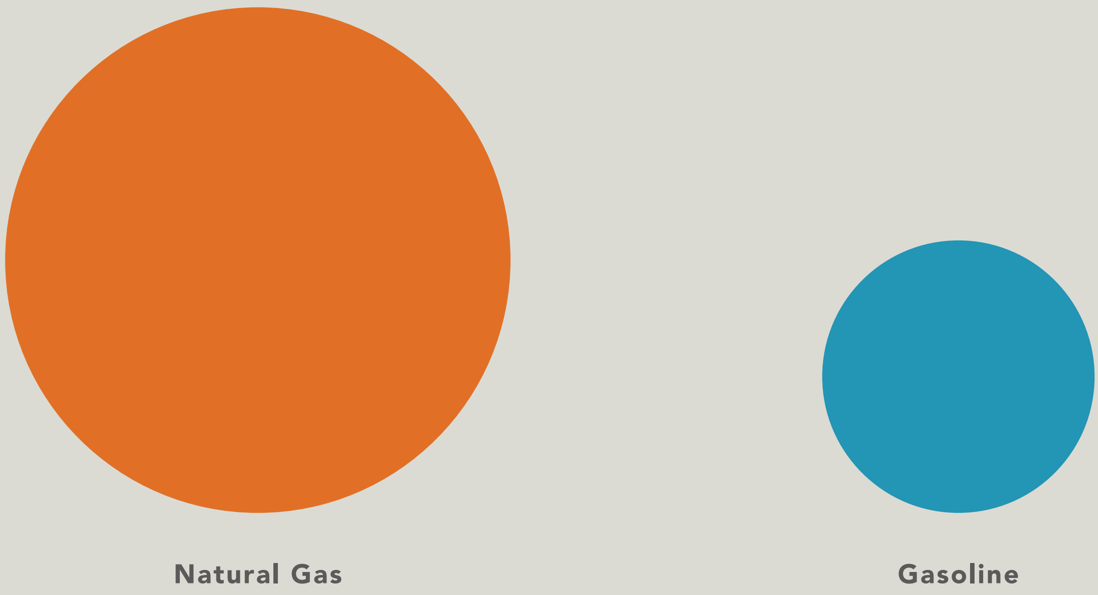
Vehicle driving range is a key purchase decision driver, and the range demanded by consumers across nearly all private use segments remains 350 to 400 miles, regardless of fuel type. Required off-site fueling of single-fuel vehicles is therefore expected to be no more than approximately weekly for most users. Consumer driving patterns accumulate about 250 miles per week, spread fairly evenly across the days of week. Long distance trips fall at about the same mileage in each direction, further supporting the need for over 350 miles of range when accounting for a margin of fuel still in tank at refuel.

Currently, a number of OEM and startup manufacturers are planning imminent release of battery electric vehicles (BEVs) with a variety of ranges but all well below 350 miles. Historical patterns and current consumer research both consistently reveal that these vehicles will fail to achieve even moderate natural levels of consumer demand due to their abbreviated distance offerings, especially without significant field charging infrastructure. The same has been true of NGVs without over 350-mile range.

Unfortunately, the architectural and cost implications of creating dedicated NGVs with 350 to 400 mile ranges are onerous (Figure 2.4.1-1). For private cars and trucks, tank size and count is simply too high for practical insertion of 350 miles worth into current vehicles, and the combined cost of these tanks would inevitably be in the thousands of dollars, even before margins are added. As such, most vehicles simply cannot accept the package and price premium required to meet range demands of North American consumers. Conversions to dedicated NGVs by SVMs demonstrate this fact, with either limited range or severely limited cargo packages (or both), very high prices, and commensurately low sales volumes. Inasmuch as NGV technology is essentially mature, technical solutions for these challenges are not forthcoming; the fundamental fuel density of natural gas is too low to make it a perfect, complete substitute for gasoline.

Figure 2.4.1-1

Due to the inherent disparity in fuel energy content, in order to hold the same amount of energy, an NGV may require approximately 3.5 times more fuel storage capacity than a gasoline vehicle.



2.4 Opportunities and Actions
2.4.2 Performance and Safety

NGVs can be made dramatically more attractive to private users by offering performance, functionality, and safety equivalent to gasoline vehicles, which can be achieved with bi-fuel NGVs.

North American consumers, without severe regulation to the contrary, will consistently demand larger, safer, and higher performing vehicles, so long as fuel economy remains mostly unchanged. AFVs are not immune to these demands, and any attempt to compromise the former to the benefit of the latter will be met with little consumer demand.

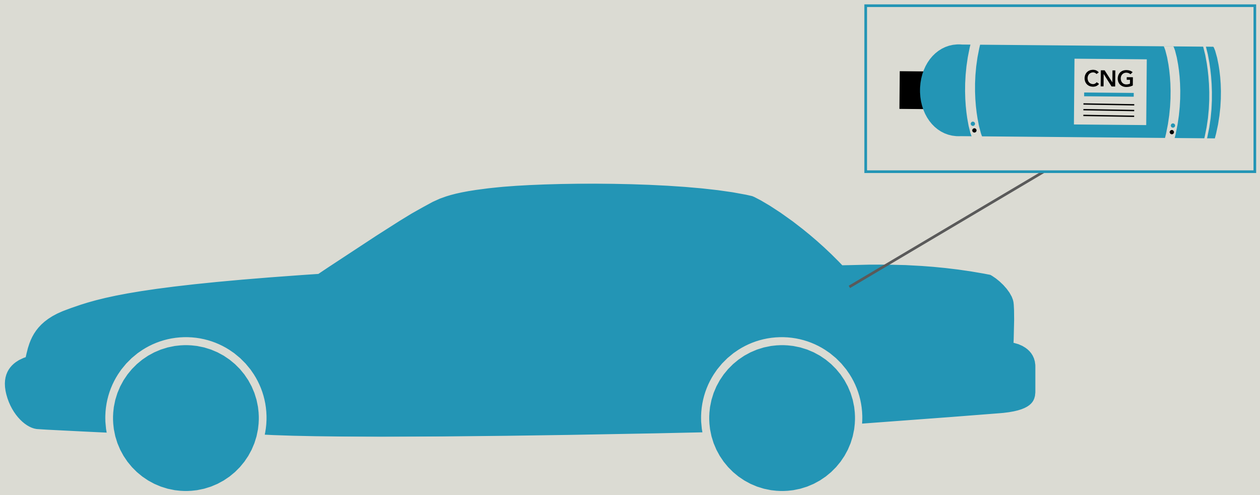
Again, the issue of natural gas energy density arises, as sufficient tank volumes cannot be achieved for almost any dedicated NGV light car or truck without degrading the effective "size" of the remaining vehicle. Compromises, for any reason, to occupant package (logically limited to second or third row seating volume) have historically been detrimental in terms of buyer appeal and subsequent market share. This has led many manufacturers to move natural gas tank volumes into cargo areas, a fact aptly demonstrated by NGV conversions of cars such as the Ford Panther (Town Car and Crown Victoria) for taxi and municipal use (Figure 2.4.2-1). While regulated livery fleets are often forced to accept such impositions on usability – even despite still extant luggage capacity demands – private consumers are so far not inclined to do so.

Another key motivator, safety, need not be compromised in either dedicated or bi-fuel NGVs. Natural gas has been used in the light- and medium-duty vehicle fleet for many years and has a laudable safety record. Furthermore, consumers do not perceive natural gas to be particularly dangerous relative to gasoline or other fuels. This leaves NGV designers and converters facing only the task of maintaining the vehicles' current crash ratings, a key objective for consumer appeal. It is incumbent on NGV stakeholders to actively encourage cohesive standards and firm regulation for use of the fuel in vehicles. Anything less risks damaging natural gas prospects in the long term. This makes a strong argument for all NGVs, both OEM and converted, to be subject to strict FMVSS testing.

In unmodified gasoline engines that have not been optimized for natural gas combustion, natural gas offers slightly lower performance than gasoline, and this presents both a planning and engineering challenge. Here, NGV creators must resist the temptation to apply natural gas to the lowest specification gasoline engines offered in particular models in an effort maximize fuel economy. Rather, conversions and bi-fuel NGV installations are better applied to mid and upper trim level powertrains to meet or exceed customer expectations, especially as natural gas is in the nascent stages of broad market exposure. Looking much farther forward, it is obvious that dedicated NGVs designed from the ground up should have engines totally optimized for natural gas, especially in terms of usable compression ratio.

Figure 2.4.2-1

Because of the inherent lower energy density of natural gas compared to gasoline, NGV tanks displace internal vehicle volume, such as the cargo volume in this 12.4 GGE natural gas Ford Panther platform conversion.



2.4.3 Payback

NGVs can be made dramatically more attractive to private users by offering short payback schedules, which can be achieved with bi-fuel NGVs.

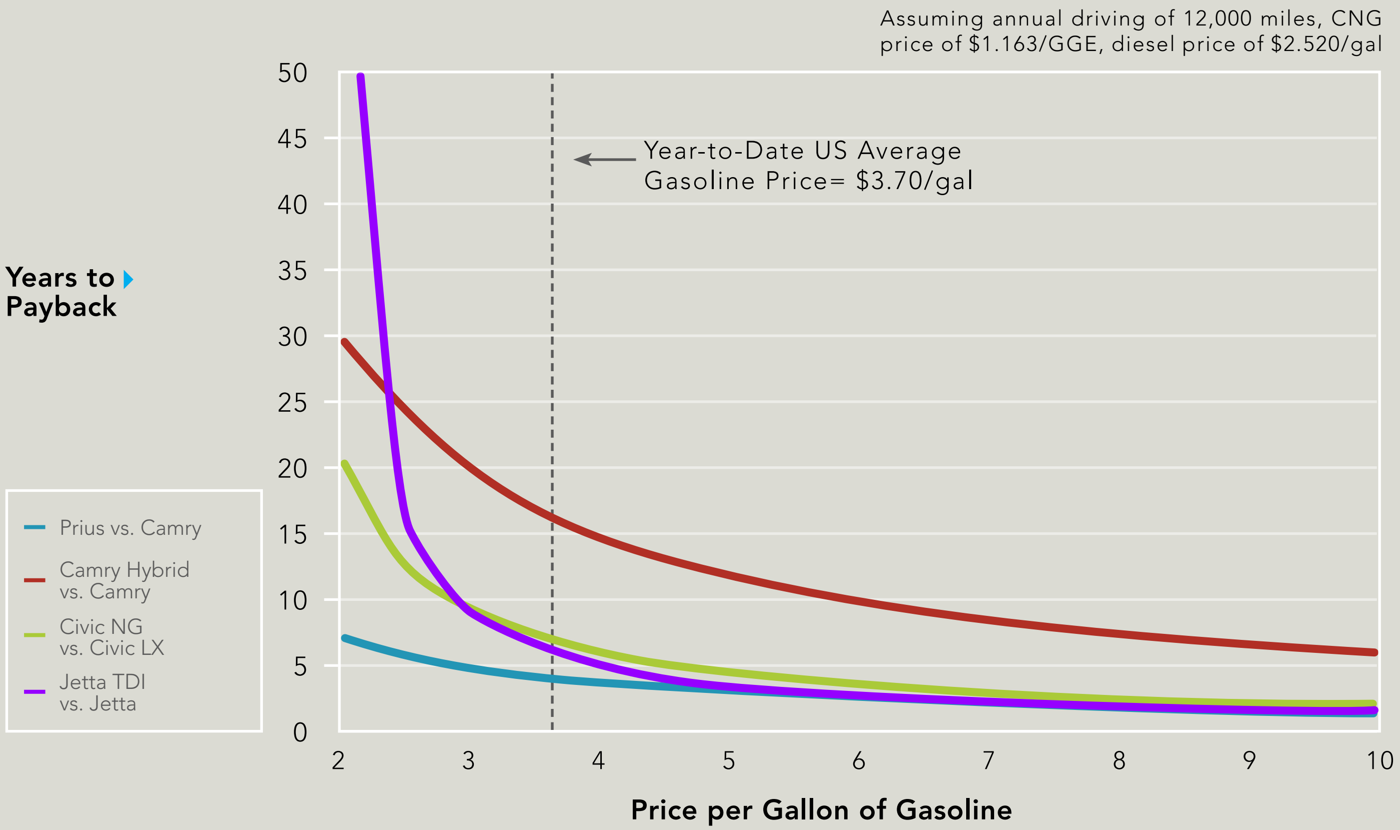
As a variety of BEVs and HEVs enter the North American market, consumers are becoming conditioned to calculate payback period when considering any AFV. Volume hybrids, for instance, owe much of their success to relatively favorable payback scenarios, with the Prius having the best payback of all contemporary hybrids (Figure 2.4.3-1). Fuel costs for light-duty vehicles may be relatively insignificant when compared to the cost premiums for acquisition of most AFVs, but any fuel cost savings will work to offset initial cost premiums.

To devise effective strategies for NGV payback, the cost drivers of BoM must be examined. Such examination shows storage – tanks in this case – to be the dominant variable cost of building NGVs (discussed further in Section 4.3 below). This further complicates the aforementioned matter of range, which is then directly related to BoM for natural gas. With average midsize sedans' window stickers currently showing around $1,500 per year in expected annual fuel costs, the math for payoff of NGV BoM with fuel cost savings is very poor. The savings associated with burning natural gas instead of gasoline are insufficient to offset the incremental price of a dedicated NGV (with 350 to 400 miles range) to the consumer. This leads logically to the same rationale of EV planning: serious consideration of decreasing costs by shrinking alternative fuel storage (whether battery or gaseous fuel tank) to a limited, daily level and relying on gasoline power to provide range and refueling ease in cases of extraordinary travel distances. Still, the reduced BoM of low-capacity bi-fuel NGVs will result in a premium relative to gasoline vehicles that will be too high to be overcome without stakeholder intervention.

As detailed in the following section, payback (as well as the vehicle's appeal from a functional standpoint) can be dramatically improved for bi-fuel NGVs as compared to traditional dedicated NGVs. However, initial production of low-capacity, bi-fuel NGVs will entail higher costs. The payback figures in the next section demonstrate what is possible once high production volumes are reached: BoM costs low enough to have payback well within the typical vehicle ownership period, without incentives and including home refueling capability. From an OEM perspective, volumes tend to be in increments of manufacturing plant capacity, where about 60,000 units per year may typically represent either one quarter or one half of a factory's capacity. Stated more broadly, more than 60,000 units per year is considered "volume." Below 60,000 units per year, vehicles are considered relatively low volume, with reduced efficiencies in both purchasing and manufacturing terms.

Figure 2.4.3-1

The payback period of the Toyota Prius illustrates its practicality over other AFVs.



Assumptions: Vehicle Make and Model	MSRP	MPG
Honda Civic Natural Gas	$25,280	28
Honda Civic Hybrid	$23,800	42
Honda Civic LX	$18,360	29
Toyota Camry	$19,720	26
Toyota Camry Hybrid	$26,150	34
Toyota Prius	$22,800	50
Volkswagen Jetta	$17,735	25
Volkswagen Jetta TDI	$22,830	34

1. No discount rate is included in this payback analysis to more closely approximate the decision making process of most consumers.
2. All MSRPs are provided by their respective manufacturers as of October 2010.

2.4 Opportunities and Actions

2.4.4 Bi-Fuel Vehicles

Unlike dedicated NGVs, and as with other bi-fuel vehicles, bi-fuel NGVs can offer the range; performance, functionality, and safety of gasoline vehicles; and short payback schedules required to make NGVs attractive to private vehicle users.

When viewed in aggregate, bi-fuel vehicles are far more desirable to consumers than dedicated AFVs. As a result, bi-fuel vehicles vastly outsell their dedicated alternative vehicle counterparts when competing equally. Such vehicles allow consumers (and OEMs) to take advantage of the alternative fuel's best properties, including presumably lower costs-per-mile and other benefits such as sustainability, for some rational percentage of daily travel. Thereafter, gasoline provides bi-fuel AFVs with distance and refueling advantages that eliminate range anxiety and allow the operation of the vehicle exactly as normal car or truck users require.

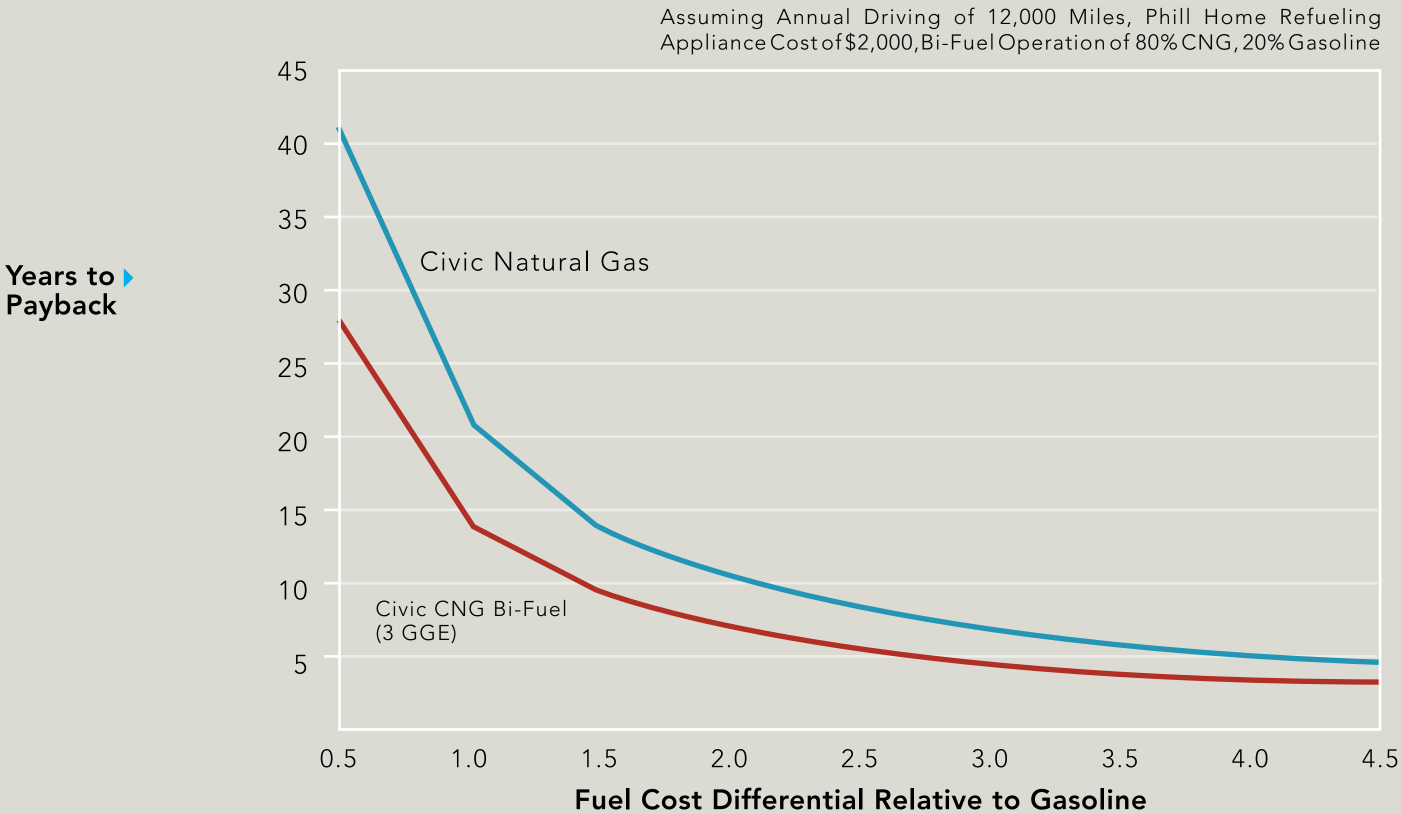
It is around this premise that vehicles like the Toyota Prius, and even the Chevrolet Volt (a range-extended EV with enough battery aboard to travel approximately 50 miles), have been planned. The intention is that the alternative fuel onboard is almost totally depleted in daily use to offset some portion of what would otherwise be gasoline consumption. In both cases, the consumer faces no required change in behavior, as the penalty for exceeding the alternative fuel (electricity in this case) range is nullified by a ready-to-go gasoline tank and engine.

The same would be true for a bi-fuel NGV. Natural gas range could be as low as 40 or 50 miles for purposes of covering most daily use, accompanied by a gasoline tank slightly smaller than normal, to yield a compound range of well over 350 miles but with the first miles achieved without gasoline. Since natural gas is typically less expensive than gasoline, users would have incentive to use the onboard natural gas first by refilling that reservoir as often as practicable (Figure 2.4.4-1). It is important to note, however, that as with the case for FFVs, users of bi-fuel NGVs are not obligated to use natural gas. A compelling option for NGVs is the dual advantages of easy, quick home refueling and low-cost fill units required only to deliver a 2 to 5 gasoline gallons equivalent (GGE) refuel overnight.

Several factors support installing the smallest CNG tank possible in a bi-fuel NGV, to the extent the commuting needs for the majority of drivers are still met (40 to 50 miles CNG range). This range exceeds the distance most personal use vehicles drive daily, providing a compelling economic case for consumers using the lower cost fuel (compared to gasoline). In addition, bi-fuel NGVs serve as a catalyst for increased use of domestic-sourced fuel and are a compelling market for providers of public and home natural gas refueling stations. Providing CNG range beyond the daily needs of most consumers comes with several limitations. With most daily driving already covered by CNG, greater CNG storage capacity will result in only marginally more natural gas usage. The cost of either larger tanks or a greater number of tanks necessary for greater CNG range hurts economic payback. Moreover, the space required for more/larger tanks begins to impose ever greater constraints on available space in the vehicle for passengers and cargo. For the bi-fuel Ford F-150, 3 GGE provides approximately 45 miles of CNG range. In the bi-fuel Civic, this same 3 GGE capacity provides over 75 miles of CNG range, suiting even individuals with longer-than-average commutes.

Figure 2.4.4-1

A bi-fuel Civic NGV would achieve payback of initial vehicle costs significantly sooner than the dedicated Civic Natural Gas NGV.



Assumptions: Vehicle Make and Model	MSRP Including Phill Unit	MPG
Honda Civic Natural Gas	$27,280	28
Honda Civic CNG Bi-Fuel	$23,276	28

1. No discount rate is included in this payback analysis to more closely approximate the decision making process of most consumers.
2. Civic Natural Gas MSRP is provided by Honda as of October 2010.
3. MSRP for CNG bi-fuel is estimated by the CARLAB using bottom-up costs of bi-fuel vehicle components

2.4 Opportunities and Actions

2.4.4 Bi-Fuel Vehicles (Concluded)

Unlike dedicated NGVs, and as with other bi-fuel vehicles, bi-fuel NGVs can offer the range; performance, functionality, and safety of gasoline vehicles; and short payback schedules required to make NGVs attractive to private vehicle users.

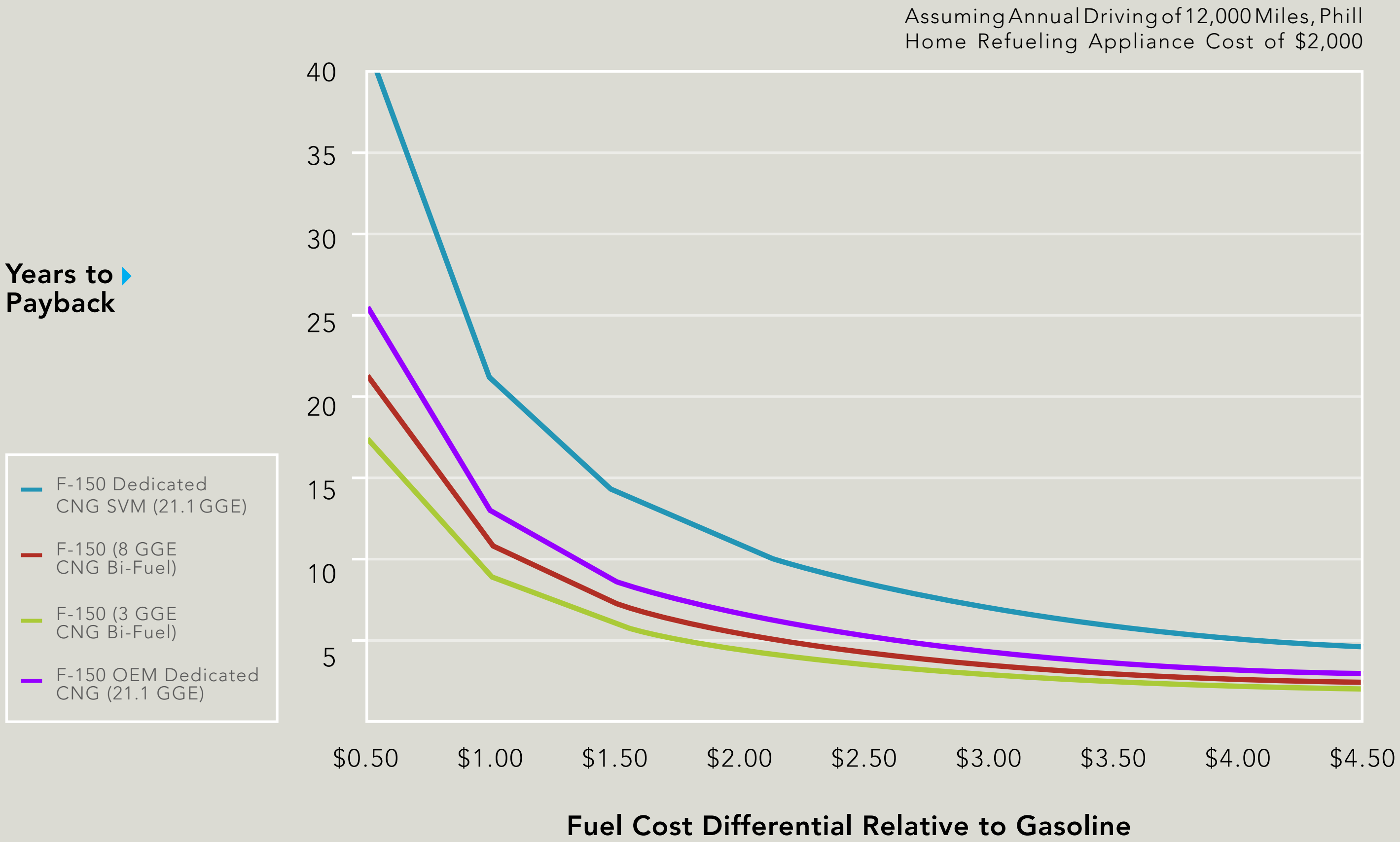
The economic benefits of natural gas would be a motivator for bi-fuel NGV users to fill with natural gas instead of gasoline. Not only would such demand encourage commercial fueling stations, but it would also lead to more entries and competition in the currently small home refueling market. With small onboard tanks, it is rational to expect a number of units to be offered, including some with accumulators giving users the ability to fill nearly instantly in their garages. Pumps on such accumulating fill units could be quite small and cheap, slowly filling pressure storage cylinders 24/7 for use anytime by their bi-fuel NGV owners.

For vehicle packaging, low-capacity bi-fuel configurations are closer to optimal. Most vehicle platforms have dedicated fuel tank areas, and in many cases, the reduction in required gasoline tank size may create nearly enough space in the same area to co-locate a natural gas cylinder of minimal size, allowing the vehicle's package to remain uncompromised. In cases where a natural gas cylinder must still be located elsewhere, its relatively small capacity (perhaps 2 to 3 GGE for a natural gas range of 40 miles) will be a considerable advantage and either still permit under-floor location or, at worst, require a small amount of trunk or bed space to be displaced.

Besides their obvious range and packaging advantages, bi-fuel NGVs offer considerably more competitive payback relative to gasoline vehicles than do dedicated NGVs. This cost advantage stems directly from the aforementioned elimination of one or more gaseous tank cylinders from the BoM for bi-fuel vehicles. The likely sole remaining natural gas tank in a bi-fuel NGV would be smaller, given a natural gas range target of less than 50 miles for private use light vehicles. As shown in Figure 2.4.4-2, the payback profile of the bi-fuel NGV is superior to that of the dedicated NGV due to its much lower BoM, ability to burn natural gas on a daily basis, and ability to still aggregate substantial annual fuel savings compared to a gasoline vehicle.

Figure 2.4.4-2

Bi-fuel F-150 NGVs may potentially achieve payback on initial vehicle costs significantly sooner than dedicated F-150 NGVs.



Assumptions: Vehicle Make and Model	MSRP (Including Phil Unit)	MPG
F-150 SVM Dedicated CNG	$36,620	17
F-150 8 GGE CNG Bi-Fuel	$27,803	17
F-150 3 GGE CNG Bi-Fuel	$26,678	17
F-150 OEM Dedicated	$30,800	17

1. No discount rate is included in this payback analysis to more closely approximate the decision making process of most consumers.
2. MSRPs for dedicated NGVs are provided by their respective manufacturers as of October 2010.
3. MSRPs for CNG bi-fuels are estimated by The CARLAB using bottom-up costs of bi-fuel vehicle components.

3 Commercial Fleet Use

3.1 Fleet Market Overview

The commercial fleet market is highly fragmented, with each individual business and government agency demanding characteristics specific to its needs. In terms of vehicle types, commercial fleets are highly oriented toward full-size pickups, full-size vans, and midsize sedans.

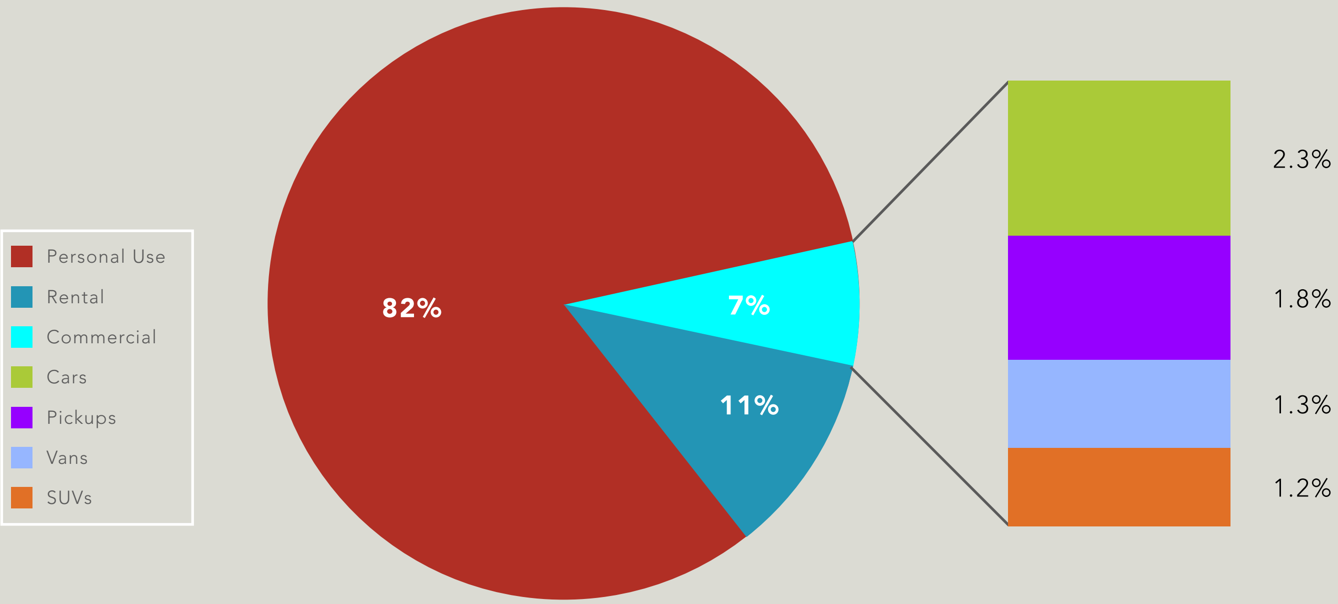
For the purposes of this analysis, daily rental fleets are not considered to be part of the "commercial fleet" market. The dynamics of the rental car business are identical to those of the personal vehicle market; a rental car is a personal vehicle "purchase" (albeit temporary) and as such, NGVs would face the same opportunities and challenges as those intended for direct private ownership.

As shown in Figure 3.1-1, the private business and government fleet markets (hereafter referred to collectively as the "commercial fleet market") represent approximately 7 percent of the total light-duty vehicle market and 38 percent of the total "fleet" market. While nearly all vehicle types and segments are represented within the commercial fleet market, commercial fleet buyers purchase more cars (primarily midsize or full-size sedans) than any other type of vehicle, followed closely by full-size pickup trucks. Vans sales to commercial fleets, a majority of which are full-size vans, are much higher percentage of the fleet mix than they are of the mass market fleet mix. Unlike the personal use market, SUVs are much less popular than vans – a testament to the overriding motivation of maximizing functionality by the majority of commercial buyers. While 2009 was an abnormally low year in terms of total market volume due to macroeconomic conditions in North America, the shares among vehicle types were not.

Government fleets are owned by a wide variety of federal, state, and local agencies, while business sales include public utility companies and a plethora of large, medium, and small private business. The challenge for participation in commercial fleet sales is quite daunting due to the hyper-fragmentation implied by the highly individualized functional requirements of these commercial users.

Figure 3.1-1

The "commercial fleet market," as defined by business and government fleets, accounted for 7 percent of the total U.S. light-duty vehicle sales in 2009.[17]



17 Automotive Fleet/R.L. Polk, 2010.

3.2 Original Equipment Manufacturer Perspective

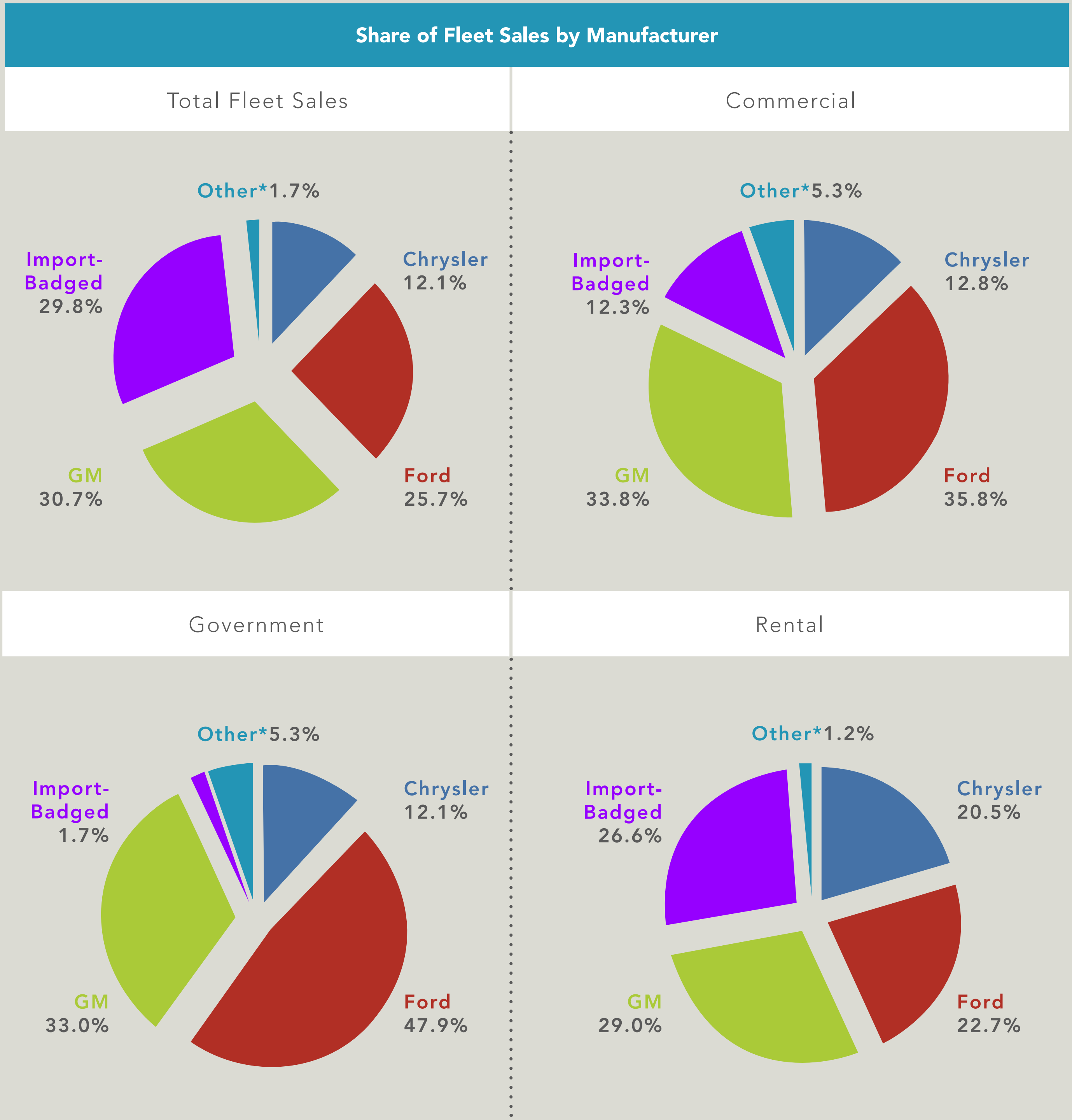
From an OEM perspective, the commercial fleet market is challenging in that this market is very fragmented in terms of critical vehicle attributes and functional capabilities, thus requiring a broad array of products.

Unlike the personal use market, commercial vehicle fleet operators have very specific, individualized requirements, all of which are impacted by not only the business in which they operate but also the location (urban, suburban, and rural) and climate in their area of market coverage. The notion of convergence on critical vehicle attributes or functional capabilities is very unlikely. The chief engineer of a large OEM's commercial division stated this fact succinctly: "To [sell] this number of vehicles, I have to participate in 300 different segments." In that context, there are few "typical" requirements for commercial vehicles, and within the group of vehicles that can deliver the functional requirements, the one that does so at the lowest cost will be purchased.

As shown in Figure 3.2-1, Ford and GM have long dominated the overall commercial fleet market in North America, particularly in the medium-duty segments. For these volume-oriented manufacturers, this implies the need for a broad array of products to fill each niche. For that reason, nearly all commercial light-duty fleet vehicles are based on existing passenger vehicles (such as full-size pickups and full-size vans), including a significant number of "rolling chassis" (typically full-size pickups or full-size vans) delivered to upfitters for installation of custom bodies. Examples include ambulances and utility service vehicles. Medium-duty vehicles are built specifically for the commercial fleet market, again typically all based on a common cab/chassis from an OEM, with most delivered to upfitters to finish the vehicle for specific business customers. For manufacturers with only one or two products, the total potential market volume is typically so low that these OEMs are deterred from making significant investment in product redesign/redevelopment, marketing, sales, and parts/service support.

Figure 3.2-1

Commercial vehicle sales require a broad array of products and as such have been dominated by GM and Ford.



*Other includes Freightliner, International, Kenworth, Mack, Peterbilt, Spartan, Sterling, and Workhorse. *Numbers rounded to the nearest tenth.
Source: Automotive Fleet Factbook 2010

3 Commercial Fleet Use

3.3 Key Decision Drivers

3.3.1 Functional Capability

Functional requirements are the first "filter" used by commercial vehicle buyers in the purchase decision. Specific functional requirements vary widely by specific individual business or entity. With the exception of governmental fleets, there is very little consideration of "green" in the purchase decision.

In contrast to private consumers, the commercial fleet buyer is motivated almost entirely by rational decision factors, most specifically those associated with financial considerations. Only in the case of governmental agencies do emotional (political) factors play a significant role in the purchase decision.

In particular, owners/operators of multi-vehicle commercial fleets base their vehicle purchase decisions first on functional capability (i.e., does the vehicle meet the functional requirements of the job?) and then choose among those alternatives on the basis of the total cost of ownership over the expected life of the vehicle. Table 3.3.1-1 lists the primary functional issues that drive the selection of specific vehicle types by commercial users.

Functional requirements for most commercial fleet owners are well defined in terms of payload, range, and duty cycle for many if not all of the vehicles in their particular fleet. In that regard, some of the more difficult emotional challenges faced by private consumers, such as range anxiety and distribution of fueling stations, are much less of a limitation on NGV penetration in the fleet market.

Notably missing from all but the governmental fleets is consideration of environmental implications of the vehicle. Businesses have little motivation for altruism; they are driven primarily by the bottom-line impact of their fleet management decisions. For political reasons, many federal, state, and local government fleet operators do include "greenness" on the list of decision criteria. For municipal fleets, alternative fuel usage is often a mandatory requirement for a certain percentage of their fleet to meet regulatory fiat and/or attain state or federal funding. For obvious reasons, utility companies are leading purchasers of alternative fuel/powertrain vehicles in the business sector, specifically those in the natural gas industry in the case of NGVs. Occasionally, private businesses do want to communicate a "green" or "tech" image through their fleet of vehicles. For example, AT&T's U-verse fleet is employing natural gas Ford Econoline vans (8,000 nationally) to communicate "leading edge" technology, consistent with its new service. However, the value typically ascribed to the image benefit is very modest and would only be a consideration if the pure financial cost/benefit relationship was at or near parity for NGVs.

Table 3.3.1-1

In terms of functional requirements, commercial fleets are most concerned with duty cycle and payload for their particular vehicles.

Commercial Fleet Functional Requirements
Duty Cycle (daily route length, speed, terrain/road conditions, hours of operation) For a majority of large commercial vehicle fleets, this factor is very consistent within their fleets, with little variation on a day-to-day basis for individual business customers.
Payload (cargo volume and weight) With few exceptions, the standard cargo-carrying requirement for any individual commercial vehicle is most often consistent on a daily basis and well defined.

3.3 Key Decision Drivers

3.3.2 Cost of Ownership/Payback Analysis

With few variations, the vehicle that meets the functional requirements of the commercial buyer at the lowest cost of ownership over the life of the vehicle will be the one selected. A core element of this financial analysis is the "payback" analysis comparing various aspects of the vehicle's expected costs during the ownership cycle.

Among vehicles capable of meeting the functional needs of the commercial operator, financial analysis of the total cost of ownership for each is the next driver of purchase. In this regard, consideration of alternative fuel/powertrain vehicles is driven by payback analysis. Typically, variable cost savings (daily operation/fuel costs) of the AFV relative to its gasoline version are examined against the purchase price premium for the alternative fuel/powertrain technology. If this variable cost analysis is favorable, the commercial buyer will then take into account any other costs involved in adopting the AFV, such as fueling infrastructure requirements, durability differences, and repair costs.

As would be expected, payback varies widely based on the relative cost difference between gasoline and natural gas, annual fuel usage, and vehicle service life. The two examples shown in Figure 3.3.2-1 illustrates the breakeven point for two popular trucks in use by commercial fleets, the Ford F-150 and the Ford F-250, in low and high mileage scenarios. The low annual mileage of 10,000 is low compared to most commercial uses, while the high mileage of 50,000 is considered relatively high for most commercial uses.[18] At current gasoline and CNG fuel prices, a commercial operator at 10,000 miles annually would need to keep the vehicle for nearly fourteen years for breakeven on an F-250 NGV, including an $8,000 offset through credits such as the previous U.S. Qualified Fuel Motor Vehicle federal tax credit for dedicated NGVs. Without the tax credit, the F-250 NGV effectively never achieves breakeven under this usage scenario, nor does the F-150 NGV with its previous $4,000 current U.S. tax credit.

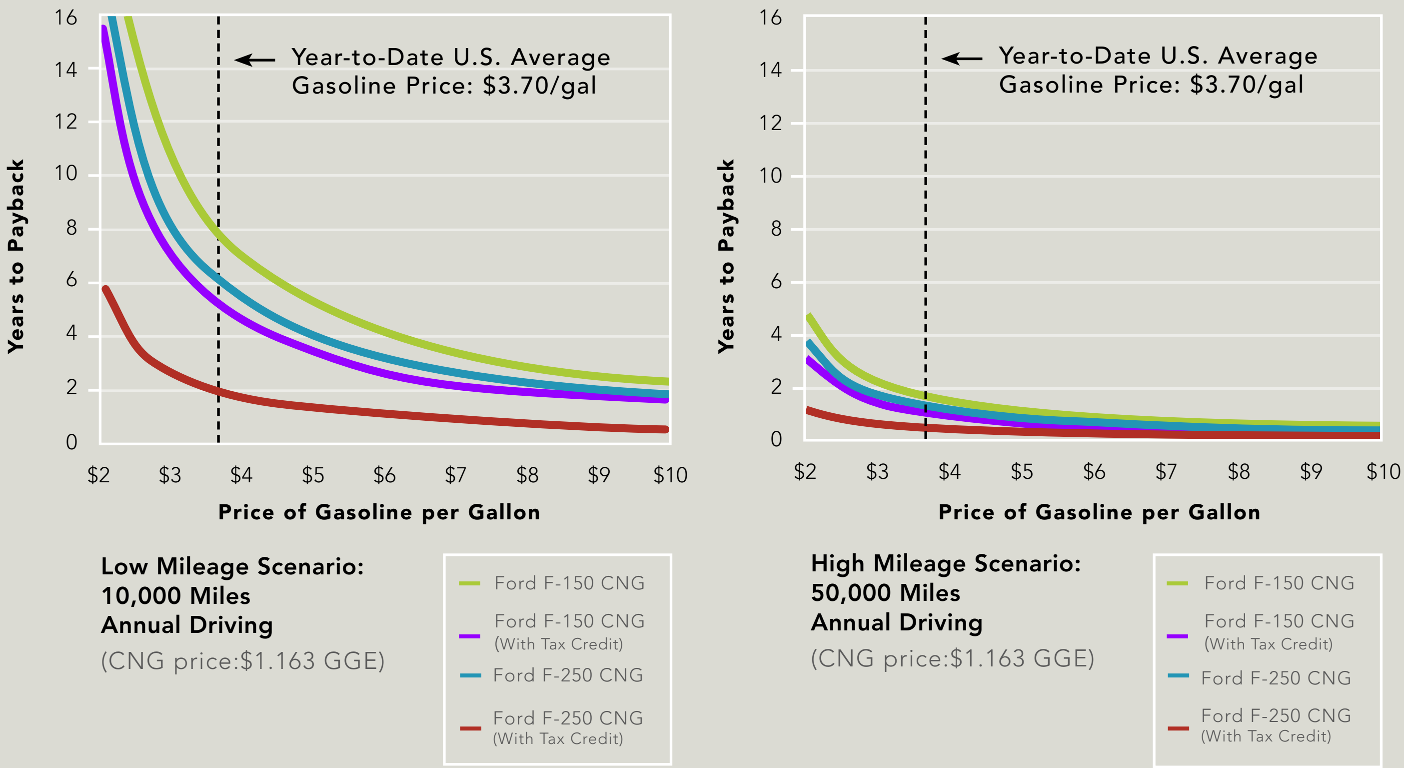
The higher mileage scenario is much more favorable. At current fuel prices, a commercial operator of an F-250 NGV driving 50,000 miles annually would reach breakeven in less than three years with a $8,000 federal subsidy. Without the tax credit, the F-250 NGV breakeven point would occur around year eight, as it would with an F-150 NGV with a $4,000 federal subsidy. Critically, this payback analysis does not include the impact of other elements in the total cost of ownership, nor does it include the potential cost of establishing on-site fueling infrastructure, all of which must also be factored in to the enterprise-level decision to adopt NGVs.

Table 3.3.2-1 lists all of the primary inputs to the total cost of ownership in order of importance. It is important to note, however, that in the case of leasing, the vehicle purchase price is not germane per se. Rather it is the cost of financing (monthly lease cost based on the difference between vehicle price and anticipated recovered value at the end of lease term) that is the largest financial factor.

18 U.S. Census Bureau. "Vehicle Inventory and Use Survey." 2002. Annual mileage of 10,000 miles may correspond to a personal transportation service vehicle (e.g., limousine) while 50,000 miles may correspond to a dump truck.

Figure 3.3.2-1

In a low mileage scenario, given current fuel prices, the payback period of NGVs is not viable for commercial fleets, while in a high mileage scenario, NGVs become a viable option.



Assumptions: Vehicle Make and Model	Conversion Cost	MPG
F-150 CNG	$11,800	17
F-150 CNG with $4,000 Tax Credit	$7,800	17
F-250 CNG	$11,800	13
F-150 CNG with $8,000 Tax Credit	$3,800	13

Table 3.3.2-1

These key drivers, in order of typical importance (most to least), determine the payback analysis that dictate purchase decisions.

Financial Drivers of Total Cost of Ownership	
Vehicle Purchase Price	Maintenance and Repair Costs
Daily Operating Costs of Fuel Consumption	Financing Costs (Lease or Buy)
End-of-Life Cost Recovery (Residual or Resale Value)	

3.4 Challenges for Purchase

3.4.1 Overview

Although the variable cost issue (payback analysis) remains the most daunting challenge for wider adoption of NGVs, fixed cost elements (primarily on-site fueling infrastructure) and vehicle availability (type of vehicle and brand) also present significant challenges.

From a commercial fleet buyer perspective, the variable cost payback analysis on NGVs remains the largest obstacle to wider adoption. Inclusion of the impact of fixed cost implications further presents a much less favorable breakeven point. The most favorable conditions for NGV adoption exist in businesses with high annual mileage (and thus high fuel costs) and a large fleet of vehicles among which to allocate the fixed costs.

Infrastructure challenges are also significant for those applications that require even occasional in-field refueling. The risk of being stranded off-site is a disruption that most business users would not find acceptable, the implication being that the bulk of current natural gas volume potential is among commercial users for whom installation of an on-site fueling facility makes financial sense or the few who have sufficient existing public infrastructure in their current daily operating area.

Vehicle availability is another challenge for NGVs in the commercial fleet market. While a vehicle's functional capability is first priority, many (if not most) fleet buyers strongly prefer to purchase from a specific brand in order to have a single-point supplier for service, maintenance, and parts. This "brand loyalty" is a large influence on purchase, and if the preferred brand does not offer an NGV of the type needed by the commercial buyer, the fleet may very well purchase a conventional gasoline vehicle from the preferred brand rather than switch brands to obtain a suitable NGV. Table 3.4.1-1 shows the few vehicles that are currently readily available from OEMs or their approved natural gas converters.

Table 3.4.1-1

The number of currently available NGVs is limited from a major OEM standpoint, excluding OEMs in the heavy-duty vehicle market.

OEM Turn-Key NGVs	GMC Savana	Chevrolet Express	Honda Civic Natural Gas	VPG MV-1
OEM Conversion-Ready NGVs	Ford Transit Connect	Ford E-Series		

3.4 Challenges for Purchase
3.4.2 NGV Purchase and Financing Costs

The higher purchase price of an NGV compared to a gasoline vehicle remains the greatest challenge for adoption. Financing costs are a challenge for natural gas adoption for fleets that preferred to lease rather than purchase due to the limited NGV resale market. For those who purchase, financing costs are a very minor issue.

Not including federal tax credits, the incremental cost of a light- or medium-duty NGV over its equivalent gasoline vehicle can range from $6,800 (e.g., passenger car) to more than $25,000 (e.g., shuttle van). This cost alone is the greatest challenge for NGV adoption in commercial fleets. Only fleets with a high mileage duty cycle would expect the fuel savings advantage of natural gas to overcome the higher initial purchase price.

Examples of commercial vehicle usage that would likely result in the most favorable payback include municipal taxi fleets, airport shuttles (rental car and airport parking), delivery vehicles with many daily stops (UPS, FedEx, and wholesale food/beverage delivery), garbage trucks, municipal buses, patrol vehicles, and just-in-time manufacturing supply vehicles. Vehicles with limited or intermittent usage (low daily mileage or highly variable daily mileage) that are least likely to provide a positive payback may include plumbing and heating service vehicles, construction site delivery vehicles, moving vans, and emergency response vehicles.

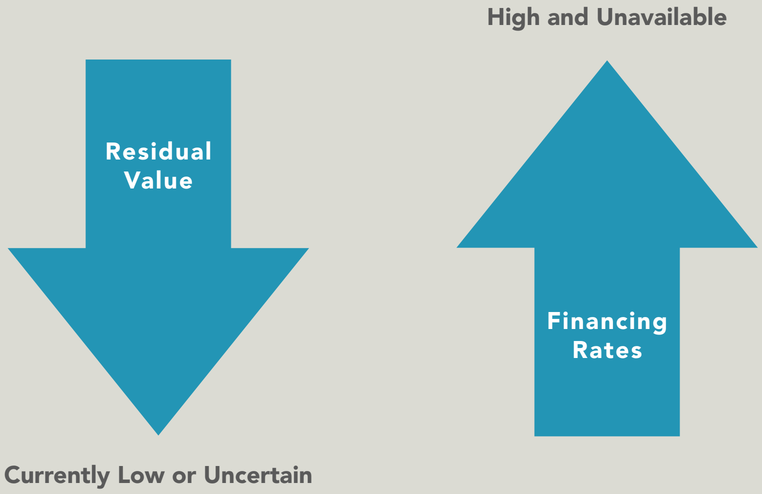
Financing costs are not relevant to the commercial fleets that outright purchase their vehicles. However, financing can be a challenge for those who finance or lease their vehicles. Some fleet operators report reluctance among financial institutions to finance the purchase of an NGV due to the limited resale market. The uncertainty of the vehicle's residual value drives higher risk and therefore higher financing rates where available (Figure 3.4.2-1).

End-of-life considerations are very significant as they pertain to financing costs. The disposal of a fully amortized (scrap value) NGV does not appear to require any substantive cost more than a gasoline vehicle, and thus for those commercial operators who drive to scrap, end-of-life issues are few. The majority of commercial buyers, however, do factor in some positive return well above "scrap value" for resale value at the end of the vehicle life as they define it. Typically, commercial vehicle owners reach a point during the total lifecycle when the projected cost of maintenance and repair are deemed too high to justify continued investment in the vehicle relative to the cost associated with acquiring a new vehicle.

At that point, they dispose of the vehicle through the resale market to recoup the vehicle's residual value. A residual value set by the lessor (a key contractual term of the lease agreement) based on resale value projections (derived actuarially) is a primary driver of cost for those who lease (as opposed to own), as the difference between the vehicle price and the residual value is the amount effectively being financed, not the total vehicle price. The under-developed resale market for NGVs is a challenge in this regard. Leasing companies that do not have firm resale values upon which to base lease rates assume zero end-of-life value for NGVs. This assumption raises monthly lease costs well beyond what would exist in a more mature vehicle market with well understood dynamics.

Figure 3.4.2-1

On top of incremental costs for NGV purchases, fleets that prefer to lease their vehicles face an additional challenge in obtaining favorable financing rates with low and uncertain NGV residual values.



3.4 Challenges for Purchase

3.4.3 Other Costs and Issues

Maintenance and repair costs for NGVs are similar to those of gasoline vehicles and thus not a significant challenge, though bi-fuel vehicles may generate somewhat higher maintenance and repair costs due to the second (additional) fuel system. Warranty coverage is not a significant challenge for adoption of natural gas by commercial fleet buyers. Due to the long history of NGV use in North America and global markets, concerns about NGV durability are not present among most commercial fleet operators.

Maintenance and repair costs for dedicated NGVs are not substantively different from those of equivalent gasoline vehicles. In this context, maintenance and repair costs are largely non-issues in the decision process. In the case of bi-fuel NGVs, due to the need to maintain two independent fuel systems, the maintenance and repair costs may be expected to be approximately 20 to 30 percent higher than for a single fuel vehicle (either gasoline or natural gas).[19] In addition, for the largest fleet operators, who often have internal vehicle maintenance staff and facilities, accepting NGVs (dedicated or bi-fuel) may drive costs higher in terms of additional technician training, natural gas-specific parts inventory, required facility modifications (if retrofitting existing facilities), and unique maintenance procedures (Figure 3.4.3-1). For those who use OEM dealers for service and maintenance, the maintenance and repair cost implication is not a differentiator between NGVs and gasoline vehicles, and most OEM fleet dealerships from which NGVs would be sourced are fully capable of supporting NGV service and maintenance needs. However, for many fleet operators who choose to use independent service shops, there are concerns that the technicians will be limited in their ability to service the NGVs.

Warranty issues are moderate challenges for the switch to natural gas but only on non-OEM or non OEM-approved conversions. The few OEM-produced NGVs (e.g. Honda GX, Chevrolet Express, GMC Savana) and OEM-approved conversions (e.g. Ford E-Series van) retain a full OEM warranty. As a general rule, most OEM warranties are void with any unapproved powertrain or electrical system alteration. Converters are required to certify their emissions control equipment consistent with EPA (three years/36,000 miles) and California Air Resources Board (CARB) (8 years/80,000 miles) required warranties. In this case, some commercial fleet buyers do have reservations about converted vehicles, despite the fact that many natural gas converters offer limited warranties on all remaining natural gas system components.

Although durability itself is a very important purchase factor for fleet buyers and a strong brand-level driver of purchase, NGV engine durability is not a major concern of commercial fleet operators nor most OEMs. OEM engineers stated that properly engineered NGVs have shown greater durability in internal testing. NGVs have been in use in other markets (Europe, Asia, and South America) in significant volume for a very long time; the durability challenges are well known and well understood by OEMs. In fact, NGVs should have fewer durability issues than gasoline vehicles because natural gas is a much cleaner fuel than gasoline, and thus the engine oil does not become contaminated as quickly or need to be replaced as often.

19 Discussions with OEM engineers suggest a consensus estimate for planning purposes of around a 20 percent increase in expected lifetime maintenance of a bi-fuel NGV over dedicated NGVs and gasoline vehicles.

Figure 3.4.3-1

Maintenance and repair costs are not substantively different between dedicated NGVs and gasoline vehicles.

3.4 Challenges for Purchase
3.4.4 Federal Regulations

Federal safety requirements are not challenges for adoption of OEM NGVs and OEM-approved natural gas conversions. The lack of enforcement of these standards on non OEM-approved conversions has yet to become an issue due to lack of awareness at present and thus remains an unrecognized risk to much of the current conversion business.

FMVSS for NGVs have been in place for a number of years for OEM NGVs (but not for natural gas conversions) in the U.S., and the requirements are well understood by OEMs (Figure 3.4.4 1). Commercial operators have voiced no concern with these issues, as all vehicles they purchase are presumed incorrectly to meet the regulatory safety requirements, when some of the conversions, in fact, do not conform to the same standards as full OEM vehicles. Generally, as with private consumers, commercial fleets prefer OEM NGVs over conversions and would likely not consider conversions if vehicles functionally suitable for their use were available with natural gas powertrains from a preferred OEM.

In Canada, tailpipe emissions testing is used to confirm that converted NGVs are cleaner than their gasoline counterparts. In the U.S., NGVs must also undergo a rigorous certification process. Technically, a U.S. converter has to document adherence to FMVSS standards as a result of the conversion but only needs to do so in terms of fire protection, not crashworthiness. The variability in competence of converters is substantial with respect to compliance in this regard (both in terms of understanding the requirements and enthusiasm for addressing them). The risk may be high that problems arising in NGVs from less diligent converters may affect all converted NGVs in terms of consumer concerns with NGV crashworthiness and safety. Commercial vehicle operators would likely be more sensitive to this risk (due to legal liability concerns) than personal vehicle owners. Therefore, the lack of consistent enforcement of these issues is a potential dark cloud looming on the horizon for greater adoption of NGVs.

Figure 3.4.4-1

Compliance with the comprehensive safety requirements within FMVSS, currently only needed for OEM NGVs, and NFPA 52 is a key issue for converted NGVs to address.

Part 571
Federal Motor Vehicle Safety Standards
CRASH AVOIDANCE

Part 571
Federal Motor Vehicle Safety Standards
CRASHWORTHINESS

Part 571
Federal Motor Vehicle Safety Standards
POST-CRASH STANDARDS

Part 571
National Fire Protection Association
VEHICLE FUEL SYSTEMS

3.4 Challenges for Purchase

3.4.5 Natural Gas Infrastructure

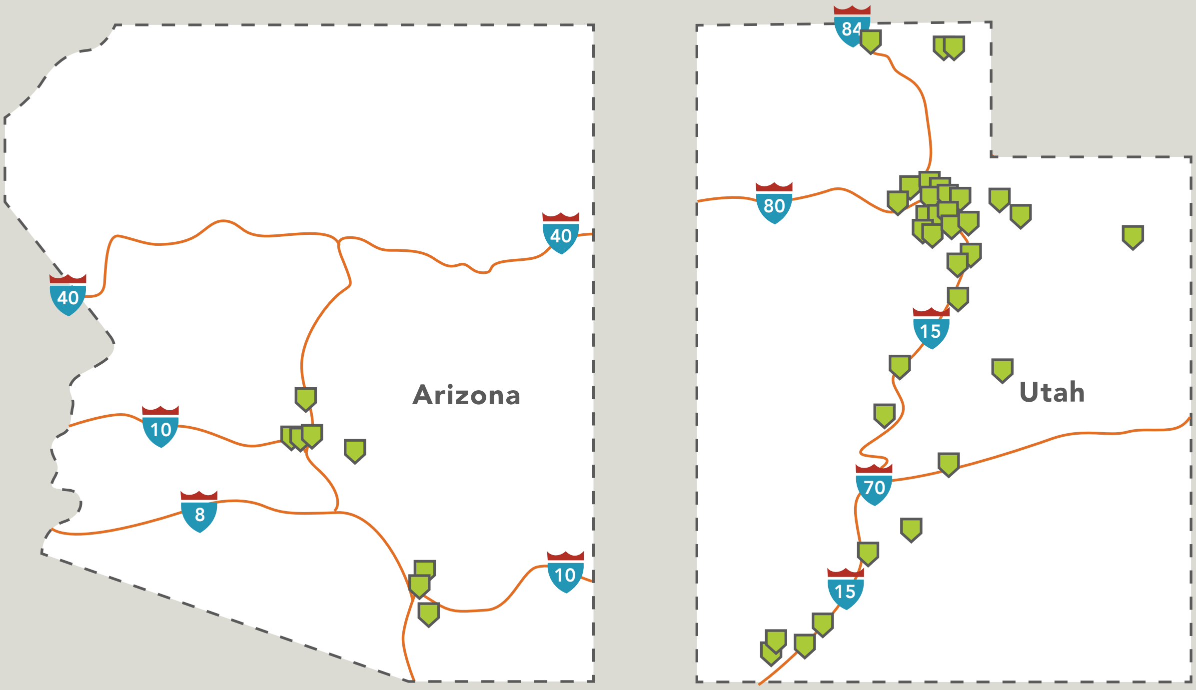
The relative lack of public natural gas fueling infrastructure is a challenge for natural gas adoption but much less of an issue for large fleet operators that can justify the cost of installing on-site natural gas fueling.

Infrastructure limitations are a significant challenge for NGV purchase for many commercial fleet buyers. Given the limited number of public natural gas filling stations nationally, the primary interest in NGVs comes from commercial buyers with fleets large enough that return frequently (daily) to a central location to justify the investment in a private natural gas filling station. Similar to the situation in private homes, the installation of a natural gas filling station may require a significant cost to upgrade gas lines into the facility itself. If the facility is not currently served by a gas line of sufficient capacity (in terms of gas flow rate), the costs to upgrade the infrastructure can be daunting and the challenges of working with local utilities and government agencies for approval frustrating. Additionally, the costs of maintaining an on-site natural gas fueling station are not insignificant. With the most favorable situation for natural gas adoption being a "continuous use" duty cycle, the occasional need for the fueling system to be off-line for maintenance and repair somewhat hinders adoption of natural gas among commercial users for whom natural gas offers the highest potential benefit. However, natural gas fueling infrastructure can be modular, allowing flexibility in capacity sizing that can expand relatively inexpensively to meet growing fueling needs.

The existence of public stations is still an important issue for many commercial vehicle operators, as the occasional need for vehicle usage above the "normal" daily pattern does arise, and the ability to refuel in the field, however infrequently, is a consideration. In the case of small business fleets, the economics of installing natural gas fueling capability on-site make adoption of NGVs very unlikely if combined with the lack of a full network of public stations within their area of operation. At present, the availability and distribution of public infrastructure varies across North America (Figure 3.4.5 1). Fortunately, unlike personal vehicle consumers, commercial consumers are much more in control of their daily usage (e.g., routing and daily miles driven) and much less sensitive to the current challenge of finding natural gas fueling stations.

Figure 3.4.5-1

The distribution of public fueling stations can vary widely across North America, as exemplified by Arizona and Utah,[20] and therefore impact commercial fleet decisions for adopting NGVs and building on-site fueling capability.



20 Alternative Fuels and Advanced Vehicles Data Center. "Alternative Fueling Station Locator." http://www.afdc.energy.gov/afdc/locator/stations/state. August 2012.

3.4 Challenges for Purchase

3.4.6 Required Vehicle Range

Commercial vehicle required driving range can vary widely by business and business use. Limited range is certainly a challenge for widespread adoption of NGVs if significantly lower than today's gasoline vehicles, but unlike privately owned vehicles, commercial applications can often accept somewhat limited range for specific uses.

Commercial fleet market requirements for vehicle driving range vary widely among and even within individual businesses. Table 3.4.6-1 shows the average annual mileage for vehicle types within the national "business" fleet (which includes rental car fleets not considered "commercial fleets" in the context of this analysis). Clearly, commercial vehicles are used much more in terms of miles per year than privately owned vehicles, which typically average 10,000 to 15,000 miles per year.

Typically, the variation in daily miles driven by commercial vehicles is much lower than in the case of privately owned vehicles. In this regard, adoption of NGVs by commercial users is much more likely as the bulk of fleet vehicles are used on well-defined routes with consistent daily mileage.

For the larger commercial fleets, even those with a significant number of AFVs, an unexpected high mileage occasional use requirement is easily addressed with the conventional vehicles that remain in the fleet. Nearly all commercial owners of AFVs purposefully retain conventionally powered vehicles for this reason.

Widespread adoption of NGVs for commercial fleets may be enhanced by delivering similar or greater range than conventional vehicles (over 300 miles per fueling), all else being equal. However, a significant share of commercial uses do not require such range (or annual mileage) capability, and other functional (e.g., space utilization) and financial (e.g., cost of additional tank capacity) implications may actually deter adoption of natural gas as a part of the commercial fleet if range is not a business requirement. For example, annual usage of 40,000 miles would imply a daily usage (range requirement) of approximately 150 miles on average. Even for fleets that currently perceive a need for significant range between fueling events, NGVs may offer an opportunity to shift their attitudes and behaviors by offering economic and public image benefits over conventional vehicles.

The mindset of the large commercial fleet operator, quite unlike that of the personal use consumer, is managing a portfolio of vehicles. In this regard, while an individual has (or perceives) the need for his vehicle to support a wide range of uses, daily driving conditions, and driving ranges, the commercial fleet operator can segment the portfolio into discrete and closely defined uses. As such, conventional vehicles, instead of being excluded entirely from the commercial fleet, are expected to be augmented by AFVs for the part of the portfolio for which the alternative fuel/powertrain delivers a superior overall business result.

Table 3.4.6-1

Commercial vehicles travel more miles annually than private vehicles, which average 10,000 to 15,000 miles per year.[21]

Commercial Vehicle Type	Average Annual Mileage
Pickup trucks	27,396
SUVs	26,916
Intermediate cars	24,384

21 U.S. Energy Information Administration. Transportation Energy Data Book, Edition 31." 2012.

3.4 Challenges for Purchase

3.4.7 Driving Patterns

Commercial vehicle driving patterns are very diverse, even within the same commercial fleet. As with vehicle range, some commercial applications may be very compatible with NGV use, accepting limitations that would not be acceptable in the private vehicle market.

For commercial fleet buyers, driving patterns are as diverse and business-specific as driving range. Driving patterns for fleets as a whole are not uniform as in the case of personal use vehicles. In order to maximize return on investment (and limit the size of the fleet), commercial fleet operators seek to minimize vehicle down-time. In many fleets, use of commercial vehicles is necessarily intermittent and limited in terms of miles or time driven per day. Service vehicles, for example, are required to drive to a job site but are then not in use during the service visit, thus for the majority of the work day, the vehicle is not in use. Particularly in urban and suburban environments, vehicle use may be limited in terms of total daily distance driven, maximum speed, and hours of operation. In that context, these applications would appear most suitable for natural gas adoption, with the caveat that the limited fuel use under such conditions may severely and negatively impact the payback for NGVs based on today's economics.

With current driving behaviors, the strongest case for NGVs, especially dedicated NGVs, is among commercial operators who keep their vehicles in continuous or near-continuous operation (e.g., airport shuttles and taxis), where the driving pattern dictates high fuel consumption and thus maximizes the fuel price benefit of natural gas over gasoline or diesel. As evidence, Yellow Cab's fleet of CNG-equipped taxis – in near-continuous operation throughout the business day – represents one of the largest private, non-utility commercial fleets of NGVs in the U.S., as shown in Figure 3.4.7-1. AT&T and Verizon are two other major fleets that have adopted the use of natural gas in their light- and medium-duty fleet vehicles.

Table 3.4.7-1

In addition to significant NGV adoption by AT&T and Verizon fleets, NGVs have been adopted by some of the largest commercial fleets in the U.S., for which a summary of all vehicles owned are shown above by fuel type.[22]

	Company	Total Alt- Fuel	CNG	Propane	Flex-Fuel	Hybrid/ Electric	Biodiesel
1	Merck & Co., Inc.	5,849			5,800	49	
2	Schwan's Home Service Inc.	5,800		5,800			
3	State Farm Mutual Auto Insurance Co.	4,471			4,339	131	1
4	GE Healthcare	3,875			3,875		
5	Xerox Corp.	3,825			3,675	150	
6	Bristol-Myers Squibb Co.	3,562			3,550	12	
7	Ferrellgas	3,530		3,530			
8	Eli Lilly & Co.	3,174			3,000		174
9	Johnson & Johnson Services Inc.	3,037			912	2,125	
10	Honeywell International Inc.	2,319			2,319		
11	Consolidated Edison Company of NY	1,804	20			23	1,761
12	Florida Power & Light	1,524			10	263	1,251
13	United Parcel Service (UPS)	1,448	725	720		3	
14	DSWater of America	1,236		1,131		105	
15	Monsanto Co.	1,131			1,125	6	
16	Liberty Mutual Insurance	1,018			1,018		
17	Delta Airlines	861	4	124	0	733	
18	Comcast Corp.	852			756	96	
19	National Grid	832	730	15	52	35	
20	Ecolab Inc.	809			809		
21	Alliant Energy	804			4		800
22	Novartis Pharmaceuticals	797				797	
23	Federal Express Corp.	786	90	696			
24	Schneider Electric/Square D	770			750	20	
25	BMHC (BMC West/SelectBuild)	738		418	315	5	
26	Cox Enterprises Inc.	676	6		413	257	
27	Land O'Lakes Inc.	601			600	1	
28	University of Michigan	578			483	5	90
29	Xcel Energy	578	112	7	102	4	353
30	Los Angeles World Airports	536	436	38		62	
31	Southwest Gas Corp.	528	430		89	9	
32	Questar Gas Company	502	502				
33	PPG Industries	500			500		
34	JEA Fleet Services	488			54	9	425
35	Dallas/Fort Worth International Airport	473	420	8		27	18
36	Consolidated Coca-Cola Bottling	402				402	
37	University of California, San Diego	394	9			335	50
38	Peoples Gas Light and Coke Co.	352	352				
39	Roche	339	97			242	
40	Archer Daniels Midland	325			200		125
41	University of California, Los Angeles	308	58	5		244	1
42	University of Washington	308			225	35	48
43	American Family Mutual Insurance Inc.	271			268	3	
44	University of California Davis	269	71		65	73	60
45	Nicor Gas	252	26		226		
46	University of Iowa	228			190		38
47	Santee Cooper	210		133		77	
48	Toshiba America Medical Systems	150		150			
49	Anixter, Inc.	150		150			
50	Walgreens	138		138			

22 U.S. Department of Energy. "Vehicle Technologies Market Report." 2010.

3 Commercial Fleet Use

3.5 Opportunities and Actions

3.5.1 Functionality

OEM offerings of natural gas full-size pickups, full-size vans, and midsize sedans with up to 150-mile range can successfully cover a majority of commercial functionality requirements.

In the commercial fleet market, the most popular vehicle types are full-size pickups, full-size vans, and midsize sedans. Full natural gas availability in these three vehicle classes alone would cover over half of total commercial fleet market sales, suggesting that an "all-new" vehicle concept is not required for broader NGV adoption, although vehicles purposely designed to operate on natural gas (dedicated and/or bi-fuel) will improve function and cost. Currently, commercial vehicle purchasers are effectively limited by the offerings of OEMs and their approved converters. Implicit in this analysis of natural gas opportunities within the commercial market are effective actions directed at OEMs (addressed in the next section of this report).

The types of functional requirements of fleets are listed in Table 3.5.1-1. Vehicle range requirements will vary widely by commercial fleet buyer. However, the average annual mileage of 24,000 to 28,000 (depending on vehicle segment) implies an average daily range of between 88 and 112 miles (based on 250 working days per year). The implication, therefore, is that to successfully cover the majority of commercial applications, NGVs should offer up to 150 miles between refueling events. As mentioned previously, NGVs may offer an opportunity to change the habits of vehicle operators by offering compelling cost propositions.

Table 3.5.1-1

NGVs must meet user requirements for functional considerations as defined by their targeted commercial fleets to be a viable alternative to conventionally fueled vehicles.

Functional Vehicle Attributes Considered by Commercial Vehicle Owners
Range (typically considered in terms of daily mileage)
Durability, reliability, and quality (which directly impact the anticipated cost of ownership)
Road condition applicability (occasionally off-road or unpaved surface capability is needed)
Safety rating (which can be a driver of vehicle insurance costs)
Payload (cargo capacity in terms of weight)
Cargo volume (including specific dimensions of the cargo area that might be required for that business' specific cargo)
Availability/capability for installation of custom bed and/or racking systems
Towing (as with off-road use, for some vehicles, towing capacity can be a key functional requirement)
Passenger capacity

3.5 Opportunities and Actions

3.5.2 Financial Parity

Low natural gas capacity bi-fuel NGVs can be justified without subsidy for the majority of commercial fleet buyers. High natural capacity bi-fuel NGVs and dedicated NGVs may require a level playing field in order to meet reasonable commercial requirements for payback.

Assuming that suitable vehicles are available with natural gas (i.e., all functional requirements are met), the total cost of ownership must be equal to or less than the equivalent gasoline vehicle. The financial support required to overcome NGV acquisition premiums minus operating cost savings will vary significantly by vehicle type and the specific functional capability of the vehicle (e.g., range and fuel capacity). As an example, the level of subsidy required for three possible natural gas variants of the Ford F-150, the most popular vehicle in commercial vehicle fleets, is discussed below.

Figure 3.5.2-1 illustrates the payback scenarios for the three variants:

1. Dedicated F-150 NGV with CNG tank capacity of 21.2 GGE, yielding a range of 360 miles

2. Bi-fuel F-150 NGV with CNG tank capacity of 12.6 GGE, yielding a range of 214 miles on natural gas, plus an additional 150 miles on gasoline (9 gallon tank)

3. Bi-fuel F-150 NGV with CNG tank capacity of 8 GGE, yielding a range of 132 miles on natural gas, plus an additional 250 miles on gasoline (14.7 gallon tank)

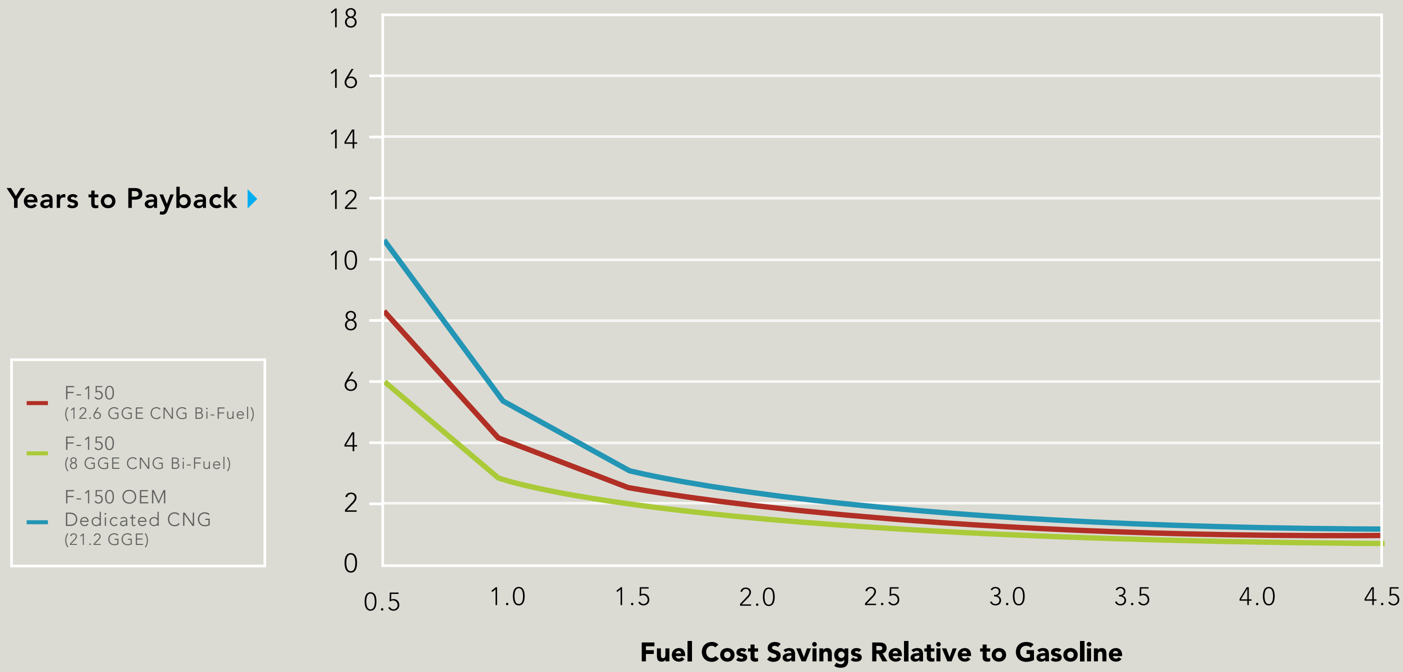
In all cases, the NGV premium is based on costs that would be associated with an OEM-produced vehicle planned at volumes sufficient to justify normal production and procurement processes consistent with other vehicle programs, not today's costs at minimum volumes through SVMs.

Without incentives for the NGV premium, the lower natural gas capacity (8 GGE) bi-fuel F-150 would be justified financially for the majority of commercial fleet buyers. To offer payback at 28,000 annual miles over an average vehicle life of four years, a dedicated F-150 NGV (at $6,980 incremental cost) would require $3,000 of subsidization, while the higher natural gas capacity (12.6 GGE) bi-fuel F-150 (at $5,501 incremental cost) would require $1,200 of subsidization. As a point of comparison, a dedicated F-150 NGV, at today's low production volumes, previously qualified for a $4,000 federal subsidy. Required subsidies are lower with higher annual mileage vehicles that are able to recover initial vehicle costs more quickly through fuel savings.

It is important to note that the level of subsidization implied in these payback analyses do not include the cost impact of fueling infrastructure (addressed in next section).

Figure 3.5.2-1

Payback on an 8 GGE bi-fuel NGV may be quick enough to be considered by fleet owners, whereas a 12.6 GGE bi-fuel NGV and a dedicated NGV would require $1,200 and $5,000 of subsidization, respectively, to offer reasonable payback.



Assumptions: Vehicle Make and Model	MSRP	MPG
F-150 (12.6 GGE CNG Bi-Fuel)	$27,321	17
F-150 (8 GGE CNG Bi-Fuel)	$25,803	17
F-150 OEM Dedicated CNG	$30,800	17

1. No discount rate is included in this payback analysis to more closely approximate the decision making process of most consumers.
2. MSRPs are estimated by The CARLAB using bottom-up costs of vehicle components.

3.5 Opportunities and Actions

3.5.3 Fueling Infrastructure

To target commercial fleet adoption of NGVs, the strategy of supporting on-site fueling capability may be more effective than expanding public station availability because the majority of commercial vehicles reside in the larger fleets for which on-site fueling makes sense.

As discussed, from the perspective of commercial fleet buyers, natural gas infrastructure offers a binary choice in its impact on the purchase decision. For those with fleets large enough and duty cycles suitable for NGV ranges, the addition of on-site fueling capability is essential to the viability of adopting NGVs, while smaller fleets can rarely justify the expense of on-site fueling capability. In the first case, the cost of the on-site infrastructure is incorporated directly into the financial analysis and NGV purchase decision. The lack of public fueling capability is more a nuisance than a challenge. In the second case, the lack of existing infrastructure essentially eliminates consideration of NGVs to replace gasoline vehicles.

While it is tempting to ideate strategies to greatly expand publicly natural gas fueling locations, such a task is daunting, particularly with regard to the accompanying financial requirements. Broad adoption of NGVs across the spectrum of commercial fleet users would require widespread availability of stations, while the majority of commercial vehicles reside in the larger fleets for which the on-site fueling option would appear more advantageous. Critically, "seeding" the market with these NGVs would provide a much better business case for expansion of publicly-available stations based on the perceived increase in demand.

The challenge, however, is that adding on-site natural gas fueling capability is expensive and capital intensive, neither of which is welcomed by commercial users. A number of potential solutions to overcome this challenge may require incentives similar to those offered to other alternative fuel infrastructure developments. Implementation, in practice, could take many forms. Utility-owned and -maintained stations could be located at the commercial user's site, the cost of which could be recouped through monthly fixed premiums to be paid by the fleet (Figure 3.5.3-1). Another solution is for private stations to offer public access in on-site areas separate from where the fleets fuel so that the same compressors may be used for higher throughput.

Figure 3.5.3-1

Expansion of natural gas fueling infrastructure to target commercial fleet adoption of NGVs may be best accomplished by first supporting the development of on-site fueling capability rather than public stations.

4 Original Equipment Manufacturers

4.1 Vehicle Availability

The interest of OEMs in NGVs is increasing, leading to greater availability of OEM NGVs.

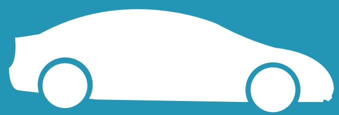
OEMs such as Ford, GM, and Toyota sell approximately 11 million vehicles every year in the U.S. and an additional 1.5 million vehicles in Canada.[23] OEM vehicles range in size from the Smart Fortwo micro-car to the Ford F-750 Super Duty heavy-duty truck, capable of hauling over eighteen tons of cargo. Like the wide breadth of vehicles produced by OEMs, their customers are equally diverse, ranging from individual personal consumers to commercial fleets and government entities. Given the overwhelming proportion of sales in the personal use market compared to the commercial fleet market, light- and medium-duty OEM perceptions of consumer demand, not business demand, are the key to motivating OEMs to invest in any vehicle platform or technology.

Today, there is only one OEM NGV being sold in the U.S. and Canada: Honda's Civic Natural Gas (Figure 4.1-1). Two other OEMs (GM and VPG) have announced plans to offer NGVs in the North American market. Ford's CNG-prepped trucks and vans are not considered OEM vehicles per se as the consumer must choose and work with a converter to obtain a completed CNG vehicle. At present, no bi-fuel NGVs are available from OEMs, despite the fact that many OEM NGVs elsewhere in the world, particularly in Europe, are bi-fuel, not dedicated, vehicles.

23 Automotive News, 2010.

Figure 4.1-1

Current OEM offerings of NGVs are limited, with greater availability on the horizon as OEM interest in NGVs grows.



Honda Civic Natural Gas

Honda has been selling its CNG Civic Natural Gas in the United States since 1998. This dedicated CNG vehicle is produced at Honda's Greensburg, Indiana plant and is currently available for retail sales in California, Utah, Texas, New York, and Oklahoma and for fleet sales in 33 U.S. states.

The Civic Natural Gas carries a premium of $6,830 when compared with a similarly equipped gasoline Civic. According to the American Council for an Energy Efficient Economy, the Civic Natural Gas as the "Greenest Vehicle in America." Although not disclosed publicly, annual sales for the Civic Natural Gas are estimated at around 1,500 per year.

Chevrolet Express

GMC Savana

Beginning with the 2011 model year, General Motors will offer a CNG powertrain option for the Chevy Express and GMC Savana vans. These dedicated CNG vans will be EPA and CARB compliant and sold through existing GM dealerships. Unlike Honda, GM will not limit sales of these vans to certain U.S. states.

The vans will come equipped with a 6.0L V8, with hardened valves and valve seats to ensure long-term durability. Two storage options will be offered: 15.8GGE and 23GGE. Pricing for the vans will start at $41,890, a $16,150 premium over the base van.[24]

For its CNG vans, GM is partnering with two established CNG conversion firms: Productive Concepts (PCI) and Natural Drive. The vans will be produced at GM's Wentzville, MO plant, shipped to PCI's Union City, Indiana plant for conversion, and returned to the GM distribution system for shipment to the dealer.[25]

VPG MV-1

Vehicle Production Group (VPG) has announced plans to produce a dedicated CNG version of its MV-1, a purpose-built wheelchair access vehicle that is expected to begin sales in 2011. This vehicle was designed from the outset with the CNG version in mind to support applications in municipal taxi fleets (New York City and Chicago, specifically), The relatively large, 21.1 GGE CNG storage capacity results in quoted driving range of 290 miles compared with 350 for the gasoline version. All MV-1s will be powered by a Ford 4.6L V8 engine. The vehicle will be sold in both the U.S. and Canada.

24 GM, 2010.
25 *Ibid.*

4 Original Equipment Manufacturers

4.2 Key Decision Drivers

4.2.1 Consumer Demand

Consumer demand for NGVs is a key decision driver for OEMs and has been insufficient to date to warrant greater OEM involvement.

In the past, there was a number of OEM NGVs offered for sale in the U.S. and Canada (Table 4.2.1-1). These same manufacturers continue to offer NGVs abroad today, including GM, Ford, Toyota, and Chrysler (Fiat). According to the manufacturers that no longer sell or choose not to offer NGVs in North America, demand for the vehicles was insufficient to justify continued production. Today, the consumers who demand NGVs are generally fleets buyers with heavy fuel usage, who enjoy a favorable payback period. In interviews, several converters corroborated that the greatest interest in their NGVs comes from commercial fleets with high fuel usage.

Light- and medium-duty customers compare alternative fuel vehicles against conventional gasoline vehicles. While consumer choice may not be based purely on economics, years of research with eco-minded consumers have shown that economics do have their role in the decision process. Payback analyses for personal vehicle consumers have demonstrated that absent a substantial premium in the price of gasoline over the comparable GGE cost for CNG, light-duty natural gas passenger vehicles will not provide financial justification for any except a very small minority of consumers. Despite green intent during the early shopping phase of the purchase process, the final purchase decision for these consumers is typically based on price and value. The Toyota Prius hybrid provides an example of this dynamic: despite not being the first modern hybrid sold in the U.S. market, the Prius has thoroughly dominated hybrid sales due to its leading payback period when compared other hybrids.

OEMs consider the lack of fueling infrastructure a major limitation to NGV demand, particularly for the personal use market. There are currently 1,091 CNG stations in operating in the U.S.[26] This number compares to approximately 118,756 gasoline stations in the U.S.[27] Unlike most gasoline stations, however, only 47 percent of the current CNG stations are accessible to the public. The OEMs do not feel responsible for creating the necessary infrastructure, and most simply do not possess the resources to do so in light of investments being made in electric and fuel cell vehicles. Electric and fuel cell vehicles (not NGVs) are the only vehicles that will comply with impending Zero Emissions Vehicle (ZEV) regulations. When asked, most OEMs found inherent appeal in CNG vehicles and hoped for a fast infrastructure build out, but most are content to wait until that happens to make any substantive investments in NGVs.

26 Alternative Fuels and Advanced Vehicles Data Center. “Alternative Fueling Station Counts by State.” http://www.afdc.energy.gov/fuels/stations_counts.html. July 31, 2012.
27 U.S. Census Bureau. “Economic Census.” 2007.

Table 4.2.1-1

The majority of CNG vehicles offered by OEMs in the past are no longer being sold in North America due to lack of consumer demand, though many OEMs continue to offer NGVs outside of North America.[28]

Vehicle	Years Sold	Bi-Fuel or Dedicated
Honda Civic Natural Gas	1998–present	Dedicated
GMC Sierra 2500	2005	Dedicated
Chevrolet Silverado 2500	2003–2005	Bi-Fuel and Dedicated
Chevrolet Cavalier	2000–2004	Bi-Fuel
Ford Crown Victoria	1996–2004	Dedicated
Ford F-150	2000–2004	Dedicated
Ford F-150 Dual-Fuel	2001–2004	Bi-Fuel
Chevrolet Express	2004, 2011	Bi-Fuel and Dedicated (Dedicated Only for 2011)
GMC Savana	2004, 2011	Bi-Fuel and Dedicated (Dedicated Only for 2011)
Dodge Ram Van/Wagon	2001–2003	Dedicated
Ford E-250 Econoline	1998–2001	Dedicated
Toyota Camry	1999–2001	Dedicated
Ford F-250	1998–1999	Dedicated
Dodge Caravan	1994–1995	Dedicated

28 U.S. Department of Energy, Enery Efficiency & Renewable Energy. "Fuel Economy." www.fueleconomy.gov. Accessed August 2012.

4.2 Key Decision Drivers

4.2.2 Regulation

Regulations provide significant motivation for OEM. However, as regulations change, OEM interest in a particular alternative vehicle technology changes as well.

OEMs must comply with a myriad of local, regional, and country-specific regulations. The costs to assess, engineer, test, and meet these regulations for a large OEM can approach hundreds of millions of dollars per year. These regulations cover all aspects of the vehicle, from safety and emissions standards to required warranty periods. Regulatory compliance involves not only additional cost but increased vehicle complexity as well and thus necessitates engineering and design compromises. Manufacturers must weigh the positive and negative effects of pursuing AFVs not only on a purely financial cost/benefit basis but also on impact (relative to other approaches) on regulatory compliance.

Regulatory compliance can provide a compelling case for manufacturers to produce a vehicle or technology. FFVs provide a recent example: the motivation to invest in FFV technology had strong roots in U.S. legislation. Aside from a select group of fleets that saw FFVs as a low-cost solution to their own regulatory demands, there was virtually no consumer pull for FFVs. A recent GM study found that approximately 70 percent of FFV owners were not even aware that their vehicles could run on E85. Of the remaining owners, fewer than 10 percent chose to use the alternative fuel.[29] However, each FFV produced earns valuable credits for OEMs that lower the manufacturer's fleet average fuel economy as required by U.S. CAFE standards and hence the explanation for OEM production of these vehicles.

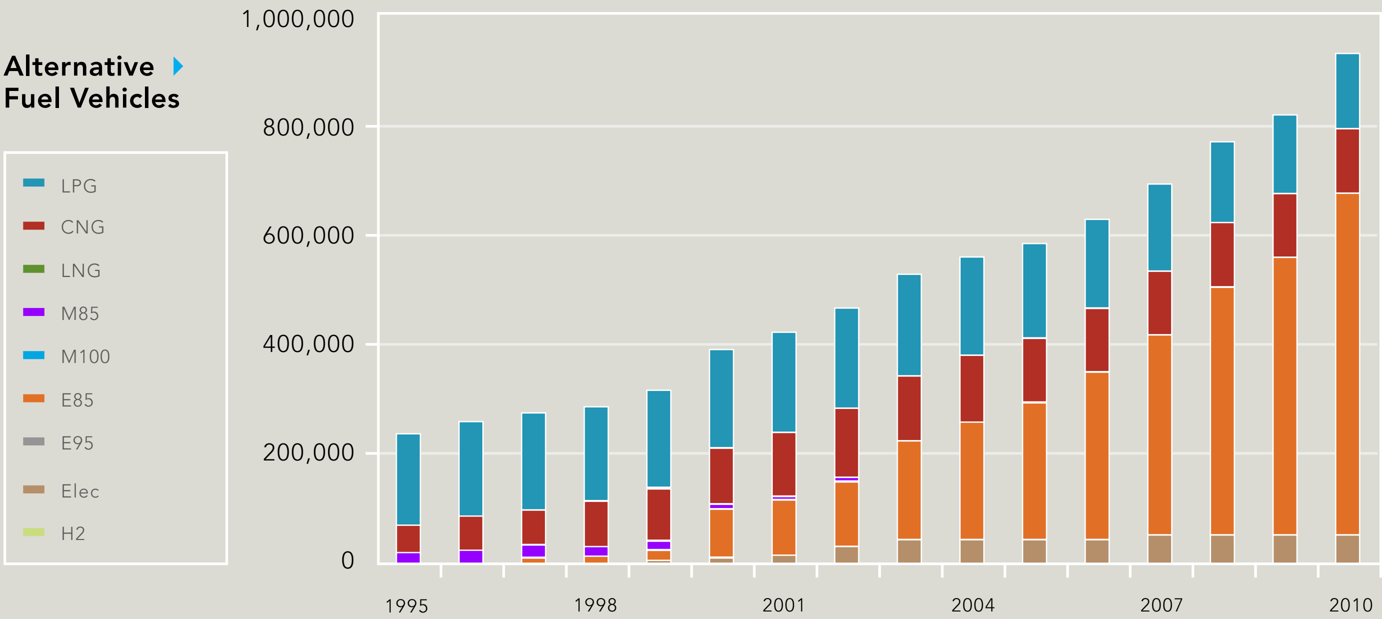
The rise of NGV sales in the mid-1990s similarly had strong roots in legislation. The Energy Policy Act (EPAct) of 1992 in the U.S. required certain state government and alternative fuel provider fleets to acquire a specific percentage of AFVs. In years following the enactment of EPAct, many fleets acquired NGVs to achieve compliance targets. However, when the regulations allowed fleet to use cheaper and more widely available FFVs to meet the mandate (regardless of whether E85 was actually used in the vehicle), OEMs reported a dramatic decline in fleet demand for CNG vehicles (Figure 4.2.2-1). OEMs, quite logically, were fully supportive of this relaxed regulation since the material changes to the fuel system and engine, other than the storage tank, are essentially identical for FFVs and CNG vehicles. Given that FFVs do not require thousands of dollars of high pressure tanks as CNG does, the market cost of FFVs was much more favorable, accompanied by large sales volume and profits for OEMs and a positive impact on CAFE ratings.

In contrast, Canadian emissions standards do not provide a credit for the sale of FFVs, and thus OEMs have very little incentive to sell E85 vehicles in Canada. FFVs are sold in Canada mostly as a result of flex-fuel engines becoming standard equipment on many U.S. OEM vehicles.

29 Cars.com. "E85: Will it Save You Money?" www.cars.com/go/advice/Story.jsp?section=fuelandsubject=fuelAltandstory=e85. June 2, 2009.

Figure 4.2.2-1

Demand for all other alternative fuel vehicles declined after fleets were allowed to use less expensive and more widely available FFVs to meet EPAct mandates, though the mandates did not require alternative fuels to actually be used in the vehicles.[30]



30 Alternative Fuels and Advanced Vehicles Data Center. "Maps and Data." www.afdc.energy.gov/afdc/data. Accessed August 2012.
Source: www.afdc.energy.gov/afdc/data/

4.2 Key Decision Drivers

4.2.3 Profitability

Profitability is a key driver for OEMs. With advanced technology resources already spread across battery, fuel cell, and hybrid vehicle development, NGVs must compete for OEM attention and commitment.

Whether publicly or privately owned, OEMs face various stakeholder demands, foremost of which is running a profitable business. Profit is far from a given for OEMs, as the recent bankruptcies of GM and Chrysler serve as testament. Large-volume vehicle manufacturers are, by nature, capital intensive businesses. Typical investments required to sustain a full line of vehicles amount to nearly $500 billion for larger manufacturers such as Ford, GM, and Toyota.[31] Historically, OEMs' low risk-adjusted return on capital has made it difficult to attract the necessary capital to run their businesses. Thus, minimizing unnecessary capital investments is critical to maintaining profitability for OEMs. This is one of many factors that result in conservative decision making and general adversity to risk for OEMs.

For OEMs with existing CNG experience, developing a natural gas powertrain for a vehicle may add approximately $50 million to the typical cost of a new vehicle program, attributable to the cost components in Table 4.2.3-1. This cost is representative of an OEM that has existing NGV experience and is looking to integrate a CNG variant into an existing vehicle (typically done concurrent with the debut of the next generation of a vehicle). In light of annual U.S. CNG vehicle sales and conversions that total less than 5,000 units a year,[32] OEM involvement has been understandably limited. Furthermore, most manufacturers have publicly and internally committed themselves to HEVs and/or BEVs. Resource constraints pose a challenge for NGV development as manufacturers are reluctant to invest in yet another alternative technology with uncertain demand, particularly since OEMs will necessarily need to subsidize early BEVs.

According to sources at several OEMs, their desired approach to NGVs in the U.S. and Canada is to be a "fast follower." These firms have plans to bring OEM NGVs to the North American market within one to two years should favorable conditions arise. These OEMs see no benefit to being the first to make a large foray into NGVs, particularly with current infrastructure limitations. Leveraging NGV offerings by these OEMs outside of North America, the quick re-introduction of NGVs to the U.S. and Canada seem quite feasible.

GM's upcoming CNG cargo vans provide interesting departures from the traditional OEM vehicle approach. By partnering with existing natural gas converters, GM leverages converter expertise while minimizing investment. The converters are forced to meet OEM requirements for durability and safety that will offer a product and experience similar to what consumers have come to expect from OEMs. Should demand increase for its CNG vehicles, GM can easily ramp up its involvement. Annual NGV sales of 50,000 units a year (less than half of one percent of the total vehicle market) would likely trigger much heavier OEM involvement, as this volume level is roughly the minimum required for full manufacturing and purchasing economies.

31 General Motors 10-K, 2008.
32 U.S. Energy Information Administration. "Alternatives to Traditional Transportation Fuels 2009." http://www.eia.gov/renewable/afv/archive/index.cfm. Accessed August 2012.

Table 4.2.3-1

For OEMs with existing CNG experience, development of a new natural gas powertrain is estimated to require $50 million in incremental costs, an investment that would be difficult to justify in this capital-constrained business with uncertain demand.

Estimated Incremental Development Cost of a Natural Gas Powertrain: $50 Million
Development of parts
Durability testing
Drivability testing
Safety testing
Emissions compliance/federalization
Investment in dealer and service training
Service parts inventory
Manufacturing plan modifications

4.3 Natural Gas Vehicle Component Cost

The cost of natural gas components is substantial, starting at around $4,000 for small cars. However, with higher production volumes and greater OEM involvement, significant cost reduction potential exists.

Table 4.3-1 outlines representative incremental costs for the natural gas components of light- and medium-duty vehicles. These BoM costs do not include additional engineering, research, and design or testing costs related to development or overhead (e.g., warranty, marketing, and personnel). The third column in the figure shows manufacturer's suggested retail price (MSRP) implications, approximately what the consumer pays for these parts, including BoM cost, manufacturing cost, margin for overhead, and an allowance for a profit margin. For automotive industry OEMs, MSRP is typically 1.65 times BoM cost. Installation and freight costs are treated separately.

Incremental BoM cost for a light-duty CNG vehicle starts at around $4,000 but can quickly rise in heavier-duty applications, primarily due to increases in the size and number of CNG tanks. The costs in Figure 4.3-1 are representative of current CNG vehicle volumes. At higher production levels that enable full economies of scale, industry experts with extensive CNG knowledge believe that BoM cost could fall to around $2,000 for a light-duty CNG vehicle like the Honda Civic.

For OEMs, the current low-volume costs of NGV components represent a very substantial increase in a vehicle's BoM cost, particularly for the market's least expensive vehicles such as the $16,640 Ford Focus,[33] which has an estimated BoM cost under $10,000. In this context, reducing the cost of a major component by $50 is considered a substantial achievement as the benefit falls directly to the company's bottom line. Generally, vehicles with higher MSRPs have larger profit margins that can better accommodate BoM cost increases while maintaining profitability.

33 Ford, 2010.

Table 4.3-1

At current NGV production volumes, the incremental BoM costs required for CNG components represent a sizeable increase in the total BoM and MSRP of the OEM vehicle.

Light-Duty	Incremental BoM Cost	MSRP
2010 Honda Civic Natural Gas	$3,900	$6,435
2011 GMC Savana	$9,788	$16,150
2011 Chevrolet Express	$9,788	$16,150

4.4 Non-Key Issues for Decision Making

Access to technology, manufacturing complexity, federalization, warranty, service, durability, and end-of-life issues for NGVs do not present substantial challenges for OEMs.

Access to Technology

Access to technology is not a challenge for OEMs (Figure 4.4-1) for two reasons: 1) the technology needed is mature, well understood, as demonstrated by the thousands of NGVs on the road today, and 2) the supplier community can easily provide all of the components – CNG tank, fuel line, and engine modifications – necessary for NGVs.

Manufacturing Complexity

At current NGV production levels, OEMs that manufacture their own NGV (e.g., Honda) rely on small batch production. A number of fully-capable suppliers exist to support small volume production, greatly lowering manufacturing complexity as a real challenge for NGV production. At higher production levels, OEMs will abandon small batch production and make necessary modifications to allow full-scale NGV production in traditional manufacturing plants.

Federalization

All vehicles sold by OEMs must be federalized, meeting standards that range from emissions to FMVSS for safety and crashworthiness. Obtaining certification for an OEM is not a challenge if a positive business case for the vehicle exists.

Warranty

OEMs offer full warranties for every new vehicle sold. A full OEM vehicle, such as Honda's Civic Natural Gas and GM's upcoming vans, will have met internal standards for durability, in part to ensure manageable warranty cost. NGV parts would not be an exception or pose additional difficulties from a warranty perspective and would be handled just as any other supplier-provided component (the majority of the components in any vehicle).

Service

OEM dealer franchise agreements universally stipulate service and parts requirements. Dealer service technicians must be qualified (usually based on OEM developed training and testing) and able to service any vehicle that is sold through their dealership.

Durability

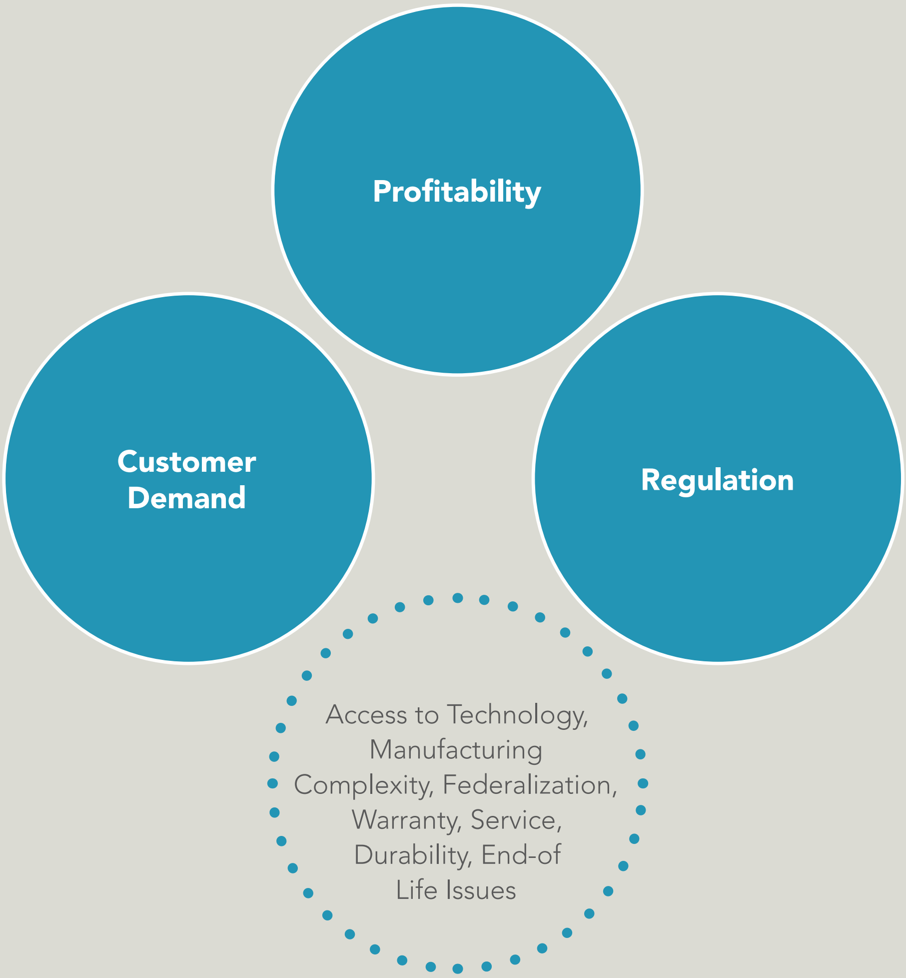
NGV technology is mature and well known. NGV engines have hardened valves and valve seats to deal with the hotter combustion temperatures of natural gas. Experts report that the cleaner burning nature of natural gas results in less oil contamination, resulting in longer service periods.

End-of-life issues

Excluding natural gas tanks, OEMs face no substantive end-of-life issues with NGVs. There is an extensive market for scrap vehicles, and recyclers are well equipped to extract the maximum value from all types of vehicles. More information about tanks can be found in the Heavy-Duty Vehicle Ownership and Production report of the overall TIAX assessment.

Figure 4.4-1

Consumer demand, profitability, and regulation drive OEM decision making, whereas access to technology, manufacturing complexity, federalization, warranty, service, durability, and end-of-life issues are considered to be minor factors.



4.5 Opportunities and Actions

4.5.1 Consumer Demand

Because economics are the first and foremost consideration of both private and fleet consumers, to increase demand for NGVs (and thus attract greater OEM involvement), upfront consumer costs for purchase of NGVs must be reduced such that the payback period is reasonable. Financial support for fleet-based infrastructure will also increase consumer demand.

Both private and fleet customers compare AFVs to conventional vehicles. Financial considerations are a key part of this comparison. Anything that can shorten payback period (time required to recoup natural gas component costs through fuel price savings) will increase customer demand for NGVs. As demonstrated in Figure 4.5.1-1, the payback period for NGVs can be long, particularly when compared to other AFVs. In this example, including a $4,000 federal tax credit, a Civic Natural Gas owner driving 10,000 miles annually would need to wait more than twenty years to recoup the $6,830 premium for the natural gas Civic through lower CNG fuel costs as compared to an identically equipped gasoline Civic.

The cost differential between natural gas and gasoline is another component of the payback calculation. However, fuel differentials are likely to have a smaller impact than those directly on the vehicle cost of acquisition, as fuel costs tend to represent a much smaller percentage of vehicle ownership costs (Figure 4.5.1-2).

Many consumers are drawn to NGVs because of non-financial benefits such as carpool lane access and preferential or discounted parking. For example, at the end of 2010, carpool lane access ended for certain early hybrid owners in California, but this benefit continues to be offered for NGVs.[34] Vehicle owners have expressed interest in NGVs purely to retain carpool lane access.

The current natural gas fueling infrastructure is a challenge for widespread adoption of NGVs. One possible solution to the cost of installing a fast-fill fueling station appears to be gaining popularity: the local natural gas provider pays for the pump and installation in exchange for a long-term fueling contract with the fleet operator. One additional benefit of this approach is that fleet operators may be able to lock in the price of natural gas, reducing fuel cost variability for their fleet.

34 California Air Resources Board. "Eligible Vehicle List: Single Occupant Carpool Lane Stickers." www.arb.ca.gov/msprog/carpool/carpool.htm. August 7, 2012.

Figure 4.5.1-1

A Honda Civic Natural Gas owner would need to operate the vehicle for 20 years to recoup the incremental vehicle cost through fuel savings.

Assuming annual driving of 12,000 miles, CNG price of $1.163/GGE, diesel price of $2.520/gal

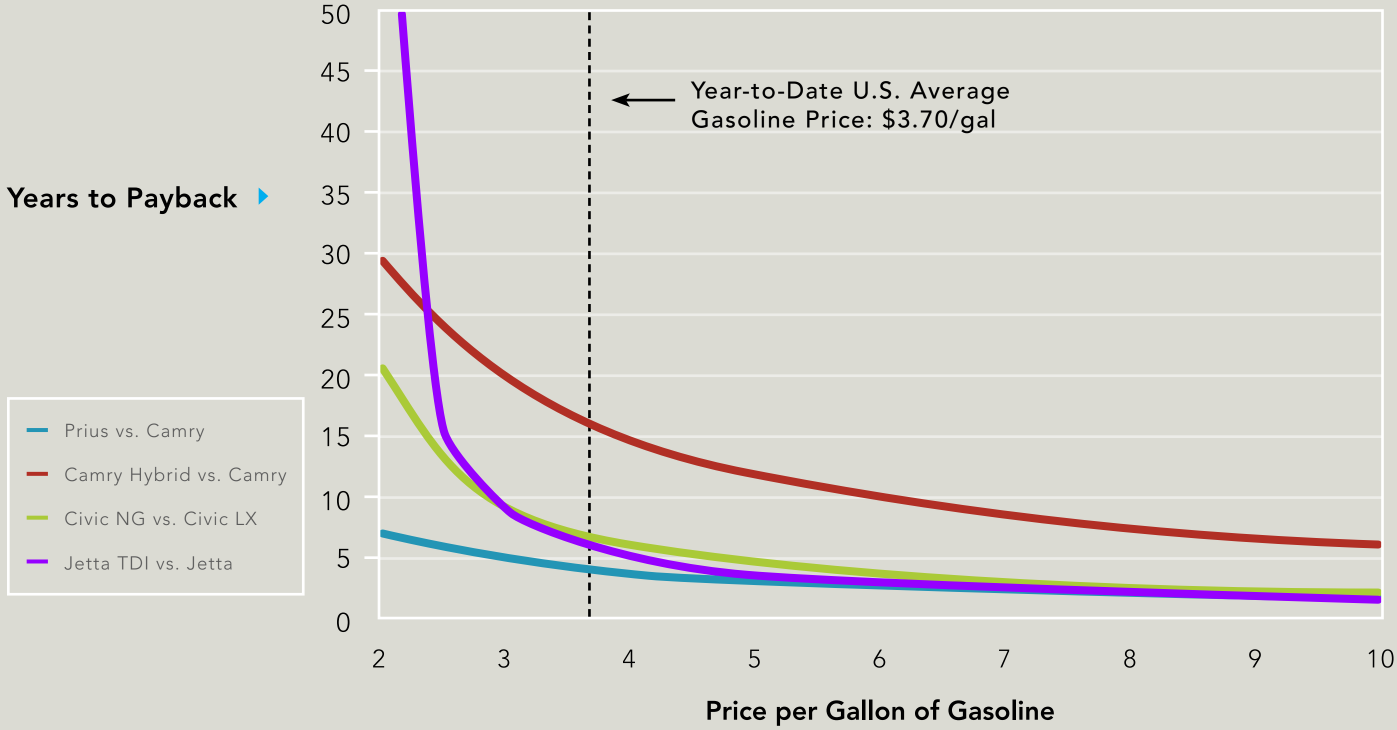


Table 4.5.1-1

For most operators, fuel costs represent a relatively small portion of purchase price.

Vehicle	**Toyota Camry** Best-Selling U.S. Car	**Ford F-150** Best-Selling U.S. Truck
Base Price	$24,250 (SE Trim)	$25,505 (XLT Trim)
Fuel Economy (mi/gal)	26	17
Annual Fuel Cost (at 12,000 mi/yr, $2.77/gal Gasoline)	$1,278	$1,955
Annual Fuel Cost as Percent of Purchase Price	5.3%	7.7%

4.5 Opportunities and Actions

4.5.2 Regulation

Regulatory support for an equal playing field among all alternative fuels would bolster broader OEM interest in NGVs

OEMs are facing strong pressure to reduce vehicle emissions and increase fuel economy (Figure 4.5.2-1), which has raised interest in all AFVs, including NGVs. Most OEMs have opted to focus on three competing alternative fuel technologies over NGVs:

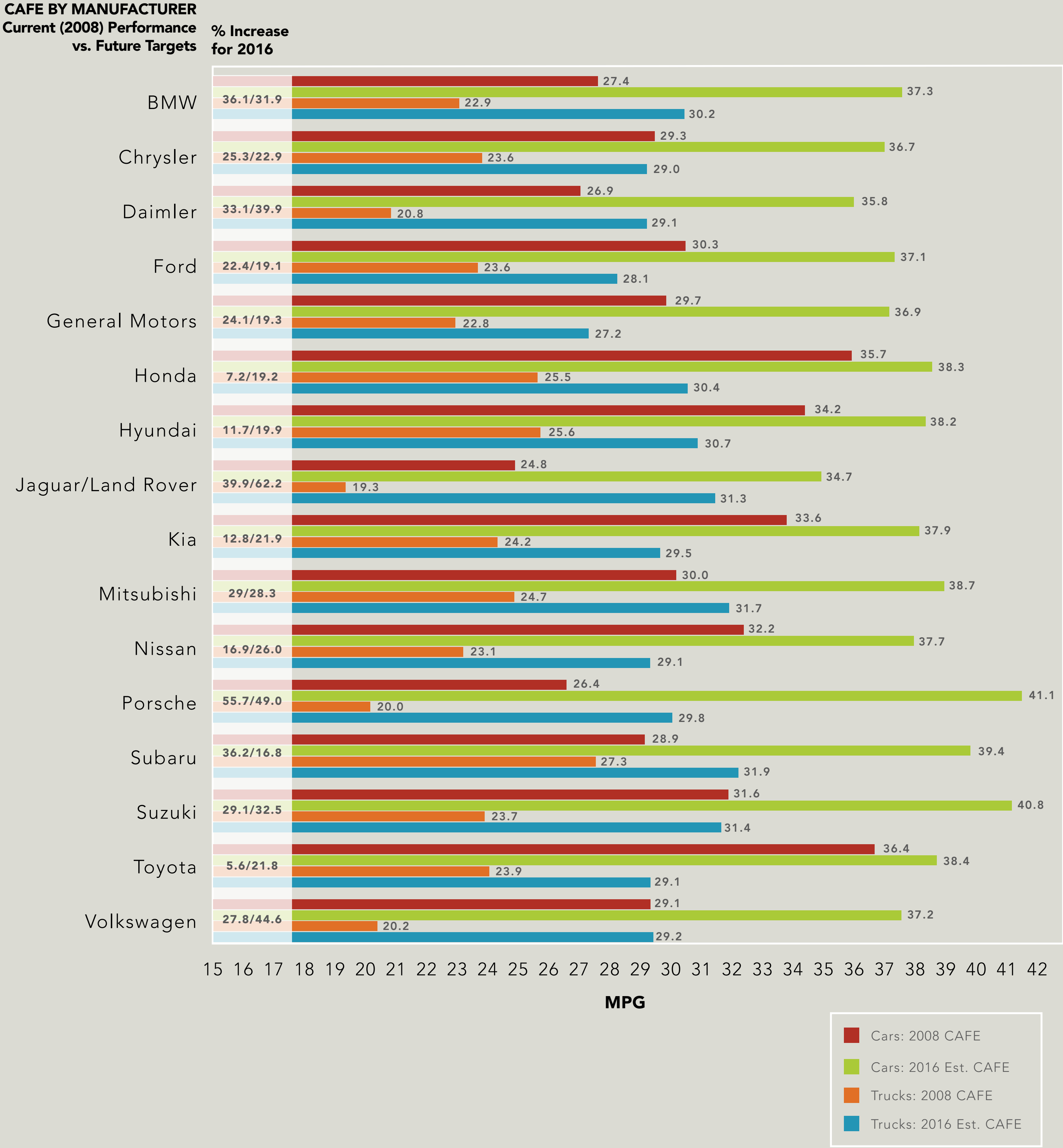
- EVs (due to regulations such as the CARB's mandate that specifically requires ZEVs)
- HEVs (due to popularity among consumers)
- FFVs (due to their relatively low cost and CAFE credit opportunity)

Flex-fuel is an example of a technology in which regulations played a major part in attracting OEMs. Due to the low cost of the technology (less than $200 per vehicle) and the favorable impact on an OEM's CAFE compliance, sales of FFVs have risen dramatically. Critically, this growth has happened despite very low demand for the technology from end consumers; indeed, very few owners use E85 to operate their vehicles. Despite low use of the alternative fuel, the regulations were written such that OEMs have no burden to prove actual alternative fuel use to receive CAFE credit.

At the federal level, lawmakers are currently evaluating efforts to create a level playing field among all alternative fuel policies, recognizing that it takes "all of the above" alternative fuels to enhance our energy security. This broader approach could bolster OEM interest in NGVs by sending a consistent regulatory signal promoting alternatives to the market and letting the OEMs decide which alternative can best compete. A comprehensive technology- and feedstock-neutral approach should be taken in evaluating current levels of federal support for alternative fuels among all areas of the federal government, including Executive branch federal fleet performance, federal agency regulatory programs such as CAFE and EPA GHG standards, existing mandates such as the Renewable Fuel Standard, and Research and Development programs.

Figure 4.5.2-1

Each OEM's vehicle fleet will need to meet increases in its corporate average fuel economy.[35]



35 Car and Driver, June 2010.

4.5 Opportunities and Actions

4.5.3 Profitability

At present, profitability for OEMs in offering NGVs will stem from decreasing the costs to develop NGVs through targeted financial and regulatory compliance support.

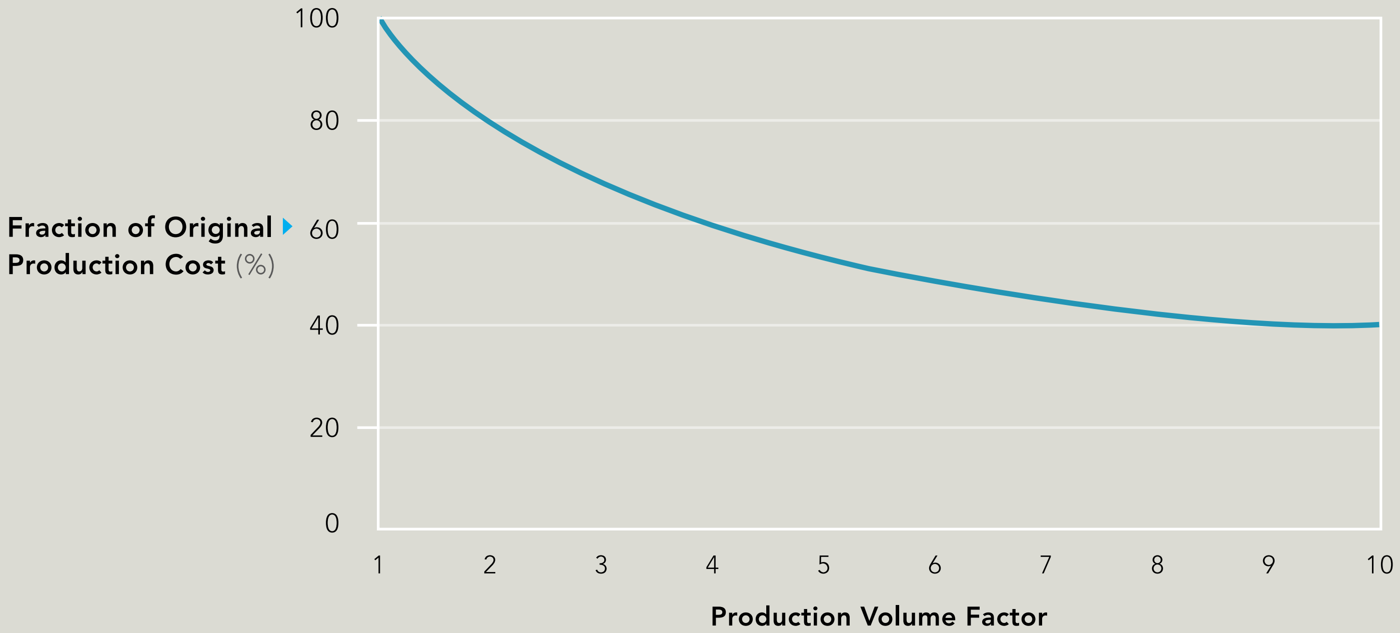
The perceived size of the NGV market relative to the entire vehicle market, combined with substantial development costs, has led to an unappealing NGV business case for most OEMs. However, the BoM cost of NGVs will fall as production volumes rise and NGVs go from small volume vehicles to more traditional high-volume, low-cost vehicle programs (Figure 4.5.3-1). To do so, OEMs need confidence that NGV demand will increase based on either regulatory support or consumer demand, or likely both.

While little can be done to lower BoM costs while volume remains low, more can be done to help OEMs address the cost to develop a NGV. Low-interest alternative fuel technology loans and grants have been made available to OEMs. In general, OEMs have used these funds for other technologies such as BEVs and fuel cell electric vehicles that have much greater investment demands than NGVs due to the nascent state of those technologies in modern automotive applications. Without funds or loans specifically earmarked for NGVs, it is unclear how much financial support for AFV development costs would specifically benefit NGV programs.

Another alternative is for the natural gas industry to approach OEMs to provide more direct support for NGV programs. Representatives familiar with OEM NGV plans stated that internal resource constraints are a significant hurdle. These individuals stressed that achieving compliance with CARB regulations is particularly onerous. This burden would be even greater should an OEM decide to engineer a bi-fuel NGV to achieve CARB compliance. Engineering for these regulations is highly feasible but prohibitively expensive under current circumstances.

Figure 4.5.3-1

As a general rule of thumb in manufacturing, every doubling of production volume results in a 20 to 30 percent decrease in production costs.[36] As such, production of NGVs at higher volumes than at present will increase profitability and attract greater OEM interest.



36 Henderson, B. "The Experience Curve – Reviewed." *Perspectives.* Boston Consulting Group. http://www.bcg.ch/fileadmin/media/pdf/the_experience_curve.pdf. 1974.

4.5 Opportunities and Actions

4.5.4 Bi-Fuel NGVs

Bi-fuel NGVs have tremendous potential for increasing the use of natural gas as a transportation fuel. However, in order to realize this potential, unequal treatment by governments of bi-fuel NGVs relative to dedicated NGVs must be addressed.

Bi-fuel NGVs are not eligible for the same federal incentives as dedicated NGVs. The result is a less compelling financial case for bi-fuel NGVs and thus lower demand. However, bi-fuel vehicles do not suffer from the same fueling infrastructure limitations as dedicated NGVs as they can rely on the gasoline infrastructure when CNG is unavailable. Particularly for personal use consumers, this allows the vehicle to accommodate varied uses (such as occasional longer trips) without leaving the driver at risk of being unable to refuel the vehicle. In general, consumers will reject a vehicle that fails to meet their functional needs and yet that is precisely what dedicated NGVs ask of consumers with their exclusive dependence on a very limited fueling infrastructure.

As detailed in Table 4.5.4-1, the BoM costs of bi-fuel and dedicated NGVs are very close. As further proof of this, several converters charge exactly the same for bi-fuel as dedicated conversions.[37] For dedicated CNG conversions, most often the donor vehicle comes equipped with gasoline tanks and lines that are removed and later sold. Given that bi-fuel NGVs have nearly the same cost as dedicated NGVs and do not suffer from the same fueling infrastructure limitations, bi-fuel NGVs should have much greater appeal to consumers than dedicated NGVs. When the incentive disparity did not exist, consumers clearly agreed. In 1996, bi-fuel NGVs outsold dedicated almost 5 to 1. In 2008, when dedicated (but not bi-fuel) NGVs were eligible for government incentives, the mix shifted dramatically in the other direction, with dedicated NGVs outselling bi-fuel NGVs 113 to 1.[38]

Assuming natural gas remains less expensive than gasoline on a GGE basis, owners of bi-fuel NGVs have a natural incentive to fuel with natural gas whenever possible. These bi-fuel vehicles provide an incentive for infrastructure build-out simply by being on the road. Thus, bi-fuel NGVs would help the market move beyond the so-called "chicken and egg" problem that has thus far stifled growth of NGVs. Figure 4.5.4-1 provides an example of the sales possibility for bi-fuel NGVs that receive more favorable incentive treatment from the government, based on similar circumstances for HEVs. HEVs are bi-fuel vehicles running on electricity instead of natural gas that have better payback periods and do not suffer the infrastructure limitations of their dedicated EV counterparts. Because of this financial and functional superiority, HEV sales have and are likely to far exceed those of pure EVs as long as EV charging infrastructure remains scarce, providing valuable lessons to the NGV market. This is a prime example of the need for an equal playing field among all alternative fuels with respect to rules and regulations.

37 CleanFuel Conversions, 2010.
38 U.S. Energy Information Administration. "Historical Data: Alternative Transportation Fuels (ATF) and Alternative Fueled Vehicles (AFV)." April 2010.

Table 4.5.4-1

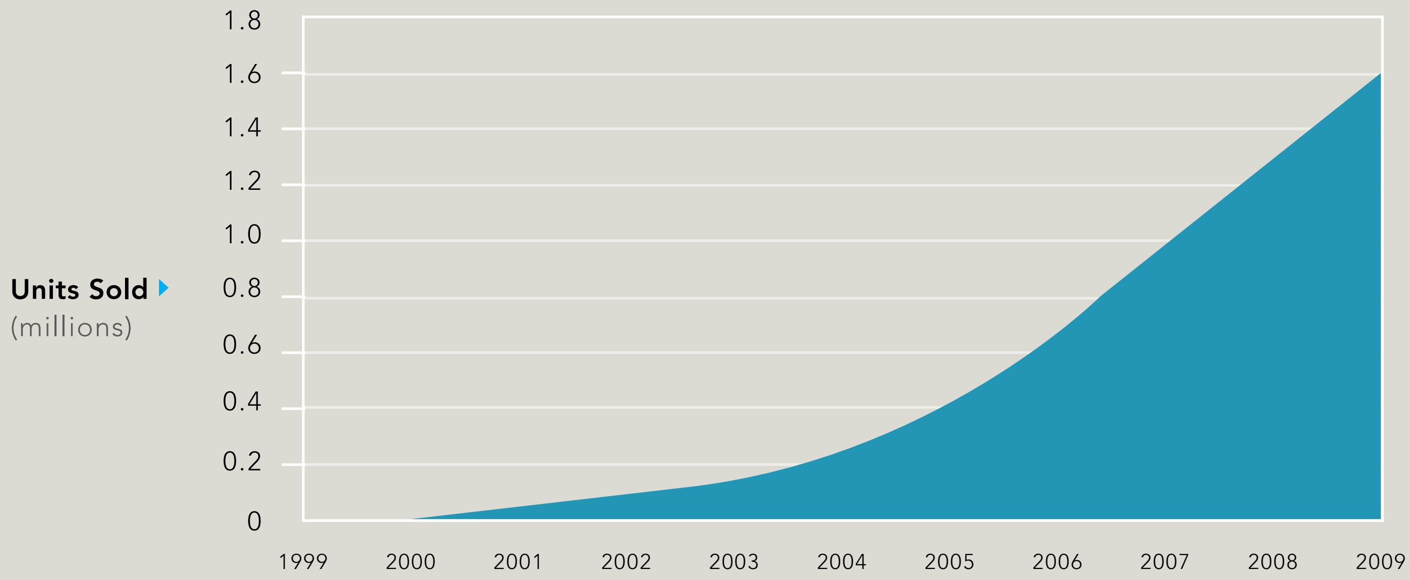
Even including the cost of gasoline fuel system components in bi-fuel NGVs, the BoM costs of dedicated and bi-fuel NGVs are similar.

Light-Duty	Dedicated BoM Cost	Hi-Fuel BoM Cost*	Dedicated Required MSRP	Bi-Fuel Required MSRP
2010 Honda Civic Natural Gas	$3,900	$4,070	$6,435	$6,720
2010 Ford E-350	$7,150	$7,340	$11,800	$12,100

*Includes cost of gasoline fuel system components

Figure 4.5.4-1

The success of cumulative sales of HEVs in the U.S. provide lessons for the NGV industry and suggest the greater potential of bi-fuel NGVs over dedicated NGVs.



5 Small Volume Manufacturers, Installers, and Repair Professionals

5.1 Overview

SVMs are important in the near term, but OEMs are the key to mass market NGV adoption.

SVMs are not the path to mass-market NGV adoption. As a whole, converted NGVs, even today, entail durability, distribution, and service compromises relative to OEM vehicles. It is estimated that the annual natural gas conversion market needs to exceed 50,000 units (less than half of one percent of the total light- and medium-duty vehicle market) before OEMs become heavily involved. GM's partnership with existing converters has allowed it to establish a presence in the natural gas space with minimal risk and yet be positioned to bring production in-house should the market reach critical mass. Figure 5.1-1 compares sales of CNG vehicles to those of other AFVs that have enjoyed greater OEM involvement. These trends indicate that increased OEM involvement, more so than SVM involvement, is a necessity for the NGV market.

Approximately 1,700 light- and medium-duty NGVs were made available per year in the U.S. from 2005 to 2009.[39] Excluding the only OEM NGV, the Honda Civic Natural Gas, converters have been the source for all other CNG vehicles. In comparison, the light- and medium-duty gasoline vehicle market averaged 15 million units per year over the same 2005 to 2009 period.[40]

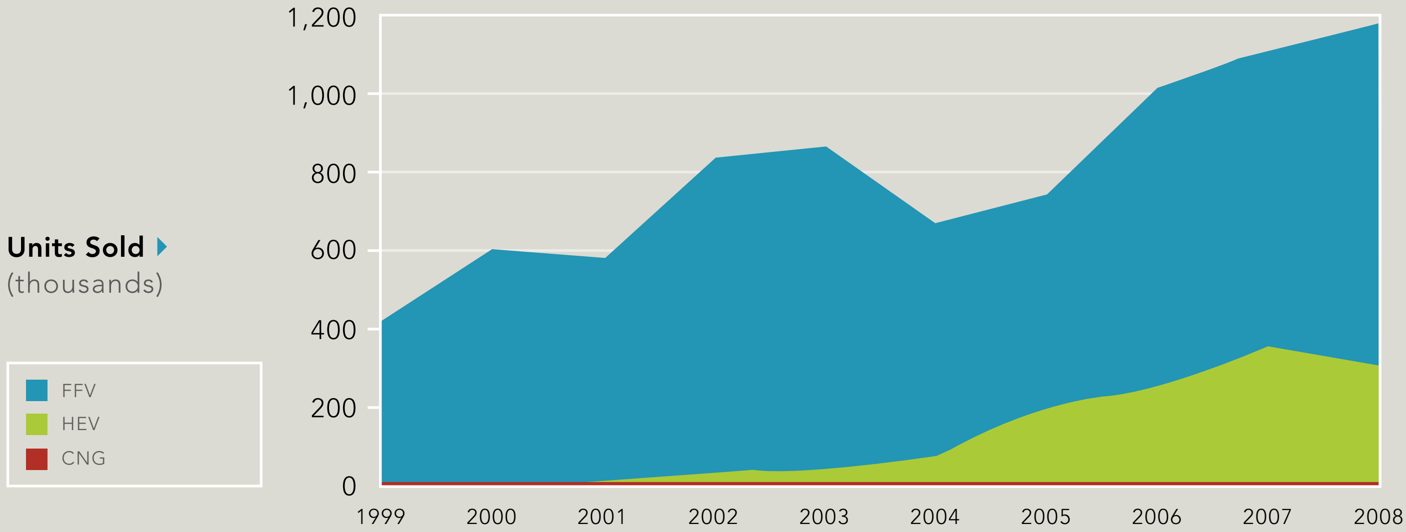
Currently, six SVMs account for most of the light- and medium-duty kits sold: Altech-Eco, BAF, IMPCO, NGV Conversions, Baytech (acquired by Landi Renzo), and Natural Drive. Installation of these CNG kits may be performed by the kit manufacturer directly or its network of qualified system retrofitters (QSRs). The EPA and CARB will only certify systems installed by QSRs, who are selected by the kit manufacturer and must receive appropriate training and documentation to ensure that the CNG systems are installed properly. QSRs operate under the SVM's certification. Training for QSRs varies from a DVD and documentation to on-site training with the kit manufacturer.

Repairs on non-CNG components can be performed by an OEM dealer, independent service shop, or, for larger fleets, internal repair professionals. Most CNG kit manufacturers will require that any warranty work on the natural gas components be done by an approved repair technician. For fleets with internal repair professionals or a shop of choice, the SVM may train these external technicians to perform CNG system repairs. However, given the relatively limited experience that service technicians may have with natural gas systems, many SVMs have natural gas system experts on staff as a resource to support outside mechanics. NGV owners can also take the vehicle to an independent shop with a mechanic certified to work on NGVs. As with any low-volume vehicle, independent shops may have little or no experience with the specific vehicle and may not have the tools or repair parts on hand for timely and high quality repairs.

39 U.S. Energy Information Administration. "Alternatives to Traditional Transportation Fuels." 2005 to 2009
40 U.S. Department of Energy. "Vehicle Technologies Market Report." 2010.

Figure 5.1-1

As exemplified by HEVs and FFVs, significant OEM involvement, whether driven by convenient benefits for the consumer or regulatory compliance for the OEM, results in higher CNG sales.



5.2 Key Decision Drivers

5.2.1 Profitability

At low volumes, SVM profitability is challenged by high component and development costs.

Unlike OEMs that may undertake an AFV program solely for the purpose of meeting regulatory compliance requirements, SVMs are generally focused exclusively on entering the space as a purely profit-driven business decision. SVMs are motivated to establish their presence in what they perceive as a growth market. These SVMs report strong interest in CNG from potential clients based on the number of inquiries and foresee increasing clientele as challenges for CNG adoption are overcome. Due to the strong focus of potential NGV clients on payback analysis, SVMs report feeling immense pressure from customers to lower kit costs. As with OEMs, kit costs broadly fall into two categories: BoM costs, with include costs of vehicle components, and development costs, which include the upfront design, engineering, and certification investments.

The cost of NGV components is significant when compared to the BoM cost of a conventional vehicle. Table 5.2.1-1 estimates BoM costs for SVMs. BoM costs decline with increasing production volumes, but current volume levels are insufficient for significant economies of scale.

SVMs must obtain emissions certification to legally sell a kit. CARB certification is required for NGVs operating in California and any state adopting CARB standards. In other U.S. states, NGVs must obtain EPA certification. According to SVMs, the cost for EPA certification starts at $70,000, rising to over $150,000 for both CARB and EPA certification.

SVMs also must comply with National Fire Protection Association (NFPA) standards that regulate the fire safety of natural gas systems. Unlike OEMs, SVMs do not need to comply with standards within FMVSS that dictate crash safety. As NFPA enforcement is at the local level, the result is wide variability in compliance and enforcement. SVMs report that compliance with NFPA is not difficult. Some SVMs voluntarily achieve FMVSS compliance. Motivations for doing so include differentiation from other converters and to receive "preferred" approval from the OEM. Completing this testing can add up to $200,000 to the development cost of a natural gas kit, a cost that must be recovered through higher cost per kit sold. The total cost to develop a kit and certify an NGV for FMVSS can exceed $300,000 for SVMs.

SVMs tend to focus on select OEMs to maximize carryover learning and minimize development costs whenever possible. By focusing on specific high-volume vehicles, an SVM increases the chance of recovering this development cost. As a result, SVMs are reluctant to expand beyond the current Ford and GM vehicle kits unless they receive orders large enough to ensure they can quickly recoup a substantial fraction of the investment.

Table 5.2.1-1

The required incremental BoM costs for converted NGVs are significant when compared to their conventional vehicle counterparts.

Light-Duty	BoM Cost	Required MSRP
2010 Ford Focus (Dedicated NGV)	$4,700	$9,400
2010 Ford F-250 (Dedicated NGV)	$5,900	$11,800

5.2 Key Decision Drivers

5.2.2 Customer Demand

Payback periods for NGVs and fueling infrastructure are key drivers of customer demand and SVM decision making. In addition, there are several smaller issues that limit the potential market for NGVs.

Potential cost savings are a primary driver of NGV demand. As a result, payback period is a key focus, particularly for fleet buyers. Factors that affect either the cost of NGVs or the price differential between natural gas and traditional fuels will directly impact demand for NGVs, which in turn drives SVM decision making.

Next, availability of natural gas fueling infrastructure is a key consideration for SVMs as it affects potential customer demand. In geographic areas with limited or no natural gas infrastructure, clients for dedicated NGVs are those who can economically justify installing their own on-site fueling capability. This tends to eliminate businesses with modest fuel usage and those whose vehicle usage requires a daily range beyond that offered by NGVs. According to an SVM in a metropolitan area with only one public CNG station, "I tell anyone who wants a dedicated CNG vehicle that their strategy had better include a tow truck." Although bi-fuel NGVs theoretically should have more appeal in areas with low infrastructure build-out, the fact that bi-fuel NGVs were previously ineligible for tax incentives reduced their appeal.

A smaller but important issue that influences customer demand for NGVs stems from drivability and durability problems experienced by fleet operators with early NGVs. Most of these problems were addressed when regulations mandated full onboard diagnostic system (OBD II) compliance for natural gas conversions, which led to various improvements in CNG conversion kits. Yet despite these improvements, some fleet operators still will not consider NGVs due to negative past experience.

For many fleets, residual value after the lifetime of the vehicle plays a major role in the purchase decision. With a limited resale market, residual values of CNG conversion vehicles are relatively unknown, further blurring the NGV business case. Many of the larger business fleet operators use external firms to finance their vehicle purchases and have reported that some financing firms do not support the purchase of NGVs due to their residual value uncertainty.

Interviews with SVMs and fleets uncovered SVM-specific warranty and durability issues that have limited demand among some end user groups (Table 5.2.2-1).

Table 5.2.2-1

SVM-specific issues regarding warranty and durability have limited consumer demand.

Warranty

By law, SVMs are required to warranty any emissions control equipment for 3 years/36,000 miles (EPA) and 8 years/80,000 miles (CARB). Warranty support for the remaining CNG kit components vary by SVM. Several SVMs offer 3 year/50,000 mile warranties on the rest of the CNG powertrain and fuel system components. This is comparable to OEM bumper-to-bumper warranties but falls short of the most generous OEM powertrain warranties, which offer powertrain coverage for 5–10 years/100,000 miles.

The impact of a natural gas conversion on the OEM warranty varies. Ford approved SVMs enjoy the full factory warranty on all but the non-Ford supplied parts (e.g., those which are changed or added by the converter). However, OEMs are not required to warranty parts that may have failed due to the natural gas components or conversion, and thus some component failures may fall into a "gray" area. This may expose customers to the risk that the SVM and OEM both refuse to take responsibility for a failed part, leaving the customer financially responsible for repairs that would have been covered on the OEM vehicle before the conversion.

Durability

The durability of conversion kits appears to be improving; however, fleet users report that the quality gap between OEM and converted vehicles still remains evident. A key development for CNG vehicles was Ford's 2010 model-year introduction of CNG conversion-ready vehicles such as its E-Series Vans, F-450, F-550, and Transit Connect[41] that offered hardened values and valve seats. The hotter combustion temperature of natural gas compared to gasoline causes non-hardened valves to recess, often as early as 60,000 miles into the life of the vehicle, much earlier than if the same engine were torun on traditional fuel.

Improperly programmed engine control modules (ECMs) have also caused durability issues even without causing discernable drivability or emissions issues which would have prevented the vehicle from obtaining EPA or CARB certification. Engines burning suboptimal air/fuel ratios can experience premature catalytic converter failure. The catalytic converter is a vital part of the vehicle's emissions control system. These ECM-based quality issues are still possible if a conversion manufacturer does not properly calibrate the vehicle's ECM for natural gas.

Generally speaking, durability is a very important decision criterion for fleet buyers as they tend to place significantly greater demands on vehicles than personal vehicle owners, including both greater total mileage before disposal and more challenging duty cycles during ownership. Moreover, the cost of vehicle repair extends beyond the direct repair cost. For commercial fleets, the cost of a vehicle that is out of service is, or at least is perceived to mean, lost business, a situation fleet operators want to avoid whenever possible. Ford and GM's greater involvement in providing conversion-ready variants will serve to improve the durability of NGVs.

41 Ford Fleet. "Compressed Natural Gas (CNG)/Liquefied Petroleum Gas (LPG)." https://www.fleet.ford.com/showroom/environmental_vehicles/CNG_LPG.ASP. October 2010.

5.2 Key Decision Drivers

5.2.3 Regulation

The complexity of obtaining emissions certification for SVMs has resulted in a limited number of firms, who are focused on the highest volume (mostly Ford and GM) fleet vehicles.

In the U.S., for vehicles less than 10,000 pounds, EPA and CARB emissions certifications (Table 5.2.3-1) are specific to a vehicle, engine, and powertrain. For instance, a 2-wheel-drive and a 4-wheel-drive Silverado with the same engine are considered distinct vehicles, each requiring a separate certification. Another example of this stringent regulation is Ford's E-Series vans and F-Series trucks, which not only share underlying architecture and chassis but engines as well. For certification purposes, these vehicles are regarded separately. If an OEM makes any change to the engine or emissions control system, including engine software updates, wiring harnesses, and air filter, the result is a new engine family designation, thereby requiring separate certification. Consequently, this requires the converters to also re-certify their kit conversions based on the OEM change. For medium-duty vehicles over 10,000 pounds, the regulations allow for greater flexibility, not requiring certification for each engine family and specific vehicle but allowing an engine to be certified along with a range of truck/van configurations.

EPA or CARB approval, once obtained, lasts for one year, generally based on the calendar year. The SVMs must reapply for certification each year, including paying the annual certification fee. This results in a narrow "conversion window" from when approval is received for a conversion until the certification expires. For instance, if Ford introduces a new engine in April 2010, a converter will need to obtain a vehicle, develop and test a conversion kit, and submit this documentation to the EPA or CARB for approval. Reportedly, the approval process (particularly for CARB) can take up to six months. This could result in kit certification being received in October 2010. Assuming kit development takes one month, this leaves only three months for converters to sell and install kits before their certifications expire.

The EPA has proposed changes to its certification process that would reduce the burden on manufacturers seeking approval for CNG vehicles. Reducing the testing burden would effectively lower the cost of achieving compliance. It is unclear if the proposed changes will extend the "conversion window" that exists once approval has been granted. While any reduction in the testing burden will benefit the CNG vehicle market, CARB, unfortunately, does not appear to be following the EPA's move. CARB's more extensive testing procedures are generally considered more costly and difficult to obtain when compared to those of the EPA. The challenge of meeting emissions regulations and selling enough kits to recover the cost has limited the number of SVMs that the market can support. Currently there are six SVMs serving the North American market. Most of these SVM kits are for the highest volume fleet vehicles, typically Ford and GM trucks and vans.

Similar to the U.S., the Canadian government regulates vehicles burning natural gas as a fuel. These regulations cover NGV safety and emissions and are very similar to U.S. regulations. SVMs must comply with Canadian regulations governing the safety of CNG fuel systems, particularly with regard to the integrity of the fuel system in the event of a fire or accident. Canadian Standard 301.2 mandates that converted vehicles be crash tested to demonstrate compliance (unlike in the U.S., where crash testing is optional for SVMs). According to representatives at Ford and GM, OEM CNG vehicles that comply with U.S. FMVSS standards (and by extension, converted vehicles that comply with FMVSS) will pass Canadian CNG vehicle standards. From an emissions standpoint, all NGVs in Canada must have received emissions certification from either the U.S. EPA or CARB. In this regard, Canadian SVMs face an identical process as their U.S. counterparts.

Table 5.2.3-1

Every light-duty vehicle and engine must be separately tested and certified to EPA emissions standards,[42] which are then used to calculate the fleet averages for the manufacturers' offerings.

U.S. EPA Federal Light-Duty Vehicle Emission Standards for Air Pollutants								
Clean Fuel Fleet Exhaust Emission Standards								
Vehicle Type	Emmissions Category	Useful Life Standard	Test Weight (lbs)	NMOG (g/mi)	NOx (g/mi)	CO (g/mi)	Formaldehyde (g/mi)	PM (g/mi)
LDVs	TLEV	Intermediate	All	0.125	0.4	3.4	0.015	-
	LEV			0.075	0.2	3.4	0.015	-
	ULEV			0.04	0.2	1.7	0.008	-
	TLEV	Full		0.156	0.6	4.2	0.018	0.08
	LEV			0.09	0.3	4.2	0.018	0.08
	ULEV			0.055	0.3	2.1	0.011	0.04
LLDTs	TLEV	Intermediate	0-3750 LVW	0.0125	0.4	3.4	0.015	-
	LEV			0.075	0.2	3.4	0.015	-
	ULEV			0.04	0.2	1.7	0.008	-
	TLEV		3751-5750 LVW	0.16	0.7	4.4	0.018	-
	LEV			0.1	0.4	4.4	0.018	-
	ULEV			0.05	0.4	2.2	0.009	-
	TLEV	Full	0-3750 LVW	0.156	0.6	4.2	0.018	0.08
	LEV			0.09	0.3	4.2	0.018	0.08
	ULEV			0.055	0.3	2.1	0.011	0.04
	TLEV		3751-5750 LVW	0.2	0.9	5.5	0.023	0.08
	LEV			0.13	0.5	5.5	0.023	0.08
	ULEV			0.07	0.5	2.8	0.013	0.04
HLDTs	LEV	Intermediate	0-3750 LVW	0.125	0.4	3.4	0.015	-
	ULEV		ALVW	0.075	0.2	1.7	0.008	-
	LEV		3751-5750	0.16	0.7	4.4	0.018	-
	ULEV		ALVW	0.1	0.4	2.2	0.009	-
	LEV		5751+	0.195	1.1	5	0.022	-
	ULEV		ALVW	0.117	0.6	2.5	0.011	-
	LEV	Full	0-3750 LVW	0.18	0.6	5	0.022	0.08
	ULEV		ALVW	0.107	0.3	2.5	0.012	0.04
	LEV		3751-5750	0.23	1	6.4	0.027	0.1
	ULEV		ALVW	0.143	0.5	3.2	0.013	0.05
	LEV		5751+	0.28	1.5	7.3	0.032	0.12
	ULEV		ALVW	0.167	0.8	3.7	0.016	0.06

42 U.S. Environmental Protection Agency. "Light-Duty Vehicle and Light-Duty Truck -- Clean Fuel Fleet Exhaust Emission Standards." http://www.epa.gov/otaq/standards/light-duty/ld-cff.htm. Accessed August 2012.

5.2 Key Decision Drivers

5.2.4 Original Equipment Manufacturers

Because SVMs convert OEM vehicles, any changes to OEM vehicle technology or availability have direct implications for SVMs.

All converted vehicles start life as OEM vehicles. The availability and convertibility of these vehicles is a key decision driver for SVMs. OEM changes to the vehicle directly result in the need for SVMs to obtain new certification (Figure 5.2.4-1). Moreover, any advancements in the OEM vehicle may increase development cost or create technical hurdles as is expect to be the case with the increased adoption of direct fuel injection and turbocharging on most gasoline engines.

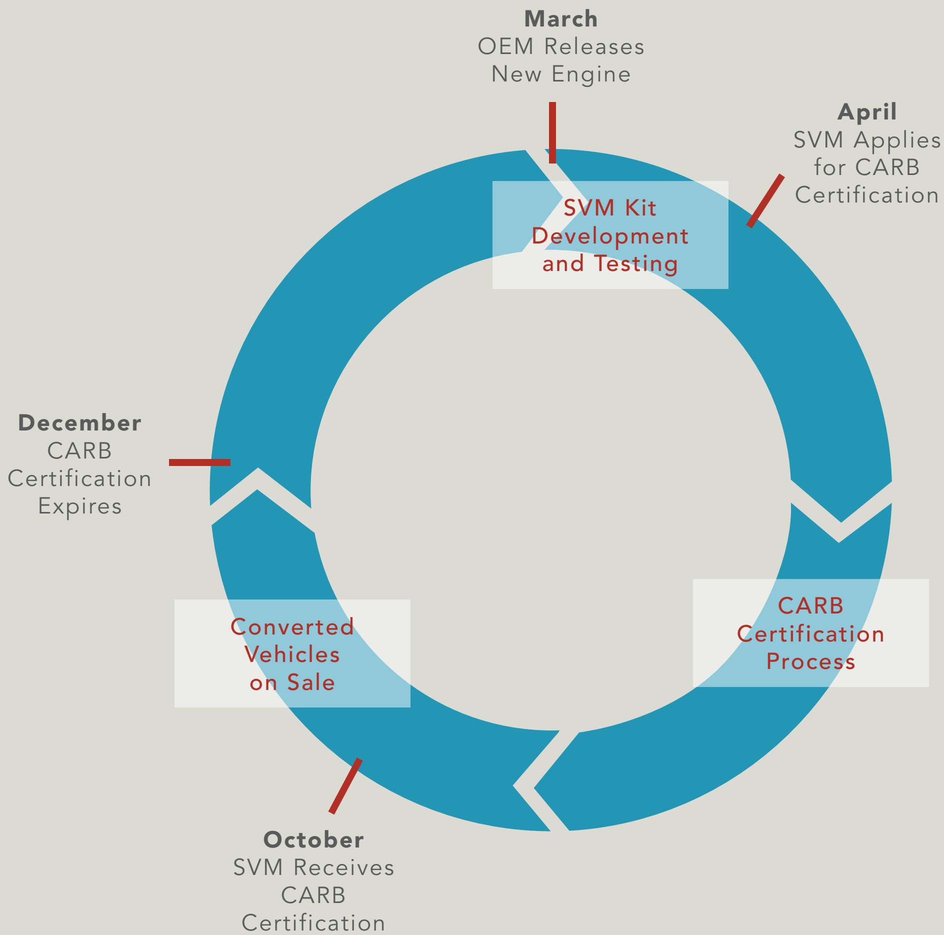
EPA and CARB certification is specific to a given engine and vehicle. For SVMs, this creates a need for engine control module (ECM) programming specific to each vehicle and engine. This ECM programming must be optimized for natural gas fuel to ensure acceptable drivability (e.g., the way vehicle behaves under acceleration and deceleration) and emissions. The ECM programming must cover very different driving conditions, including wide variation in temperature, air density, and payload. Further complicating this programming task is that OEMs consider ECM programming to be highly proprietary and thus provide no ECM technical assistance to SVMs.

If an SVM obtains certification for a vehicle and unexpected OEM updates create a new engine family, the certification will not carry over to the updated engine. For example, a converter that received certification for Ford's F-150 prior to an OEM engine update will need their customers to purchase the model year Ford F-150 manufactured before the engine changes took effect, while they test, await, and pay for certification for the new engine family.

Updates to an engine designed to burn gasoline generally do lead to similar improvements while burning natural gas. However, some of these changes add complexity for firms designing natural gas conversion kits. For example, as OEMs seek additional fuel economy gains, many are switching from port to direct fuel injection. The older system relies on injecting fuel into the engine's intake port at relatively low pressure (approximately 50 psi). Direct injection sprays the fuel directly into the cylinder at high pressure (approximately 2,000 psi). This poses a significant challenge for SVMs, who must develop new gaseous injectors and ECM programming to work with this new, more complex system. New technologies such as direct injection increase development costs for SVMs and could eventually lead to technical hurdles that SVMs may be unable to overcome.

Figure 5.2.4-1

This sample conversion timeline illustrates the important role of OEMs in setting timelines for SVMs.[43]



43 Based on actual timing related by SVMs in interviews.

5.3 Opportunities and Actions

5.3.1 Profitability

SVMs will continue to play an important role in the NGV market in the near term and thus ensuring SVM profitability, through reduced costs for EPA and CARB compliance, information sharing between OEMs and SVMs, and/or financial support for development costs, will help to sustain the NGV market in North America.

Overall, mainstream light- and medium-duty vehicle buyers will only accept OEM vehicles. Converted NGVs entail some compromises in durability, distribution, and service support. The vast majority of consumers will not accept these functional compromises nor do they need to, given the number of viable OEM alternatives. That said, SVMs have played an important role in the NGV rollout to date and will continue to do so as long as total market NGV volumes remain too low to justify greater OEM involvement. High development and component costs have challenged SVM profitability as these firms must recoup these costs over a relatively small number of unit sales. Furthermore, as long as volumes remain low, SVMs will be challenged to significantly reduce component costs. Ultimately, greater production volumes are needed to achieve greater economies of scale.

Reductions in development costs will help support SVM profitability and, through competition, also result in lower prices for customers. The cost to engineer, test, and obtain emissions certification is substantial for SVMs. Therefore, any progress with the EPA's proposed streamlined compliance procedures should help SVMs contain development costs. Similar moves by CARB would also help, particularly given the greater burden SVMs report regarding CARB regulations for obtaining CARB emissions certification.

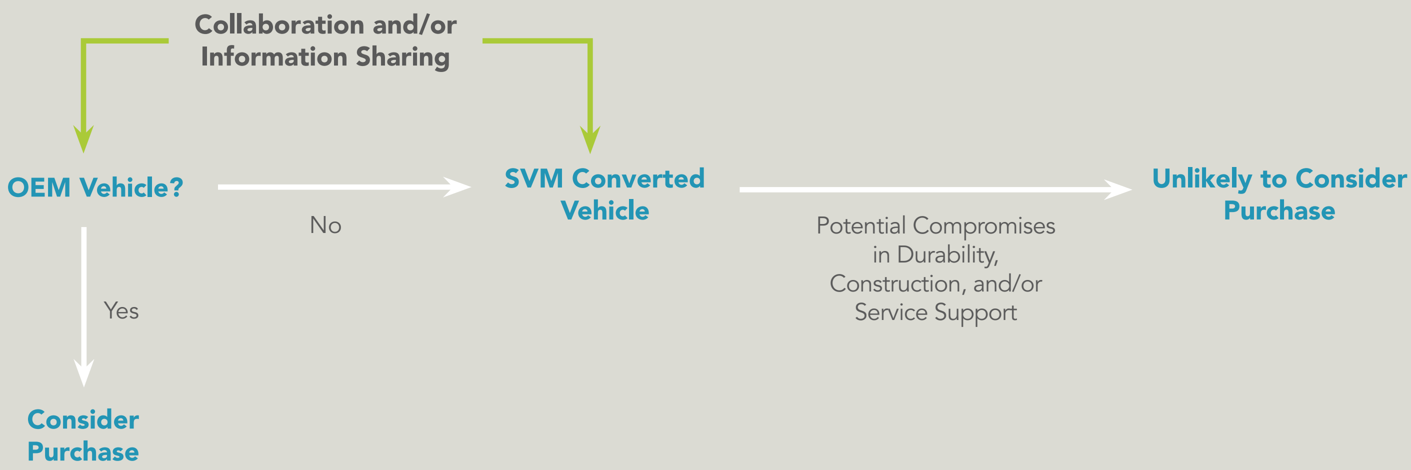
Greater sharing of information between OEMs and SVMs would undoubtedly reduce development costs for SVMs (Figure 5.3.1-1). However, given that OEMs consider this information to be proprietary, it is unlikely that they would acquiesce, particularly if they see no benefit to doing so.

Similar to OEMs, SVMs would benefit from grants or low-interest loans to help fund development costs. With their focus on NGVs, SVMs may be more likely to use funds on NGVs instead of other alternative fuel technologies, as the OEMs have reportedly done.

Ultimately, as long as volumes remain low, profitability will remain a key issue for SVMs. Should the NGV market increase dramatically in size, OEMs are likely to become the dominant players due to their greater size, distribution, and brand recognition.

Figure 5.3.1-1

For the mainstream light- and medium-duty customer's decision making process, greater collaboration and/or information sharing between OEMs and SVMs may result in NGVs that are more consistent with OEM products and thus more attractive.



5.3 Opportunities and Actions

5.3.2 Customer Demand

Actions that positively impact customer demand for NGVs, notably reducing vehicle payback time and increasing fueling infrastructure availability, will have the greatest impact on increasing SVM involvement.

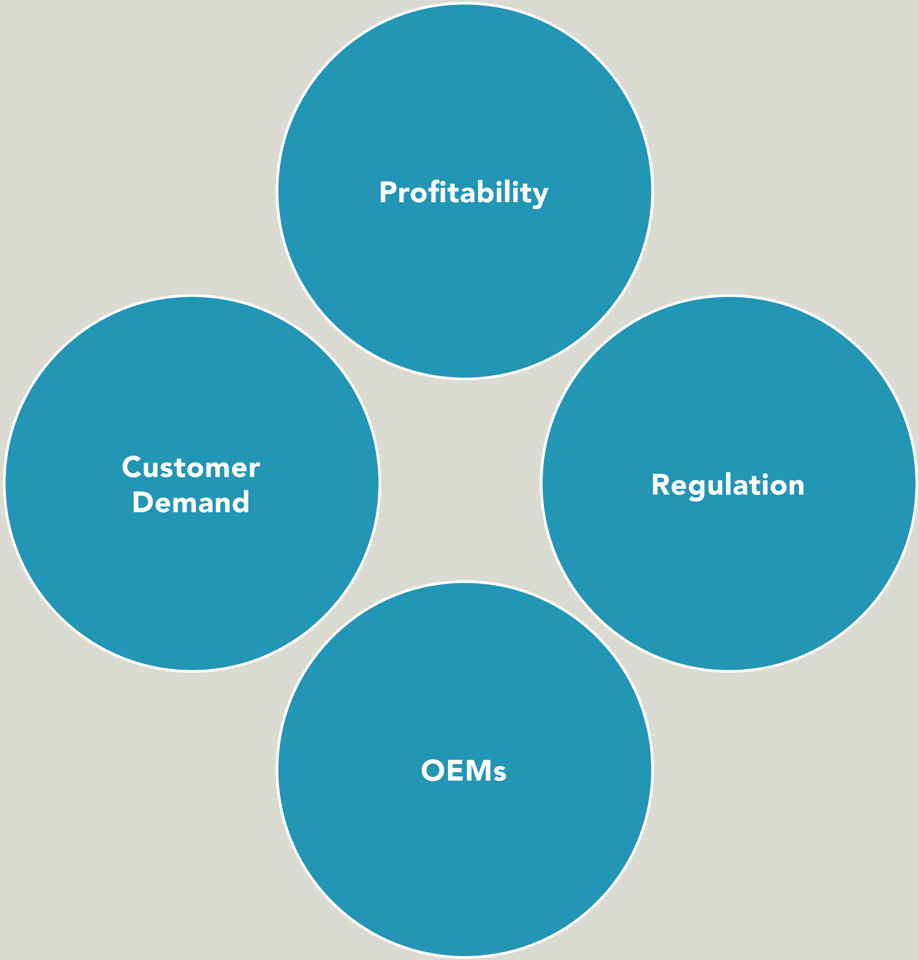
Increased customer demand would benefit all firms in the NGV space, including SVMs (Figure 5.3.2-1). Given the overwhelming focus on payback period and comparisons to gasoline vehicles, any action that reduces payback period for NGVs will increase demand.

For a limited number of fleets with heavy fuel usage, NGVs provide an economic incentive for purchase (a short payback period). Higher incentive levels to further shorten this payback period would stimulate customer demand and accelerate the process of achieving volume-based cost reductions for NGV components. Similarly, incentives on natural gas itself improve the payback period for NGVs, as will all alternative fuels.

The inherent dependence of dedicated NGVs on natural gas fueling stations has severely limited NGV demand. However, even in areas with a moderately developed base of natural gas fueling infrastructure, such as Southern California, NGV penetration is relatively low, in part because even in these areas, the natural gas infrastructure is truly convenient for only a limited number of customers. Use of bi-fuel NGVs would also help overcome this challenge, as these vehicles can utilize the existing gasoline infrastructure when natural gas is unavailable.

Figure 5.3.2-1

As with OEMs, one of the major decision drivers for SVMs is customer demand for NGVs, which is strongly influenced by vehicle costs and infrastructure availability.



5.3 Opportunities and Actions

5.3.3 Regulation

From a regulatory perspective, mandating complete FMVSS compliance for converted NGVs and offering an equal playing field for all alternative fueled vehicles may ultimately expand the market for NGVs.

SVM-converted NGVs are not required to demonstrate total FMVSS compliance. These regulations provide an advantage for SVMs that choose not to undergo this optional testing. By foregoing testing, these firms significantly lower their kit development costs, allowing them to be better positioned for cost-conscious buyers who do not value greater safety, or more likely, are unaware that not all NGVs have passed FMVSS. The downside of optional FMVSS testing is the increased risk of a safety incident that creates negative publicity for the entire NGV industry. SVMs that voluntarily meet FMVSS would benefit from required testing. The end result would be more expensive but ultimately safer and more OEM-like NGVs. It is unclear which of these courses of action would have the most positive impact on the NGV industry. However, with OEMs such as Ford offering "recommended" status for SVMs meeting specific standards (including FMVSS), the SVM industry looks to be moving toward more comprehensive FMVSS testing.

Previously, only dedicated light- and medium-duty NGVs were eligible for federal tax incentives (Table 5.3.3-1). Equal treatment of bi-fuel NGVs from a regulatory and incentive standpoint offers the promise of dramatically higher NGV sales. Several SVMs offer bi-fuel NGVs, which sell for nearly identical cost as their dedicated counterparts yet overcome the limitations of the current natural gas fueling infrastructure. When bi-fuel and dedicated NGVs were treated equally in the past, bi-fuel NGVs greatly outsold dedicated NGVs.

Table 5.3.3-1

As estimated for light-duty passenger cars, unequal government tax credit amounts for bi-fuel and dedicated NGVs result in dramatically unequal comparisons between the two types of vehicles.

	Incremental Cost	Eaxmple Tax Credits*	Net Incremental Cost
Dedicated NGV	$3,900	$4,000	–$100
Bi-Fuel NGV	$4,070	$0	$4,070

*As previously provided by the U.S. Qualified Alternative Fuel Motor Vehicle federal tax credit

This assessment was sponsored by America's Natural Gas Alliance with the support of participating American Gas Association companies.

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The opinions expressed within the Executive Summaries of Modules 1 and 2 of this market assessment are the work product of America's Natural Gas Alliance (ANGA) and participating American Gas Association (AGA) companies based upon data provided by TIAX LLC.

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