PikeResearch
Cleantech Market Intelligence

Research Report

Natural Gas Vehicles

Market Analysis and Global Forecasts for CNG and LNG Cars, Trucks, and Buses

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Section 1

Executive Summary

1.1 Key Market Issues

Natural gas vehicles (NGVs) have been available in many parts of the world at least since the oil crisis of the 1970s. Despite this long history, natural gas has yet to be universally accepted as an automotive fuel, and competes among an array of alternative fuels for “shelf space” on manufacturers’ product plans.

NGVs are available in the form of light duty (LD) passenger cars and trucks as well as medium and heavy duty (M/HD) trucks and buses. The market for NGVs is characterized by highly regionalized demand:

North America – Demand for NGVs in North America is largely relegated to the fleet market due to a lack of convenient refueling stations and factory warranties for NGVs sometimes voided or limited during conversion from petroleum-fueled vehicles. Given this, LD trucks, M/HD trucks, and M/HD buses represent the main NGV segments in the United States. NGV demand in the United States varies substantially by state, and is greatest in California, New York, Utah, and Oklahoma – states that also lead the way in terms of NGV infrastructure.

Latin America - Latin America is the second largest region for NGVs and home to two of the largest NGV markets in the world: Argentina and Brazil (combined, they account for 28% of total NGVs globally).

Western Europe – Italy is the largest European market, and Fiat, an Italian OEM, offers a variety of compressed natural gas (CNG) vehicles in Italy and other European countries. The European NGV market varies widely between countries, as many markets that have strong traditional vehicle sales have very low NGV sales (including Spain and the United Kingdom). Because much of the natural gas in Europe has to be either piped or shipped in, many countries have decided to support other alternative fuels or drivetrains.

Eastern Europe – Ukraine has experienced rapid growth in its fleet of NGVs, which rose from essentially zero nine years ago to now comprise the largest cumulative total number of NGVs in Eastern Europe (and Western Europe with the exception of Italy). However, Ukraine’s NGV growth has been sporadic, as its government has grappled with Russia’s gas supplier, Gazprom, over pipeline issues.

Asia Pacific – India has been heavily pushing NGVs for its transit fleets and now has one of the largest fleets of CNG buses in the world. The availability of stations and low-cost fuel is also spurring adoption of CNG vehicles within the passenger car market. Meanwhile, China, the region’s other large market, has been focused on using natural gas as an industrial energy source, and as a result has not seen as strong a development of NGVs. However, the country is now beginning to see movement toward CNG buses.

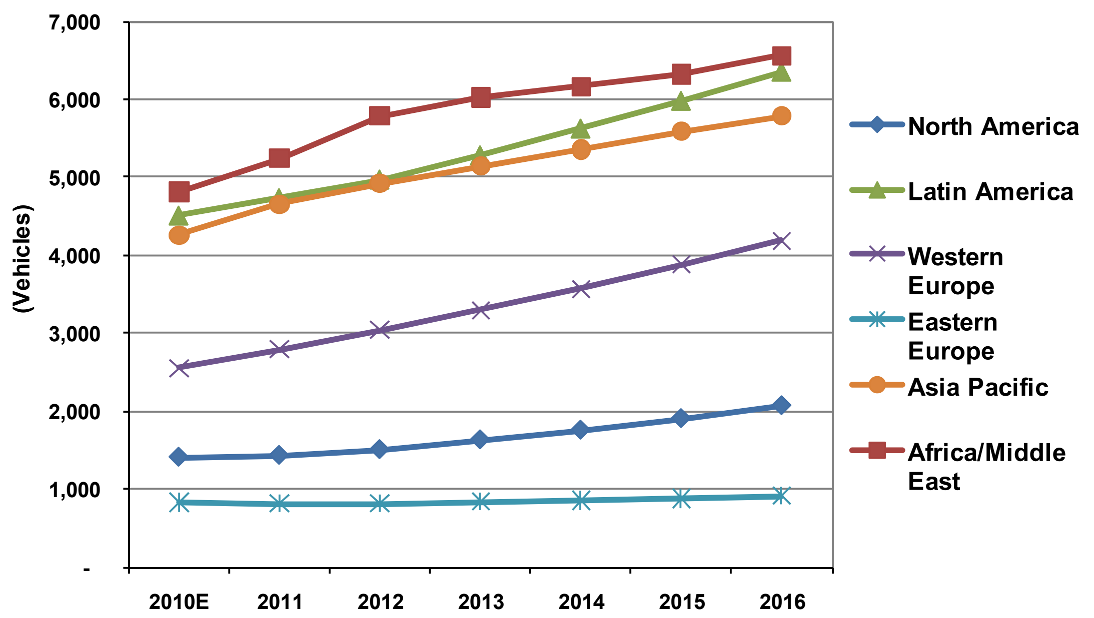
Middle East/Africa – Pakistan and Iran are the largest markets for NGVs. Neither country has a strong gasoline refining capacity; consequently, both have pursued NGVs to avoid the importation of gasoline. Pakistani NGV sales have led the world, but are volatile due to demand outpacing supply for natural gas and challenges in tapping existing natural gas sources.

1.2 Refueling Infrastructure Issues

Refueling infrastructure remains a key challenge for the NGV market. In regions where NGVs are widely available, long vehicle queues may form despite an apparently large number of refueling stations (the ratio of NGVs to stations may still be too high: the global average is currently 685 vehicles per station). Alternatively, in areas like the United States, the infrastructure remains comparatively limited, but is much more likely to support only specific fleets designed for shorter-distance driving (i.e., refueling locations all within a city). In North America, the focus has been on the fleet market, with the expectation that the consumer market will catch on once a sufficient number of stations are in place. This focus will bring 1,972 refueling stations online by 2016 (about 90 vehicles per station).

Bi-fuel vehicles represent one solution to current inadequacies in NGV infrastructure. Featuring two separate fuel tanks, these vehicles can run on either gasoline or CNG. This design is popular in Latin America where almost 90% of NGVs are bi-fuel vehicles, compared to 83% dedicated NGVs or dual-fuel vehicles in North America. A dual-fuel vehicle burns a small amount of diesel (typically about 5% to 10%) to ignite the natural gas in the engine cylinder.

Table 1.1 NGV Refueling Stations, World Markets: 2010-2016



(Source: Pike Research)

In general, NGVs are most likely to be CNG rather than liquefied natural gas (LNG), due to substantially lower equipment costs for CNG. Out of a current total of 1,327 natural gas refueling stations in the United States, only 60 or so are LNG. LNG is generally more appropriate for HD trucks as it permits the vehicle to carry more fuel; however, the equipment to keep the gas liquefied is both heavy and expensive.

1.3 Demand Drivers and Barriers

There are four almost universal key drivers in the NGV market:

- **Economics –** Because NGVs have an incremental cost above traditional vehicles, the fuel either has to be less expensive such that the owners break even quickly, or government incentives have to be available for purchase.
- **Environmental benefits –** NGVs have substantially lower emissions of GHGs, particulate matter, and NOx than gasoline or diesel powered vehicles. As governments look to reduce emissions from diesel engines and GHG emissions from LD vehicles, NGVs are seen as a tool to meet those requirements.
- **Energy security –** In most regions, the use of natural gas as a transportation fuel is viewed as a means to reduce dependence on imported crude oil or imported refined gasoline.
- **Availability –** Fuel, vehicles, and repair technicians must all be readily available or the market will not grow; this is the key reason the consumer market has failed to launch in North America.

Economics and availability are the key issues, particularly for the fleet market, though Pike Research's interviews reveal just as frequent mentions of the environmental benefits and energy security implications. Interestingly, these issues appear to be broadly acknowledged across many different regions.

While the U.S. Environmental Protection Agency (EPA), California Air Resources Board (CARB), and European Union have led the way in terms of emissions restrictions, governments of countries such as China and India have also recognized the need for reduced emissions. This often results in a focus on moving toward alternative-fuel-powered transit buses, refuse trucks, and delivery vehicles, including NGVs.

1.4 Market Forecasts

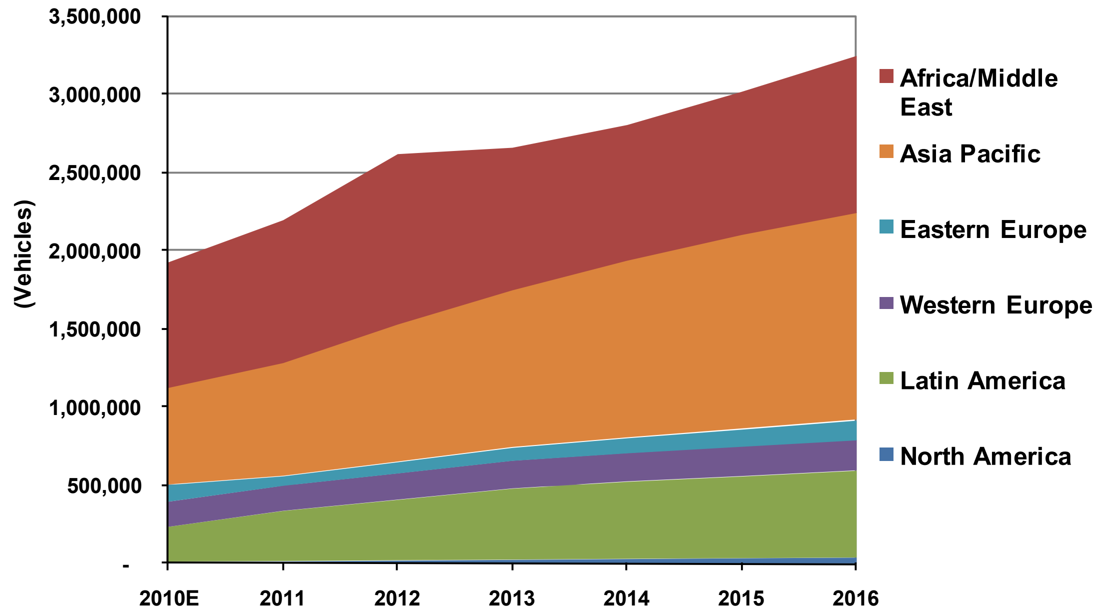
Overall, the NGV market will see strong growth between 2010 and 2016 with 9.1% compound annual growth rate (CAGR). The growth in vehicles will lead to growth in usage of natural gas for transportation fuel, which is expected to reach 19,123 million cubic meters of gas globally (6.7% CAGR between 2010 and 2016).

India is expected to overtake Iran for the lead in NGV sales in 2014, and will have a market of 612,389 NGVs in 2016 (12.0% CAGR). Despite some volatility in Pakistan and stagnation in the Iranian market, both Iran and Pakistan are expected to remain among the top NGV markets, and are projected to rank second and third, respectively.

China will see strong growth (20.8% CAGR) as NGVs spread in the fleet and consumer markets. However, as a whole, NGVs will remain a very small part of the market as China's government focuses its incentives mainly on automobile electrification.

The U.S. market for NGVs is expected to produce the strongest growth, with 25.4% CAGR between 2010 and 2016 resulting in 32,619 vehicles sold in 2016. The potential for new emissions regulations on both LD and M/HD vehicles and the passage of some form of the NAT GAS Act early in 2011 are expected to contribute to growth in the U.S. market.

Table 1.2 Annual Natural Gas Vehicle Sales (Including Conversions), World Markets: 2010-2016



(Source: Pike Research)

Section 2

MARKET ISSUES

2.1 History

While the use of natural gas in vehicles stretches back to the advent of the internal combustion engine (ICE), early natural-gas-powered vehicles were not very practical. The first ICE ran on natural gas in 1860. In the early 20th century, the vehicles required large bladders to carry the hefty amount of fuel necessary to travel a useful distance. In fact, practical NGVs did not surface until the 1960s. The oil embargo in 1973 and the price shock in 1979 caused the greatest interest in NGVs, both events spurring development as a means to conserve liquid oil fuel.

The growth of natural gas as a fuel for vehicles has varied by country. In Europe, natural gas was used for vehicles during World War II due to gasoline and oil shortages, but NGV development subsequently slowed in much of the region. While development in France and Germany began as early as the 1920s and 1930s and slowed significantly until the late 1980s, Italy saw steady growth that has accelerated more rapidly since the 1970s.

In 1986, the International Association for Natural Gas Vehicles (IANGV), a trade association, was formed. This was followed by the formation of the NGV Coalition in the United States in 1988 (which later became NGV America), and by the European NGV Association, which was founded in 1994. Japan, Australia, and New Zealand also formed NGV associations in the 1990s. These organizations helped to develop standards for gas producers and vehicle components, and to support legislation.

In Europe and South America, NGVs are more prevalent than in North America, in part because of the high cost of gasoline and the availability of refueling infrastructure. By the mid-1990s, multiple vehicles with engines powered both by gasoline and CNG were available in Europe from automakers.

In the United States, the 1973 oil embargo sparked interest in natural gas as an alternative fuel. In addition, concerns regarding urban pollution throughout the 1970s helped push the cause of NGVs. While auto manufacturers showed interest, the vehicles of the 1970s and 1980s in the United States were primarily conversions from gasoline-powered vehicles. Honda is one of the few automakers to continuously market a dedicated natural gas vehicle in the United States, offering the Civic GX since 1997.

2.2 Light Vehicles

Natural gas vehicles have developed at an uneven pace throughout the world, due largely to oil prices/subsidies and government policies – particularly for light-duty vehicles (LD -). Latin America, the Middle East, parts of Europe, and parts of Southeast Asia are widely accepting of light-duty NGVs, but the United States and Canada remain well behind the other markets.

Light-duty dedicated NGVs are almost exclusively fueled by compressed natural gas. The tanks for CNG take up more space than a traditional gasoline fuel tank for an equivalent amount of fuel. Because many vehicles are currently conversions from gasoline-fueled vehicles or designed from gasoline versions (such as the Honda Civic GX), the CNG tanks are added to a current vehicle's architecture. In cars, particularly small cars, the addition of a CNG tank reduces the amount of cargo space in a vehicle (tanks are often placed in the trunk). However, in countries where cars remain the dominant vehicle purchased by consumers (European and Latin American countries), CNG-powered cars perform well in the marketplace. Light-duty NGVs converted in other parts of the world are more likely to be wagons, vans, or small trucks – vehicles with the space to accommodate the new tanks with no substantial loss of utility.

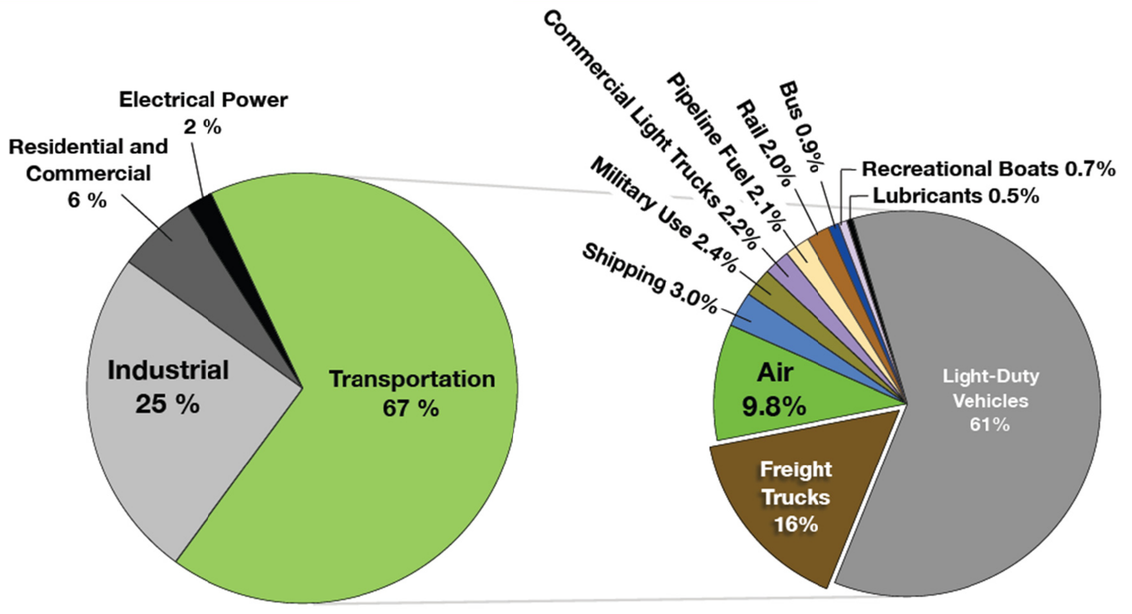
In many LVs, CNG tanks supplement gasoline tanks, as bi-fuel vehicle engines can run on both fuels. A gasoline tank in combination with a CNG tank increases the range of a vehicle and removes concerns about the availability of CNG filling stations; however, this set-up also comes at the expense of cargo capacity.

2.3 Medium- and Heavy-Duty Trucks/Buses

The architecture of large trucks and buses is well-suited for the tanks required for either CNG or liquid natural gas (LNG) storage. In addition, buses, refuse trucks, and delivery trucks with circuitous routes are good candidates for natural gas: With a set range of travel and a return to a central location, these vehicles require only a single refueling facility. Additionally, in the case of CNG, the refueling centers can often be of slow-fill design, alleviating the need for large tanks that store the natural gas at a compressed rate. While the slow-fill process takes additional time, a vehicle that sits unused through a shift could be a good fit.

Trucks and buses are a target for alternative fuel because of the large amounts of fuel they consume. The U.S. Energy Information Administration and the U.S. Department of Energy have estimated that over-the-road (OTR) trucks (commonly known as semi tractors) are responsible for consuming 10.7% of all the petroleum-based fuel used in the United States, while the Rocky Mountain Institute estimates that all freight trucking (including deliveries, refuse, OTR, etc.) consumes 16% of all petroleum, and buses consume 0.9%.

Figure 2.1 U.S. Petroleum Consumption by Sector: 2007

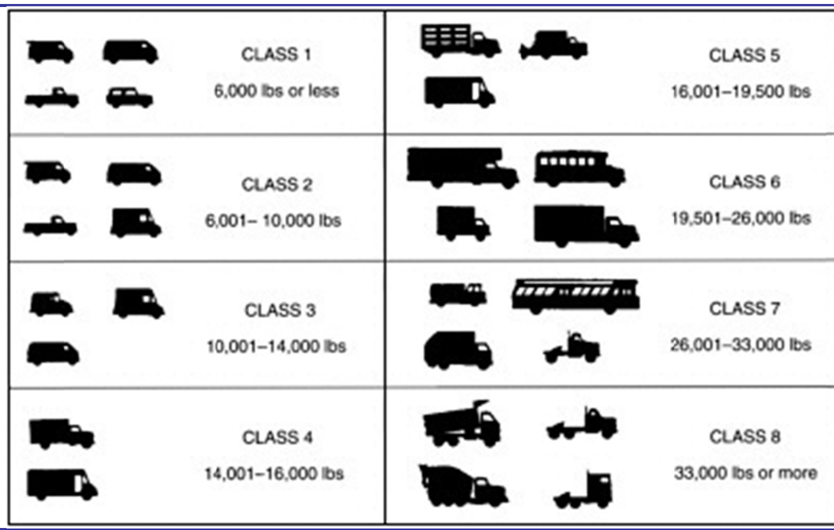


(Source: Rocky Mountain Institute, U.S. EIA)

2.3.1 Truck Class Definitions

In the United States, a truck can be classified by two methods: gross vehicle weight (GVW) rating, which measures the weight of the fully loaded truck, and equivalent single-axle load (ESAL), which measures the weight of traffic on the road. There are eight weight classes; for emissions and fuel economy regulatory reasons, however, class 2 trucks are divided into class 2A (less than 8,500 pounds) and class 2B (more than 8,500 pounds). While class 2A trucks are classified with light-duty vehicles, class 2B vehicles (which include pickups, SUVs, and full-size vans) are classified with the heavier truck classes 3 through 6 for emissions and corporate average fuel economy (CAFE) regulations.

Figure 2.2 United States Truck Classes



(Source: U.S. Department of Energy)

In Europe, vehicles are classified by the operator's license type, which corresponds with the U.S. GVW rating. This system creates essentially three main classes of commercial trucks for the purpose of emissions regulations: class N1 includes light vans under 7,765 pounds (3.5 tonnes); class N2 includes vans weighing between 7,765 pounds (3.5 tonnes) and 26,455 pounds (12 tonnes); and class N3 includes vehicles over 26,455 pounds. For passenger vehicles, the classifications are split by passenger cars, buses that hold more than eight passengers and weigh less than 11,023 pounds (5 tonnes), and buses that hold more than eight passengers and weigh more than 11,023 pounds.

Table 2.1 European Vehicle Classes

Vehicle Category	Vehicle Description	Weight
M1	Passenger cars	
N1	Light vans and trucks	Less than 7,765 pounds (3.5 tonnes)
N2	Midsize vans and trucks	7,765–26,455 pounds (3.5–12 tonnes)
N3	Large vans and trucks	More than 26,455 pounds (more than12 tonnes)

Vehicle Category	Vehicle Description	Weight
M2	Midsize passenger bus	More than 8 passenger seats and less than 11,023 lbs (less than 5 tonnes)
M3	Large passenger bus	More than 8 passenger seats and more than 11,023 lbs (more than 5 tonnes)

(Source: Ireland Road Safety Authority)

Chinese, Japanese, and South Korean commercial vehicle classifications are similar to that of Europe, but with additional classes for passenger cars based on their length.

For the purpose of this analysis, Pike Research considers the weight classes to be:

- Light-duty (LD): 8,500 lbs or less (Class 1 and 2A, European M1, N1)
- Medium-duty (MD) trucks/buses: 8,501 to 26,000 lbs (Classes 2B through 6, European N2, M2, some M3)
- Heavy-duty (HD) trucks/buses: 26,001 lbs. or more (Classes 7 and 8, European N3, some M3)

2.4 Natural Gas Supply

Natural gas is plentiful in areas where oil is also plentiful, but its availability extends beyond those countries and regions. The major producers of natural gas also include Russia, Canada, and the United States.

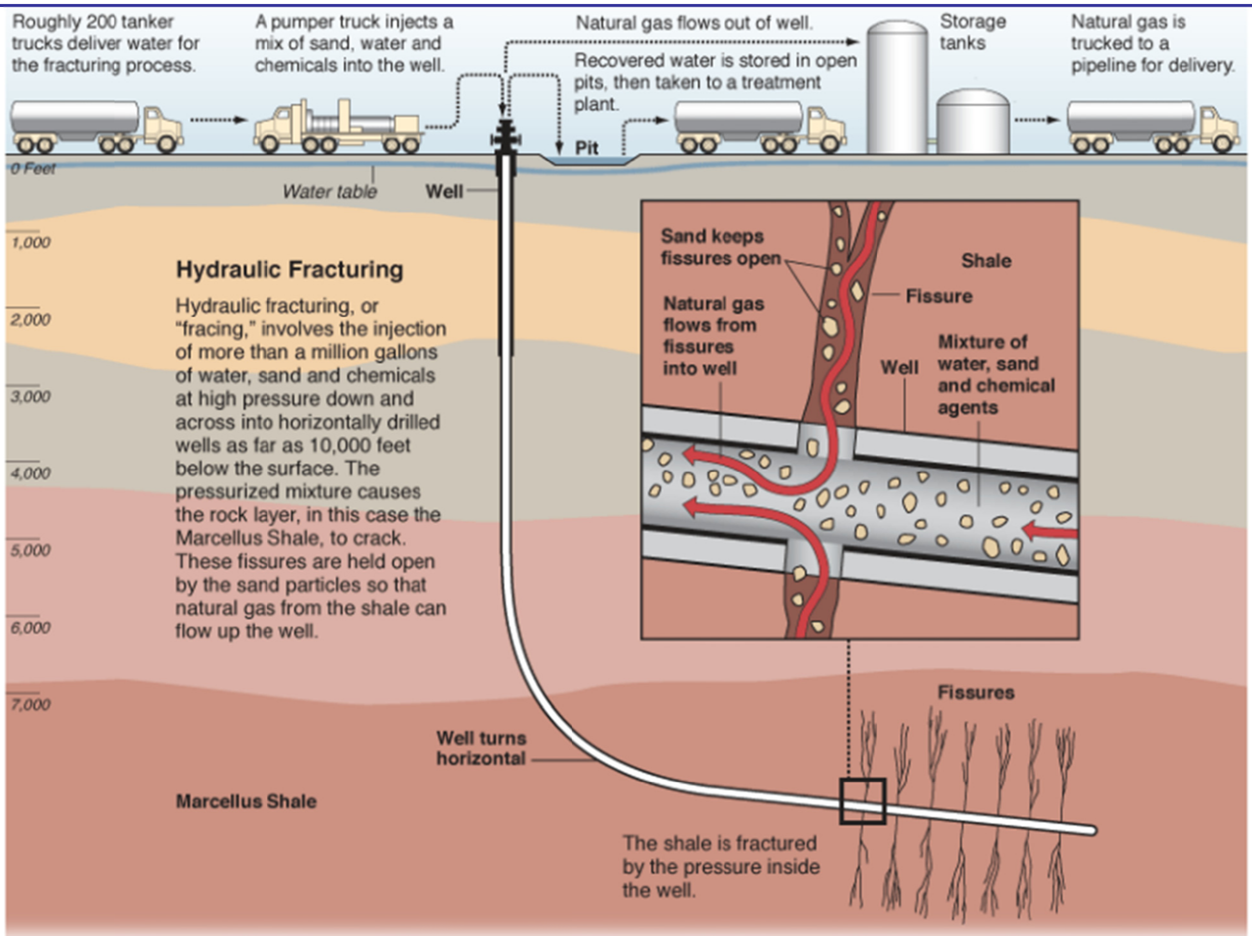
2.4.1 Gas Mining

Natural gas is considered the domestic fuel for the United States because the production of natural gas within the country is substantial (i.e., little is imported). Most of this gas is currently drilled from pockets in the rock bed below ground. Drilling for natural gas is an expensive prospect and requires a substantial investment for exploration, research, permits, environmental impact studies, and the actual production itself.

Shale is another important source of natural gas. Gas is trapped in the shale and is released by pumping water into the rock to cause it to crack (called hydraulic fracturing, Figure 2.3). This crack releases the gas. Shale gas is not as profitable for each well, but is also not as risky a proposition as traditional drilling since the gas is more likely to be found.

In recent years, some residents near hydraulic fracturing sites have claimed that the process has damaged the water table in the area. While safety concerns have not yet had a broad impact on gas production, they are likely to affect costs for some facilities in the long run. However, such concerns are not expected to result in a slowdown in production.

Figure 2.3 Hydraulic Fracturing Diagram



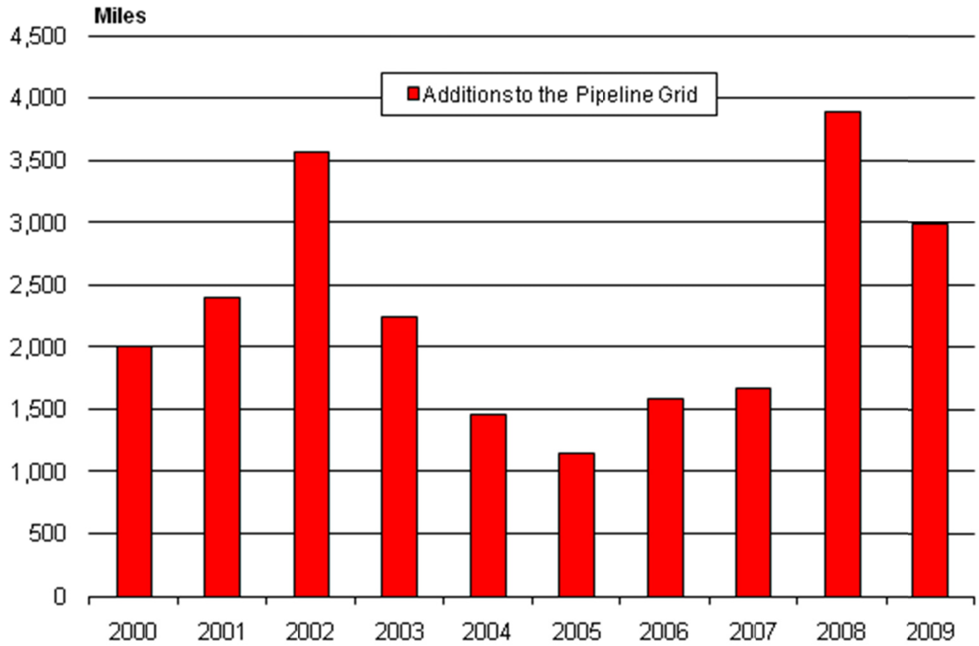
(Source: Propublica)

The Colorado School of Mines estimates that there is a total of 1,836 trillion cubic feet of natural gas in the United States, of which about 21% is from shale according to the International Energy Agency (IEA). Rice University's New Baker Institute estimates that the gas contained within shale in North America is enough to influence the world market, even though Russia is the largest producer of natural gas.

2.4.2 Transportation of Fuel

Once natural gas is extracted, there are essentially three ways to transport it to the end user: pipelines, trucking, or via ship. In 2008, the United States had substantial growth in its natural gas pipeline capacity. As the Energy Information Administration stated in its 2009 Natural Gas Year-in-Review, "Pipeline construction activity in 2009 was substantial, but declined from the exceptionally high pace of additions in 2008, when close to 4,000 miles were added to the pipeline grid…. Nonetheless, these projects added close to 2,988 miles of pipeline to the national natural gas pipeline grid and represented investment of about $9.9 billion." Yet, the growth of pipelines does not necessarily correlate with the growth of natural gas used as a transportation fuel because transportation uses less than 0.5% of the U.S.' total natural gas supply.

Figure 2.4 Natural Gas Pipeline Additions, United States: 2000-2009



(Source: Energy Information Administration, GasTran Natural Gas Transportation Information System, Natural Gas Pipeline Projects Database)

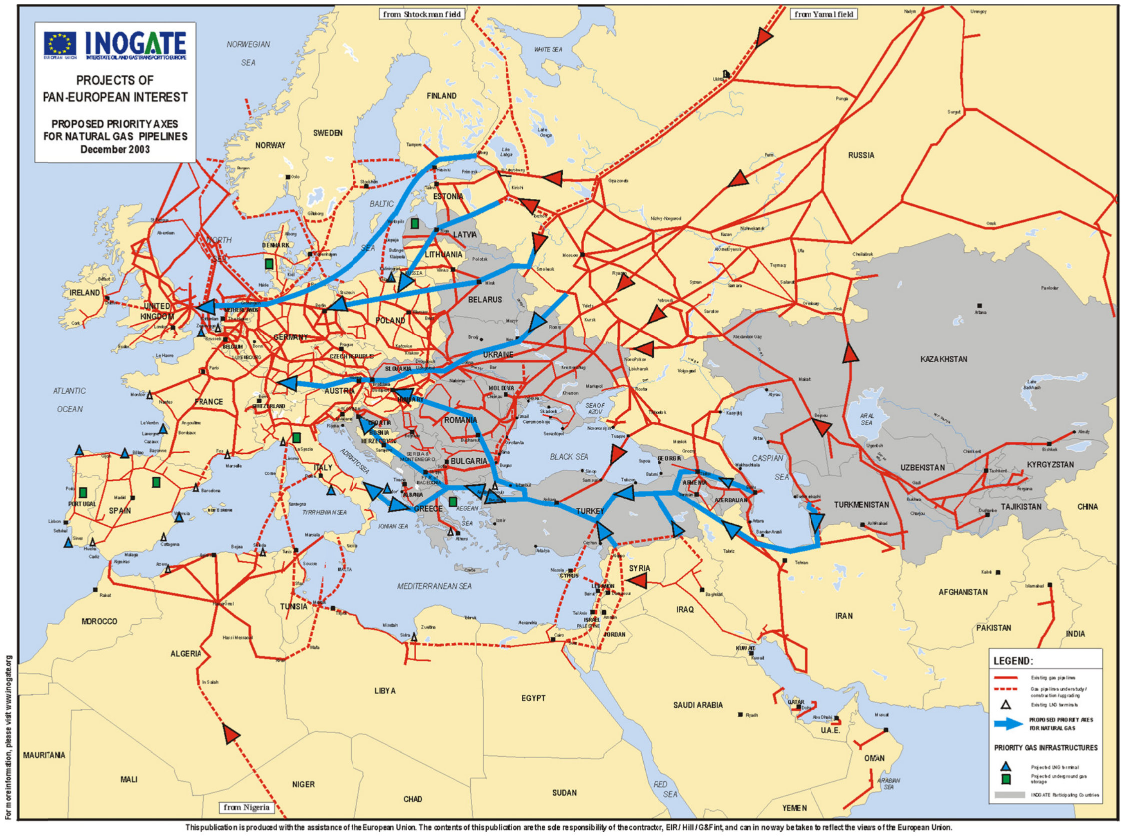
Outside of the United States, gas pipeline issues have much broader geopolitical implications. Much of Europe has traditionally relied on pipelines from Russia to supply between 25% and 50% of each country's natural gas (Figure 2.3). Russia is currently in the process of building two new pipelines – Nord Stream under the Baltic Sea and South Stream under the Black Sea (Figure 2.5) – both of which will circumvent pipelines through Ukraine to bring Russia's natural gas to the European markets.

In 2006 and again in 2008, Ukraine's gas company, Naftohaz Ukrainy, and Russia's Gazprom were involved in a pricing dispute that led Gazprom to limit the gas supplied to Ukraine pipelines. Given that much of the gas sold to Europe ships through pipelines in Ukraine (Figure 2.5), many countries saw shortages or price spikes. The politics of this issue are a subject for an entirely separate analysis, but the bottom line is that Russia is looking to reduce its reliance on Ukraine to reach European markets.

Russia and Germany are strong partners for the Nord Stream gas pipeline. Germany was instrumental in securing the financing and approval from the EU for the project. Gazprom is supplying the gas and will be the 51% controlling owner of the pipeline (the remaining share will be split by two German firms, BASF and E.ON Ruhrgas with 15% each, and other firms sharing the remaining ownership stakes).

The South Stream ultimately ends in Italy and has been cautiously opposed by the United States. In 2010, the pipeline received final approval and construction began. The United States has proposed a different pipeline, Nabucco (Figure 2.5), that would supply gas from outside of Russia; however, Nabucco has received little support from the EU and construction has not yet begun. The goal of the Nabucco pipeline would be to reduce the reliance of the European markets on Russia and Germany's resale of Russian gas, and subsequently reduce Russia's influence on world gas pricing.

Figure 2.5 Natural Gas Pipelines, Europe and the Middle East



(Source: INOGATE)

Figure 2.6 Russian and European Natural Gas Pipelines

(Source: International Energy Agency)

Figure 2.7 Projected Routes of Nord Stream, Nabucco, and South Stream Pipelines

(Source: Centre for Research on Globalisation)

The alternative to a pipeline is to truck or ship natural gas. By liquefying natural gas, the product can be shipped like other liquid fuels. During the Ukrainian gas crises of 2006 and 2008, many wealthier European countries began orchestrating LNG shipments to replace gas losses from the pipelines. Poland is currently building a large LNG receiving plant that will reduce requirements for Russian and German gas.

LNG is shipped in large, double-hulled tanker ships to ports where it is then stored, shipped by truck, and/or gasified and piped to its final destination. Ports that can accommodate large tanker ships have begun to experience growth in NGV usage.

2.4.3 Refilling Infrastructure Availability

One of the challenges often cited in research regarding the consumer market for NGVs is the lack of infrastructure for refilling NGVs. In the North American market, this lack of infrastructure stunted growth within the consumer market throughout the 1980s and 1990s. The consumer market for NGVs has flourished in regions where publicly available refilling stations have grown in number. In North America, Pike Research estimates 1,327 natural gas stations will be available at the end of 2010 (18,380 stations globally), compared to 161,768 gas stations in the United States available at the end of 2008, according to NPN Petroleum & Convenience.

There is a pervasive question as to whether the refilling infrastructure drives the marketplace for vehicles or if vehicles lead the infrastructure. (This question is more than just historical curiosity in regions like the United States that are working to develop a robust market for NGVs.) The consensus seems to be that the market for both infrastructure and vehicles has developed together. Often spurred by public investment in vehicles, infrastructure, or natural gas subsidies (or all three), the marketplace has grown in terms of both infrastructure and vehicle availability.

2.5 Regional Markets

2.5.1 United States/Canada Consumer Market

In the United States and Canada, the consumer market for NGVs is very small when compared to traditional-fueled vehicles. In fact, it is anticipated that the consumer NGV market will consist of approximately 1,423 vehicles in 2011 (a miniscule amount when compared to the overall U.S. vehicle market of 12,134,941 in the same year).

The low number of NGVs sold to consumers is due largely to the lack of availability of vehicles through dealers (i.e., without aftermarket conversion). In many cases, aftermarket conversion can void the manufacturer's warranty (or parts of it). Additionally, in many parts of the country, consumers are unlikely to have access to convenient refueling stations.

Within the United States, sales of NGVs are very regional, largely because of the availability of natural gas infrastructure. California, New York, Utah, and Oklahoma are the states with the greatest number of refueling stations. However, Eastern states are also adding stations at a faster rate, with Massachusetts and New Jersey adding stations (11 and 10, respectively) at about the same rate as Utah and Texas (12 stations each). Massachusetts and New Jersey are seeing interest in NGVs for use in their ports and their refuse and transit companies. Meanwhile, California leads the nation in new NG refueling station activity, adding 27 in the last year.

In Canada, NGVs are not currently mass-marketed; thus, consumers have to seek a converter that will adapt their vehicle from a gasoline engine to run on CNG (again, this may void parts of the OEM warranty). In the United States, one major manufacturer offers a CNG vehicle as original equipment: Honda, with its Civic GX. Additionally, as in Canada, many conversion companies offer conversions for different vehicles; yet the majority of these vehicles are marketed toward commercial and government fleets rather than consumers.

Table 2.2 NGV Stations by State, United States: 2010

State	Number of NG Stations	Δ from 2009	State	Number of NG Stations	Δ from 2009
California	244	27	Wyoming	9	-2
New York	100	7	Louisiana	7	-1
Utah	72	12	Alabama	6	0
Oklahoma	50	0	Maryland	5	2
Arizona	41	-3	Rhode Island	5	-1
Texas	33	12	South Carolina	5	0
Illinois	25	2	Arkansas	5	2
Pennsylvania	24	1	Tennessee	4	0
Colorado	23	4	Montana	4	0
Massachusetts	22	11	New Hampshire	3	0
New Jersey	20	10	Alaska	3	0
Georgia	18	0	Dist. of Columbia	2	1
North Carolina	16	4	Kansas	2	1
Wisconsin	16	-2	Mississippi	2	0
Washington	15	0	North Dakota	2	0
Connecticut	14	5	Vermont	2	0
Florida	14	1	Delaware	2	1
Michigan	14	1	Maine	1	0
Oregon	12	0	Minnesota	1	0
Virginia	12	1	Nebraska	1	0
Nevada	11	0	West Virginia	1	0
Ohio	11	2	Hawaii	1	0
Indiana	10	-2	Iowa	0	0
Idaho	9	1	Kentucky	0	0
Missouri	9	0	South Dakota	0	0

(Source: U.S. Department of Energy)

Table 2.3 Natural Gas Refueling Stations by Province, Canada: 2010

Province	Number of NG Stations
Ontario	33
British Columbia	22
Alberta	12
Saskatchewan	10
Quebec	3
Other Provinces	0

(Source: Canadian NGV Association)

2.5.2 North American Fleet Market

While the consumer NGV market remains very small in the United States and Canada, the North American NGV fleet market is growing. Fleet demand for NGVs is expected to see a compound annual growth rate of 25.2% between 2010 and 2016 (Pike Research anticipates that all fleet sales will see 3.3% CAGR in North America over the next seven years). Although this represents a strong growth figure from a percentage standpoint, NGVs are not expected to compose a significant portion of the overall fleet market. Specifically, NGV sales to fleets are expected to reach 10,981 in 2011; this compares to a total fleet market of 3,472,970vehicles. Many of the vehicles sold will be heavy-duty trucks and buses used by government and commercial fleets.

The NGV industry has been targeting fleets in North America since the infrastructure requirements are not nearly as onerous as trying to develop a consumer market. The vehicles sold to fleets are generally dedicated CNG/LNG vehicles, though many are dual-fuel vehicles that incorporate diesel. Fleets can often justify setting up a refilling station to serve their NGVs, particularly in operations where natural gas is used for other purposes such as forklifts or generators. Such operations are often related to large institutional fleets – transit agencies, airport or seaport operations, large delivery services, waste services, and gas companies, for instance – with an existing infrastructure. Gas companies are one of the largest proponents of NGVs, and often have refilling stations available at their facilities.

2.5.3 Latin American Market

Latin America is home to two of the largest NGV markets in the world: Argentina and Brazil (combined, they account for 28% of total NGVs globally). Regardless, the market remains relatively small compared to other vehicles and regions (anticipated Latin American sales in 2010 amount to 224,827NGVs – including conversions). These sales are in large part conversions of flex-fuel vehicles using technology developed by Bosch and Magneti Marelli. Fiat and Honda also currently produce CNG vehicles for the Latin American market, and many of these are bi-fuel vehicles. Other manufacturers, including General Motors, Toyota, Kia/Hyundai, and Nissan also have dedicated or bi-fuel CNG vehicles in Latin America.

2.5.4 European Market

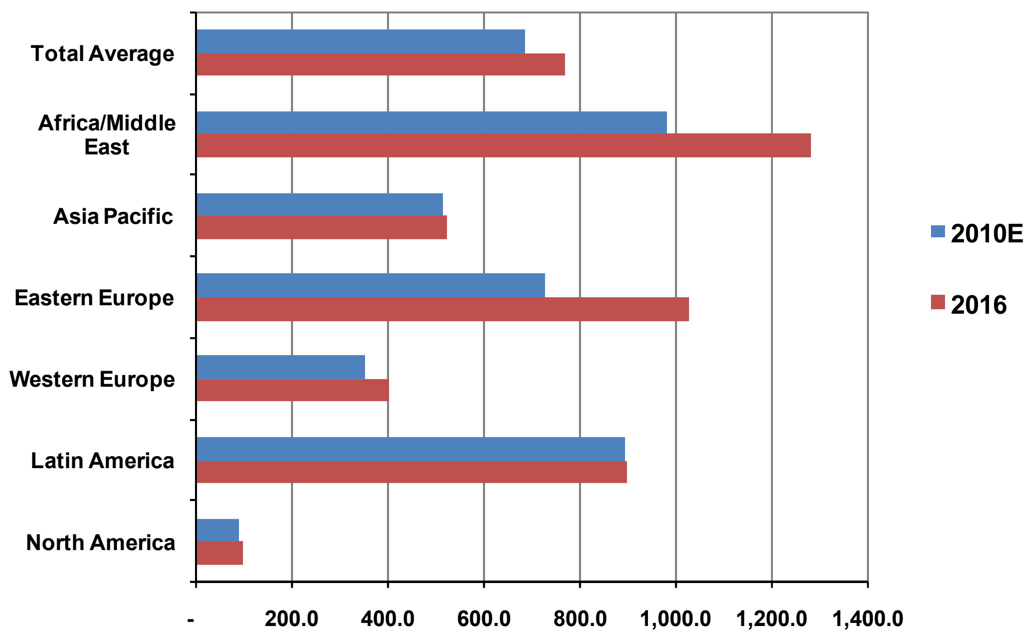
Government policies have helped drive the NGV market in many European countries. Italy has the largest number of NGVs on the road (746,020 expected by the end of 2010), followed by Ukraine, Russia, and Germany (154,869, 104,707, and 90,184 NGVs, respectively, by the end of 2010). Italian automaker Fiat is one of the largest manufacturers of OEM NGV systems, and many of these are bi-fuel vehicles.. However, Volkswagen, Citroen, Saab, and Opel also offer NGVs in the European markets.

As in the United States, a variety of natural gas-fueled buses and M/HD trucks are used in Europe, particularly in Eastern Europe (254,951 natural gas M/HD buses and trucks are expected in 2010). These vehicles are used for transit, delivery, refuse, airport, and seaport operations.

The European NGV market varies widely between countries. While Italy, Russia, Ukraine, and Germany are large NGV markets, other countries with a substantial volume of traditional vehicles are not. For example, the United Kingdom, Spain, and France are comparatively small NGV markets (294, 2,539, and 12,450 vehicles, respectively, at the end of 2009) and have not seen substantial growth over the last several years; these are mainly fleet markets with very little consumer demand or access to fuel. Additionally, a lack of abundance of domestic natural gas in the United Kingdom and Spain are likely to keep those markets small, particularly as electric vehicles and hybrids become more widely available.

Ukraine has seen substantial growth in NGVs during the last few years. Within the last nine years, the country has gone from zero NGVs to having one of the largest cumulative totals of NGVs. This is largely due to the fact that Ukraine is essentially awash in natural gas, thanks to pipelines moving the fuel from Russia to the Western European market. In 2006 and again in 2008, disputes with Russia's major gas company Gazprom resulted in natural gas pipelines being cut off (please refer to Section 2.4.2 for more details on this dispute and pipelines in Ukraine). During these years, sales of NGVs were stagnant; however, the country returned to strong growth in 2009, with the number of NGVs rising 67% from 2008 to reach 200,019. Because of the weak economy and the contract with Gazprom, Pike Research anticipates that Ukraine will remain a volatile market for NGVs. The refueling infrastructure is currently lagging for the number of vehicles (892 vehicles/station, compared to 409 in Russia and 352 in Western Europe), and this will impact sales. In addition, infrastructure growth in Ukraine is expected to be modest because of the weak economy.

Chart 2.1 Number of NGVs per Refueling Station, World Markets: 2010, 2016



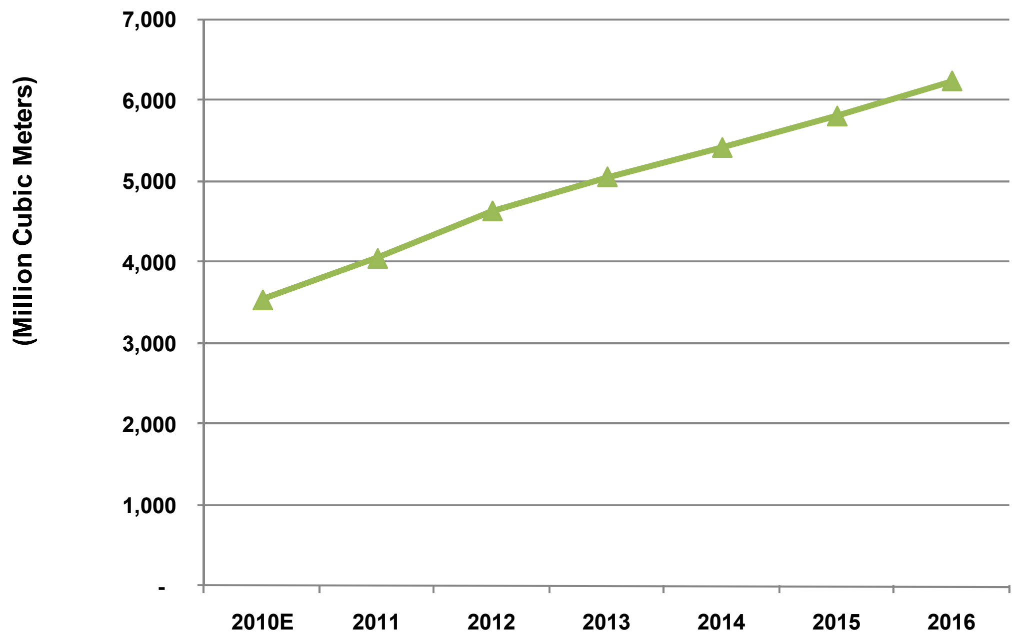
(Source: Pike Research)

2.5.5 Africa/Middle East Market

Two of the world's largest NGV markets are located in the Middle East: Pakistan and Iran. Both countries have come to compose large NGV markets because of an abundance of natural gas and the ability to use it as fuel with little to no refining. Iran, which has a large crude oil supply, uses its natural gas as a transportation fuel due to country's limited refining capabilities. Thus, Iran can sell more of its crude oil for a profit. Iran is expected to have 2,013,104 NGVs by the end of 2010, which will rank it second, just ahead of Argentina (1,832,796 NGVs). It was estimated in 2006 that up to 18% of the world's supply of natural gas is located in Iran.

Pakistan has the largest NGV market, with a projected 2,560,629 NGVs on the road by the end of 2010. CNG is a domestic fuel for Pakistan, whereas oil generally has to be imported. There are some concerns that Pakistan will start to see natural gas shortages after 2012 due to transportation usage, and the country has begun to investigate the importation of LNG.

Chart 2.2 Natural Gas Used for Transportation Fuel, Pakistan: 2010-2016



(Source: Pike Research)

Pakistani political support for CNG as a transportation fuel has been strong as the government looks reduce foreign imported oil and cut emissions. The Pakistani government has cut tariffs on imported CNG equipment and supported low-cost loans to build refueling stations. Additionally, conversion kits for vehicles have become much less expensive over the past few years.

Africa does not have a strong NGV market. Egypt is the region's largest market, with 119,679 NGVs in 2009 (approximately the size of the U.S. NGV market); the rest of the region has only fleet programs, resulting in about 250 NGVs spread across the continent.

Similarly, Egypt has 119 refueling stations for natural gas, but outside Egypt there are only eight stations on the whole continent of Africa, according to the IANGV.

2.5.6 Asia Pacific Market

In Asia Pacific, natural gas has only recently been used for transportation. Growing concerns regarding pollution in some of Asia's largest cities have helped drive an interest in NGVs. India has led the way thanks to a lawsuit that resulted in a 1998 ruling from the Supreme Court of India that said all transit buses had to be NGVs. While the ruling required natural gas to be used for transit buses by 2001, the court was not pleased with the progress and pushed for greater conversion in 2002.

Since that time, pollution restrictions in India and other countries have pushed the market for NGVs in Asia. As a result, India is expected to have 647 natural gas refilling stations by the end of 2010 to serve the projected 1,028,500 NGVs in the country (approximately 1590 vehicles per station in 2010).

China recently completed a second pipeline for natural gas, and has invested heavily in the construction of refueling stations (with an anticipated 1,550 stations by the end of 2010). However, the country is more likely to continue to use natural gas for industrial and heating purposes. Gasoline and diesel fuel remain similarly priced to CNG; thus, little economic incentive exists for consumers to use CNG as a transportation fuel. As a result, China's NGVs are largely in the bus and heavy-duty truck segments (accounting for 36% of the 496,000 NGVs in 2010), and bus manufacturers have been moving forward with natural gas buses as that market grows in China.

The Chinese government has focused much of its legislative and incentive attention on electric vehicle (EV) production, and several Chinese manufacturers have announced EV programs for domestic and export markets.

Other countries in Asia are following the pattern of first growing their fleet and transit NGV businesses and then promoting the consumer market. In the case of Australia and New Zealand, many cities now have natural gas-powered bus systems. The Philippines has maintained a small fleet of buses (36 vehicles) for several years with an inadequate refueling infrastructure (only three stations).

2.6 Current Market Opportunities and Barriers

As was the case in Pike Research's 4Q 2009 report, those Pike Research interviewed in locations with a substantial build-out in natural gas refueling stations remain very optimistic about the opportunities for NGVs. In the United States, for example, many are optimistic about the NGV market in the Southwest and Northeast. Other parts of the country will see growth, but in much more modest terms.

Internationally, optimism is also very regional. In parts of the world where NGV infrastructure and fleet markets are already well-established (the Middle East, South America, and parts of Western Europe), those we spoke with seem confident that the market for NGVs will continue to grow. In other regions, much smaller-scale growth is expected given that the expensive infrastructure is not yet in place. While this offers an opportunity for new refueling station growth, it also presents the stalemate often seen from the "chicken or the egg" dilemma: whether stations or vehicles should come first in a region. In North America and other regions with low NGV penetration, this takes the form of a lagging consumer market while governments and fleets look to build infrastructure based on the economic model of cheap fuel for their vehicles.

2.6.1 Private Ownership

In most countries with strong consumer sales of NGVs, private ownership is predominantly driven by economics. Natural gas is cheaper than gasoline or diesel, and cars can be converted or purchased without a substantial increase in the price of the vehicle. In some developing markets (such as China), vehicles can easily be converted to natural gas at home for relatively little cost. In North America and Europe, private ownership is also driven by a desire to reduce one's environmental impact. However, the refueling infrastructure is critical to the development of the private consumer market. Many fueling stations remain closed to private consumers, and are used only for fleet services (this is likely due to the type of refueling system at "fleet only" stations). In fact, some estimate that as many as half of the refueling stations in the United States are not open to the public. While home refueling has been pursued, it has not seen the level of success expected in Europe or North America (please refer to Section 3.3.1.1. for more details on the current state of home refueling appliances).

2.6.2 Conversion versus Original Equipment NGVs

The line between conversion and original equipment (OEM) NGVs is somewhat blurred: Many manufacturers utilize conversion companies to provide an NG engine conversion. In other words, GM may not make an NG version of the Express Work Van, but has an upfitter convert it prior to shipping the vehicle to the Chevy dealer. Thus, the conversion to NGV is invisible to the final customer.

In regions where OEM NGVs are widely available, the quality of the NGV is considered generally higher than an aftermarket conversion. The electronic components of an NGV engine can be tricky to manage to ensure that the engine is running most efficiently with the new fuel, and a poorly tuned NGV that fails to properly regulate fuel in the engine can negate much of the environmental benefit of using natural gas. However, many governments require that conversion systems be certified for the engines they are used with to make certain that they provide the full range of benefits.

2.6.3 Fuel Costs

One advantage of natural gas is that, due to a much greater supply, its cost is lower than gasoline or diesel. Additionally, many governments subsidize the cost of natural gas in an attempt to shift demand from traditional fuels. The United States' fuel taxes are substantially lower than those of other countries, and natural gas taxes in general match the gas and diesel taxes. The NAT GAS Act includes an additional incentive of a refund of the natural gas fuel taxes. The most recent refund expired at the end of 2009 and is not expected to be reinstated because fuel prices for CNG (in gallon gas equivalents (GGE)) are significantly lower than the cost of a gallon of gasoline.

For LPG, the per-gallon price tracked by the DOE is $2.85 (as of October 2010); however, most fleets are buying LPG in bulk, which significantly lowers the cost. In addition, most refueling stations price their fuel based on bulk pricing. On average, bulk pricing of LPG lowers the price between 80 cents and $1.00 per gallon depending on the location (Table 2.4). The cost recovery calculations in Table 3.1 assume bulk pricing for the LPG fuel.

Because CNG and gasoline are pumped in different ways (one is a liquid and the other a gas), and because they have different energy levels, it takes more CNG fuel compared to gasoline to travel one mile. There are two ways to compare the cost of CNG to gasoline: either by the GGE, which is the cost to produce the same energy as one gallon of gasoline, or by cost per mile.

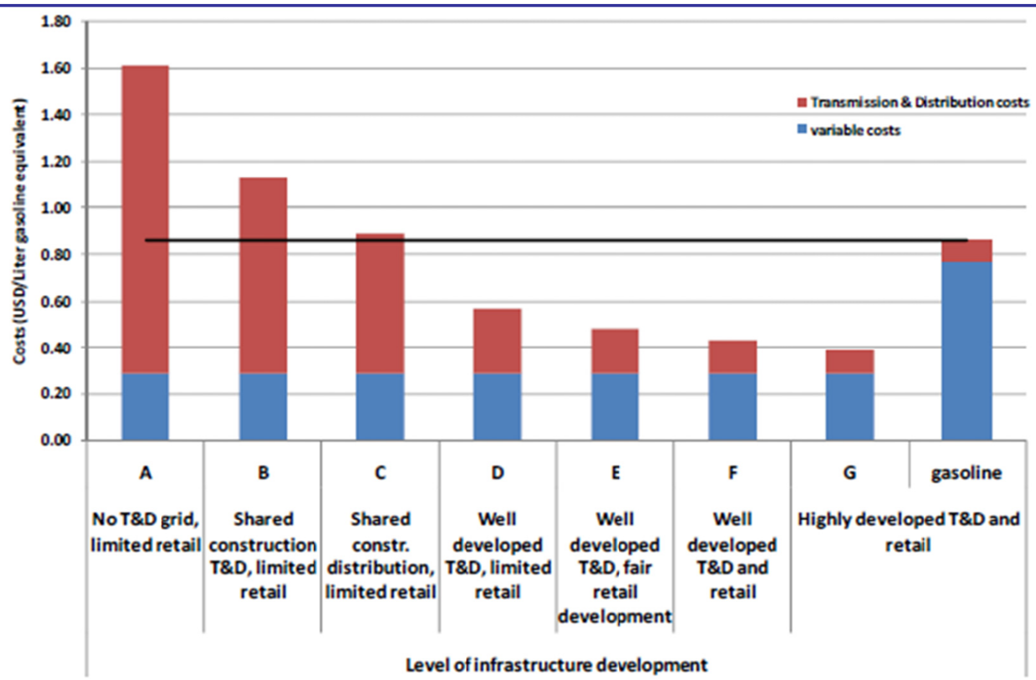
Table 2.4 Cost of Natural Gas Compared to Other Fuels

	CNG	Gasoline	Ethanol (E85)	Diesel	Biodiesel (B20)	LPG
Fuel Cost (in GGE, Oct. 2010)	$1.95	$2.78	$2.44	$3.07	$3.14	$2.85 $1.88 (Bulk)
Fuel Cost per Mile	$0.083	$0.111	$0.132	$0.113	$0.073	$0.127 $0.086 (Bulk)

(Source: U.S. Department of Energy, Alternative Fuels and Advanced Data Center)

The cost of natural gas as a vehicle fuel can vary from region to region, depending on the level of development of the gas grid and retail networks. The International Energy Agency (IEA) found that when compared to the price of gasoline, the favorable prices for CNG were dependent on the level of infrastructure development. The IEA identified several different scenarios of development. While not explicitly stating the particular countries that fell within a given scenario, it appears that the United States would be categorized as either scenario D or E (Chart 2.3), while parts of Western Europe and the Middle East could be viewed as scenario F or G. The IEA concluded that "…in principle, natural gas is cheaper as a fuel, but gasoline benefits from the position that it built up over the course of many decades."

Chart 2.3 Costs of CNG versus Gasoline in Different Scenarios of Transportation & Distribution Grid Development



(Source: IEA)

2.6.3.1 *Performance versus Diesel/Gasoline Engines*

The BTU rating of natural gas is lower than that of gasoline, meaning it is unable to produce the same horsepower as gasoline in the same engine. Yet, the octane level of natural gas is higher; thus, the spark can ignite the fuel more quickly. Basically, this relationship means that an engine has to be specifically designed for natural gas to achieve the full benefit of the fuel. Such a design includes increasing the compression within the piston cylinder and advancing the spark.

Because natural gas has a lower BTU rating, it takes longer for the fuel to burn in the piston cylinder (it ignites faster, but burns longer). By advancing the spark to ignite the fuel while the piston is still traveling up the cylinder, the fuel has more time to burn completely and push the piston back down at its most efficient point. Since the octane level is so much higher than in gasoline, the compression can be substantially higher, providing an increase in horsepower (gasoline engines typically have compression of 9:1 to 11:1, whereas NGVs can have compression of 12:1 to 14.7:1). Without these changes, the vehicle will not have the power necessary for strong acceleration (like climbing hills or merging onto a freeway).

In M/HD truck applications, large diesel engines are designed for very high compression (often with a compression ratio of up to 25:1), making them well-suited to the higher octane of natural gas. Therefore, medium/heavy-duty NGVs can provide similar power to that of diesel-fueled engines.

2.6.3.2 *Maintenance on NGVs versus Diesel/Gasoline Engines*

Overall, NGVs have numerous components that are similar to those of a traditional vehicle; therefore, the majority of maintenance costs will be comparable between the two types of vehicles. Brakes, shocks, air conditioning, and electric systems are very similar and require similar maintenance; however, oil changes and spark plug changes are not likely to be required as often for NGVs. In the large diesel engines, there are no requirements for the urea tank exhaust scrubbers, meaning there is no need to replace the urea routinely. Meanwhile, some M/HD trucks are now likely to have spark plugs that will require maintenance.

2.7 Competing Technologies

Nearly unanimously, interview respondents for this report indicate that alternative fuels all compose part of the solution, and note that there is no single “right” fuel to replace gasoline or diesel. Depending on the application and the needs, however, natural gas already plays a larger role in the transportation arena than other alternative fuels in some regions.

2.7.1 Other Alternative Fuels

A wide variety of alternative fuels exist, and availability depends on the region. In Europe and Asia, diesel is used in passenger vehicles because it costs less than gasoline. Additionally, its higher efficiency provides better fuel economy than gasoline. In Latin America, gasohol (100% ethanol) is a widely used alternative fuel, and ethanol mixed with 20% gasoline is considered a standard fuel rather than an alternative in Brazil. Meanwhile, due to its abundance, coal gasification is being explored in China specifically as a transportation fuel. In North America, E85 (85% ethanol) and propane are used as alternative fuels in some regions.

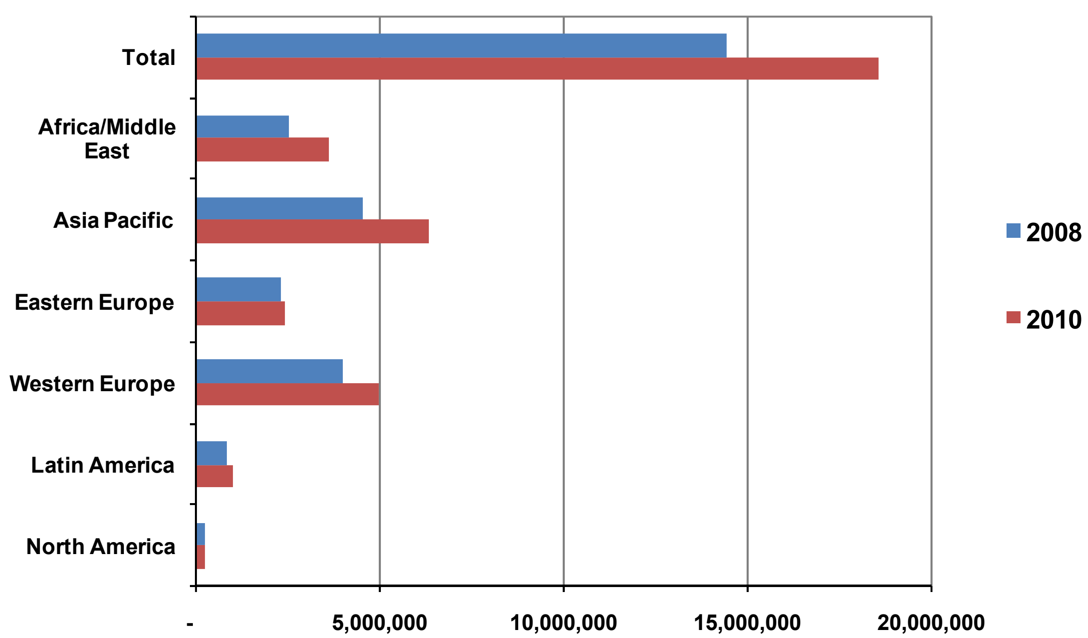
2.7.2 Liquid Petroleum Gas (LPG)/Autogas

Propane or LPG (or autogas as it is called in Europe) is widely available and used in Europe and the Middle East as a vehicle fuel. It has properties similar to that of natural gas: it must be stored in pressurized tanks and is typically gasified before being injected into the cylinder to be ignited by the spark. As with natural gas, LPG is often used in bi-fuel vehicles in Europe. However, because it must be stored in pressurized tanks, LPG is not available with CNG on multi-fuel vehicles. LPG is much more widely available in Europe and the Middle East than natural gas, and many view the two fuels as competing.

The main reason that LPG is more widely available is that its associated costs are lower than for natural gas, particularly for refueling infrastructure. In fact, upgrading an existing fuel station to LPG can cost as little as $20,000, depending on availability of the land. As a result, there are about three times as many LPG refueling stations as NGV stations.

Overall, the market for LPG is focused in many of the same areas as natural gas, with the major exception of some key South American markets. In South America, the availability of natural gas and the focus on ethanol in Brazil and Argentina have largely left LPG non-existent in these markets.

Chart 2.4 Number of LPG Vehicles, World Markets: 2008, 2010



(Source: World LP Gas Association, Pike Research)

2.7.3 Hydrogen

Hydrogen is an interesting replacement for gasoline due to its high chemical efficiency compared to gas, its lack of emissions, and its abundance. There are essentially two methods for using hydrogen in vehicles: burning it in an ICE or using fuel cells to generate electricity to power an electric motor. In both cases, the process essentially emits only water, making it attractive when measuring vehicle emissions. Most major automakers have hydrogen fuel cell programs, with Honda having the only “production” vehicle (the FCX Clarity), which is available for lease in Los Angeles for $600 per month.

Natural gas is considered by many to be a “gateway” fuel to the hydrogen economy. The infrastructure for both CNG and LNG refueling stations is very similar to that of a hydrogen refueling station. Many believe that if the infrastructure is in place for NGVs, the switch to a hydrogen fuel will be much easier and less expensive. Similar to natural gas, hydrogen boils at -252.9°C (natural gas boils at -160°C) and must be vented as it boils off. Mixed with CNG, hydrogen is already being used as a fuel (HCNG) in some areas, helping to reduce the amount of CNG used without suffering a loss in performance.

2.7.4 Hybrid and Electric Vehicle Technologies

Hybrids (HEVs), plug-in hybrids (PHEVs), and electric vehicles (EVs) use electricity for power in some way. Every segment of the vehicle market has experienced at least some testing of hybridization, and several plug-in electric vehicles are now reaching the market in both passenger and M/HD truck form. Toyota has sold its market-leading Prius since 1997, and almost every major manufacturer now has an HEV, PHEV, or EV in development (if not already commercially available).

Vehicle uses that are most amenable to both the current NGV infrastructure situation and EV design are those with a set route that return “home” – where they can recharge or refuel. Those interviewed for this report, however, remain skeptical that hybrid or EV HD trucks and buses can deliver the same combination of range and environmental benefits offered by NG buses or trucks. Consequently, many fleets view electric vehicles and NGVs as tools for different types of jobs. NGVs are generally considered better-suited for:

- Long range requirements (over 100 miles)
- Those groups that must meet EPACT requirements (i.e., government fleets) or are looking to move away from gas or diesel for other reasons
- Areas with an existing natural gas infrastructure

The major drawback to plug-in electric vehicles involves cost; lithium-ion batteries are currently the cost drivers, but are expected to drop in price during the next couple of years as additional manufacturing plants come on line. As the batteries’ expense decreases, the appeal of EV and PHEV options is expected to increase substantially in developed nations, though this will likely be at the expense of gas and diesel powered vehicles rather than NGVs.

2.7.5 Fuel Cell Advancements

In 2003, President George W. Bush announced the Hydrogen Fuel Initiative (HFI), which was followed by legislation to help develop infrastructure and technology to make fuel cell vehicles more practical by 2020. A great deal of research continues, but there is no consensus as to when fuel cell technology will be cost-effective for the consumer vehicle market. Automakers signed a memorandum of understanding that states they will bring fuel cell vehicles to market by 2015. However, these vehicles are unlikely to be cost-competitive with gasoline or NG vehicles for many years.

Fuel cells remain promising as a very clean and consistent source of electricity to power vehicles, and the development of these vehicles continues at both the university level and among major automakers. However, big hurdles remain, including cost and the hydrogen refueling infrastructure to power the fuel cell. Many within the natural gas refueling market assert that natural gas infrastructure is a precursor to hydrogen infrastructure.

2.8 CNG/LNG Handling Training Issues

NGVs do entail some special training for maintenance and repair. Several organizations provide specific NGV repair training for technicians. While many components of NGVs are similar to those of other vehicles, the specialty parts for the pressurized or thermos tanks, fuel lines, and ECUs require specialized knowledge.

NGV refueling stations also necessitate specialized training. Because methane gas does not behave in a similar fashion to gasoline in a leak, there are specialized training programs to help station operators understand how to work with the fuel. These training programs also help operators (and drivers) understand how the refueling systems work, as well as how to safely remove LNG fuel from a vehicle.

Section 3

TECHNOLOGY ISSUES

3.1 Chemical Characteristics of Natural Gas

Natural gas consists largely of methane (CH_4). Methane burns with lower energy, which means that more fuel is required to generate the same amount of energy as gasoline or diesel. However, because it only contains one carbon atom for the four hydrogen atoms, compared to diesel's sixteen carbon atoms ($C_{16}H_{34}$), natural gas emits far less carbon monoxide and carbon dioxide. According to the U.S. DOE, natural gas reduces greenhouse gases by 21% to 26% over gasoline engines.

Table 3.1 Properties of Natural Gas Compared to Other Fuels

	Gasoline	Ethanol (E85)	Diesel	CNG	LNG	LPG
Physical State during Storage	Liquid	Liquid	Liquid	Gas	Liquid	Liquid
Octane Number	87-93	100–105	N/A	120	120	110
Boiling Temperature (°F)	80-450	173	360-600	N/A	-259	-44
Auto-Ignition Temperature (°C)	250	363	254	460	460	450
Lower Heating Value (BTUs)	115,400	75,670	128,700	19,760	76,300	81,000
Non-methane Hydrocarbons		12% increase[a]		50%-75% increase[a]	50%+ reduction[b]	>40% reduction[a]
Methane		91% increase		400%+ increase[a]	400%+ increase[a]	
Carbon Monoxide Emissions		18%-20% reduction[a]		90%-97% reduction[a]	90%-97% reduction[b]	30% reduction[a]
NOx Emissions		20%-55% reduction[a]		35%-60% reduction[a]	35%-60% reduction[b]	40% reduction[a]
Particulate Matter Emissions		33% reduction[a]		~100% reduction[a]	90% reduction[b]	~100% reduction[a]

[a] Compared to a traditional gasoline engine in a similar vehicle
[b] When tested in a dual-fuel diesel engine

(Source: U.S. Department of Energy)

When natural gas is drilled or recovered, it must be cleaned of contaminants before it is pure enough to use as fuel. These contaminants, including oil, water vapor, hydrogen sulfide, and carbon dioxide, can corrode tanks and fuel lines and prevent the fuel from burning efficiently in engines (or homes).

3.1.1 Liquefied Natural Gas

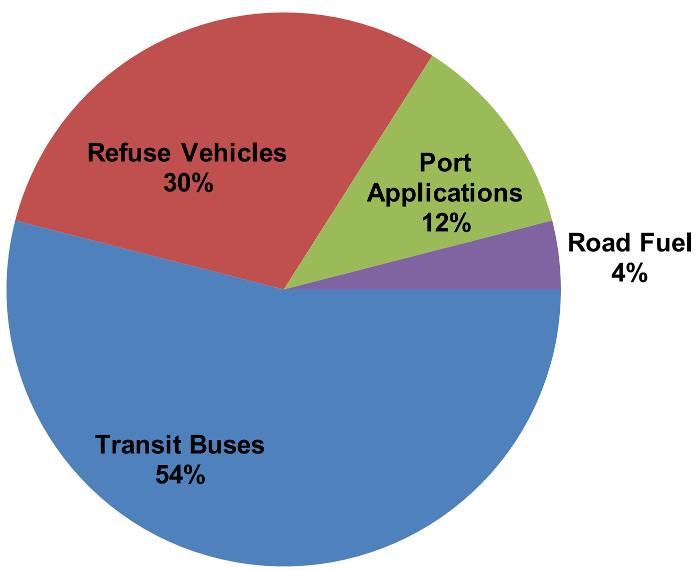
Natural gas is gaseous methane at room temperatures; it must be super cooled to -259°F (-160°C) to be liquefied. The gas does not take up as much "space" when in a liquid state: LNG occupies about 1/600th of the space of non-compressed natural gas and about 30% less space than CNG. Consequently, LNG can fit more fuel in the same amount of space as a CNG.

LNG vehicles have what essentially amounts to advanced thermoses for fuel storage tanks. These vacuum-sealed tanks hold the cold temperatures required for LNG, but must also be vented to avoid a build-up of pressure as the fuel warms up and begins to vaporize. Therefore, one of the drawbacks of the LNG system is the boiling off of fuel over time; depending on the size, the tank will be completely empty in a matter of days. Additionally, the vapors that are vented off are methane, a greenhouse gas.

The natural gas has to be vaporized before it can be injected into the combustion chamber. Thus, an LNG-fueled engine requires additional equipment to return the natural gas to a gaseous state without causing too great an increase in the pressure and losing too much fuel to venting. Combined with the large tanks, this additional equipment typically adds more weight to a vehicle than a comparable CNG system.

The applicability of LNG is hindered by the limited number of refueling stations offering LNG; the United States, for example, has approximately 60 LNG stations – and only a handful of these are open to the public. For the most part, LNG is used by fleets with a "hub and spoke" type design, where the vehicle returns to a central refueling point; very few vehicles are able to use LNG for OTR fuel.

Chart 3.1 Usage of LNG, United States: 2010



(Source: International Energy Agency)

3.1.2 Compressed Natural Gas

Natural gas that is at room temperature in gaseous form can be compressed to about 250 bar pressure (3,600 pounds per square inch) to increase the amount of fuel a vehicle can carry. If the gas were not pressurized, the fuel would be too bulky to carry. Since CNG is already in a gaseous state, it can be used in its current state in the engine, which reduces the amount of equipment required on the vehicle (compared to an LNG vehicle). CNG engines require a pressure regulator to control the pressure of the gas entering the engine.

3.1.3 Biogas

Biogas is methane produced as a byproduct of the breakdown of different organic materials. Sources include biomass, manure, sewage, landfills, or other waste facilities. Once it is produced and the impurities cleaned out, biogas can be treated like any other natural gas. Because plants use CO_2, it is often considered a “carbon neutral” fuel: After the biogas is burned, the CO_2 emitted by the vehicle is used by plants that will then be made into fuel.

Biogas is still in the early stages of development, and is therefore very expensive to produce. Several biogas plants operate in the United States, and these essentially use landfill gas to fuel trucks or to be pumped into the natural gas pipeline. For its part, Sweden has invested heavily in biogas production and is considered on the leading edge of the technology. According to the Swedish Gas Association, biogas composed 58% of the natural gas used as transportation fuel in Sweden at the end of 2008, or approximately 2% of the total fuel used by its vehicles for 2008.

3.1.4 Propane (Liquefied Petroleum Gas)

Propane is derived from natural gas and petroleum refining. While liquefied petroleum gas (LPG) or autogas is almost all propane (C_3H_8), a small amount of butane (C_4H_{10}) is mixed in. This fuel is still considered low-carbon because it has significantly fewer carbon atoms than diesel’s 16. While the ratio of propane and butane may vary by season (with more propane used in winter months), it is composed of no less than 90% propane and 2.5% butane.

The boiling point for propane is low (-44°F), resulting in fuel that is easily gasified for combustion. However, this also means that LPG has to be compressed to store a large enough volume for vehicles to use effectively. LPG tanks typically are compressed to between 22 and 25 bar (about 360 psi). At this pressure, the fuel will liquefy within the tank, and tanks are typically filled to about 80% to 85% capacity (depending on the ambient temperature) to leave room for vaporization.

3.1.4.1 LPG Infrastructure

Compared to other alternative fuels, including natural gas, the infrastructure requirements for LPG are relatively simple. Propane tanks can easily be filled and transported and do not require a pipeline. A tank of LPG can be delivered on a truck and a fueling station can be set up for as little as $25,000. Because of this low cost, many fleets and gasoline stations have found they can inexpensively convert gasoline pumps to LPG pumps. In addition, propane does not degrade over time.

3.2 NGV Engines

There are essentially two types of natural gas vehicle engines: one for CNG and one for LNG.. However, the differences between the two are in terms of fuel storage – not within the engines themselves. Both CNG and LNG engines require a spark to ignite the fuel in the combustion chamber; hence, the engines for gasoline, CNG, and LNG look similar.

Diesel engines are also often converted or designed to run natural gas. However, diesel fuel ignites in the combustion chamber due to pressure and not spark. As a result, a diesel engine has to be modified to use a spark ignition with natural gas.

In most regions, NGVs are designed to be capable of running on two types of fuel (most often a combination of gasoline and natural gas). For example, vehicles in Brazil can run on CNG, gasoline, 20% ethanol, and 100% alcohol (sometimes called tetra-fuel vehicles). (Note that most traditional vehicles in Brazil can run either ethanol or 100% gasoline – even though most driven within the country only use fuel that is an ethanol mix.)

3.2.1 Dedicated Mono-Fuel Engines

"Dedicated" NGVs are vehicles that accept only natural gas as a fuel. These may be either CNG or LNG vehicles, but use no gasoline or diesel fuel. Many heavy-duty vehicles now being produced are mono-fuel LNG or CNG vehicles.

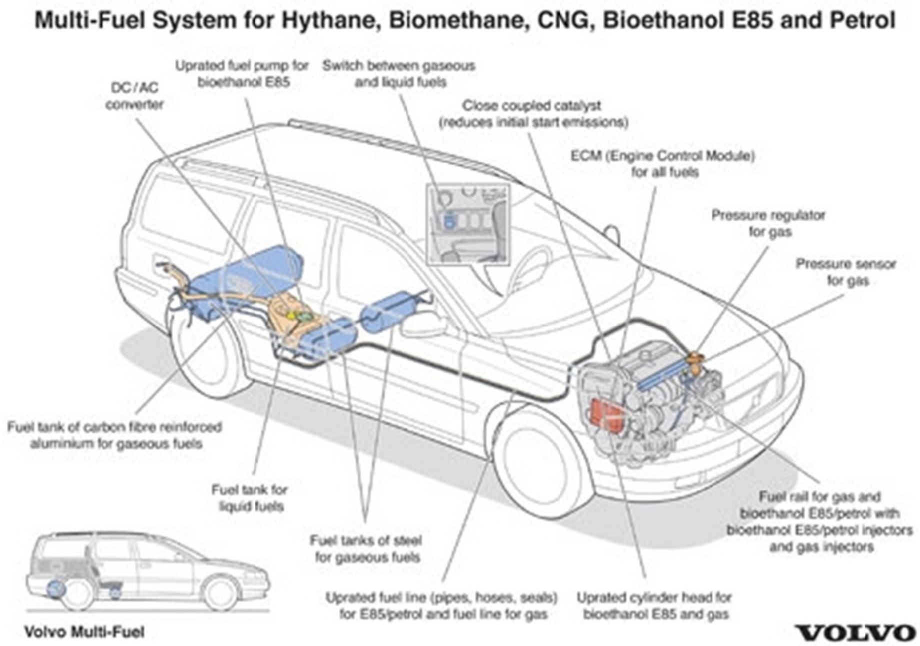
The main advantage to mono-fuel vehicles is the simplicity. There are fewer components to the vehicles, a reduced complexity in the engine control unit (ECU), and no need for electronic equipment to switch fuels. This helps to maintain a lower overall cost than for bi-fuel vehicles. The main disadvantage for mono-fuel NGVs is the range in light-duty vehicles. Because CNG tanks take up much more physical space in a vehicle than a traditional gasoline fuel tank, the range is lower in LVs where space is at a premium. LNG allows for the storage of more fuel in the same space as a CNG; therefore, the range is greater. However, LNG tanks are larger overall and more equipment is required for the purposes of venting the tanks and using the fuel. Consequently, LNG is more often used with heavy-duty vehicles given their capacity for larger tanks.

3.2.2 Bi-Fuel Engines

Bi-fuel NGVs have separate tanks for the natural gas and the gasoline or ethanol. In this design, the vehicle can switch over to traditional fuel after exhausting the supply of natural gas. This process can be accomplished via a switch on the vehicle's dashboard or through automatic electronic switching. Modern designs allow the switch to occur while the vehicle is running, and can be nearly imperceptible to the driver.

Bi-fuel vehicles offer an expanded driving range over mono-fuel NGVs, and can eliminate users' fears of being stranded between natural gas refueling stations. Largely due to the decreased size of the fuel tank, CNG cars for the most part cannot achieve the same range as their gasoline or diesel counterparts. By providing smaller tanks with both types of fuel, the range can reach that of a traditionally fueled vehicle. However, a bi-fuel vehicle still benefits from reduced emissions and reduced fuel costs because a portion of the driving is fueled by CNG.

Figure 3.1 Bi-Fuel Vehicle Diagram



(Source: National Alternative Fuels Training Consortium)

3.2.3 Dual-Fuel Engines

Dual-fuel engines are similar to bi-fuel engines in that they contain two fuel tanks. Instead of spark ignition systems, dual-fuel engines use a small amount of diesel fuel in the combustion chamber to ignite, and natural gas is then injected into the chamber and ignited by the diesel.

Dual-fuel engines produce substantially lower levels of emissions than traditional petroleum-fuel vehicles since they burn less diesel. Unlike bi-fuel engines, however, dual-fuel engines will always consume a little bit of diesel to generate the ignition. Dual-fuel engines may run burning 100% diesel or switch over to use 5% to 10% diesel in the ignition chamber (often running more than 90% on natural gas).

3.2.4 OEM Prepared Engine Conversions

Ford and General Motors in the United States have started to offer engines that are prepared for conversion to NGV. While marketed differently, the concepts are the same. In Ford's case, the engine is ordered as an option package (91G) – as an engine prepped for vehicle conversion to CNG or LNG. Often for the end customer, this may be transparent and appear to be simply ordering a NGV from the dealer. The engine is ordered and then the vehicle is sent out for conversion to NGV before the customer sees the vehicle. However, Ford is not marketing these as NGVs per se. In GM's case, the vehicle is marketed as an NGV and ordered from the dealer as a complete NGV. However, in reality the GM factory is prepping the engine before sending the vehicle to a pre-selected converter (Productive Concepts International).

In most cases, OEM NGV engines are similar to their gas or diesel counterparts (e.g., a 6.0L V8 gasoline engine is similar to a 6.0L V8 CNG engine). In addition to different fuel systems (pressurized tanks, lines, pressure regulators, etc.), NGV engines themselves will often have some different parts since natural gas burns at a much higher temperature than either diesel or gasoline. The internal engine components that are revised are done so to maintain the durability of the engine while burning natural gas.

Table 3.2 Engine Components Typically Upgraded by OEMs

Engine Component	Upgrade
Piston Rings	Harden for higher temperatures
Valves	Harden with tungsten and/or nickel for higher temperatures
Valve Seats	Harden with tungsten and/or nickel for higher temperatures
Transmission	Reprogrammed for different power curve
Pistons	In some cases, piston designs may be revised for higher compression rates

(Source: Pike Research)

Aside from the components noted in Table 3.2, parts unrelated to the fuel system must also be upgraded: the engine control unit (computer) must be reprogrammed; spark plugs must be able to endure higher temperatures; and the catalytic converter must be optimized for methane fuel exhaust. These changes are most often completed by converters, but the OEMs will provide specifications that enable the warranty to remain effective.

3.3 Refueling Technology

Because NG is either compressed or liquefied at a low temperature, the refueling infrastructure differs from a typical gas pump. While the consuming public must learn a specific procedure to refuel these vehicles, most professionals in the industry feel the learning curve is small.

3.3.1 CNG Refueling

As mentioned, natural gas has to be compressed into the tanks. There are two different points at which this can happen: as the fuel is being pumped into the vehicle or in storage tanks prior to pumping it into the vehicle. Natural gas that is compressed as it fills the vehicle has the advantage of being a smaller operation (there is no need for large compression storage tanks). However, it takes substantially longer to fill the vehicle with fuel. In the “fast fill” systems, the fuel is already compressed and is pumped at pressure into the vehicle; these are the systems typically in use at retail CNG fuel stations.

Home refueling of CNG has been a reality for some time, though it has struggled to gain acceptance. The concept of home refueling of CNG seems valid and a similar model is used by some fleets that are set up to refuel their vehicles overnight, thereby reducing the cost of the infrastructure.

3.3.1.1 Home Refueling Appliances

A majority of homes in the United States and Europe have natural gas lines running into them, so connecting a small compressor to refill the tank of the vehicle makes sense. Yet, the economic reality of home refueling has not worked out in either Europe or North America. Over the years, few home refueling appliances have come to market. The FuelMaker-manufactured Phill “Home Refueling Appliance” became the most widely available and best-known thanks in no small part to a partnership with American Honda to distribute the appliances with the Civic GX. The company declared bankruptcy in April 2009 after Honda decided to withdraw from the partnership. IMPCO (a division of Fuel

Solution Systems) picked up of the majority of FuelMaker's assets, and plans to begin selling the refueler again in late 2010.

The system originally sold for around $1,000 (not including installation); however, at the time of FuelMaker's bankruptcy, the system was selling for between $3,500 and $4,000 (not including installation). IMPCO's FuelMaker is likely to retail for between $4,000 and $4,500 and currently qualifies for a $2,000 federal tax credit in the United States. Despite the failure of home refueling appliances in both the United States and Europe, many in the industry still indicate that home refueling is ultimately required to make NGVs appealing to the consumer market.

3.3.2 LNG Refueling

LNG is stored in a cryogenic tank and kept at a temperature of -259°F in order to remain in the liquid state. While the fuel is in the liquid state, it can be pumped in a manner similar to that of gasoline (since both are liquids). Due to the extremely cold temperatures required for the methane to turn into a liquid, the LNG may be trucked or shipped to the station. In some cases, the natural gas is liquefied either on site (which is very expensive) or nearby and piped to the refueling station.

LNG refueling stations are generally set up to serve fleet customers only, largely because this fuel is only used by fleets. However, many stations are set up to offer both CNG and LNG refueling. The cost of an LNG station is substantially higher than that of a traditional gasoline station: $300,000 to $1,000,000 for equipment only, compared to $50,000 to $150,000 for gas/diesel station equipment, according to the Idaho National Laboratory.

3.4 Natural Gas Production

3.4.1 Safety Issues

Many believe that because natural gas is unsafe because it is contained in high-pressure tanks. As one interviewee stated, "some of my staff won't drive it [an NGV] because they think they are sitting on top of a bomb." This reputation originated from poor tank designs of the past. However, with the development of new storage tank technology, new venting safety features, and better refueling nozzle technology, the danger of explosion from NGVs has been greatly reduced. Additionally, since natural gas is lighter than air, it dissipates very quickly when released or vented into the air.

3.4.2 On-Vehicle Storage Tanks

Tanks are designed to withstand crashes (and even small-caliber bullets). All CNG tanks for vehicles must meet the FMVSS 304 (49 CFR 571.304 – Compressed Natural Gas Fuel Container Integrity) standard. Many OEMs install tanks that meet ANSI/CSA NGV2, Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers, which is an updated standard set that is more stringent than FMVSS 304. The tanks also have several safety features, including high temperature pressure release valves that release the natural gas before the tank heats up beyond its threshold. Additionally, the tanks are designed to accept up to 25% more pressure than their rating indicates. This safety feature fulfills two requirements. First, it allows the pressure in the tank to rise as the temperature rises; temperature and pressure rise and fall together, so while tanks are supposed to be filled to 3600 psi, the pressure may actually be higher in hotter climates. It also allows the tanks to be filled to a slightly higher pressure than the 3600 psi because as the tanks are filled, the temperature rises with the pressure. After the fill is complete and the temperature in the tank falls to the ambient temperature, the pressure also falls to the desired 3600 psi.

There are four types of CNG tanks:

- All steel or aluminum – These tanks are heavy, but inexpensive.
- Metal tanks with a structural fiberglass or carbon fiber resin on the outside middle of the tanks – This design reduces weight, but increases costs.
- Metal tanks with a complete wrap of fiberglass on the outside – The wrap decreases the weight further for the tank, but also increases costs.
- A hard plastic tank with a complete wrap of fiberglass or carbon fiber – This design cuts the weight even further, but is the most expensive style.

All tank styles have to meet the safety requirements.

While LNG storage tanks do not have to maintain the same pressurized contents as CNG tanks, they are double-walled with a vacuum (similar to a thermos), making them heavy. In addition, LNG tanks are required to have a vent. As the LNG boils, the tank emits the methane that is now a gas to relieve pressure and maintain the necessary temperature of -160°C.

Section 4

DEMAND DRIVERS

4.1 Market-Based Demand

The market for NGVs stems from four basic demand drivers: economic interest, environmental benefits, energy security, and the availability of fuel and vehicles.

Table 4.1 Demand Drivers for the NGV Market

Economics	Environmental Benefits	Energy Security	Availability
Fuel is less expensive	Reduced GHG emissions	Domestically available fuel	Availability of vehicles and conversions
Vehicle cost is recouped quickly	Increasingly strict government environmental diesel standards	Reduces dependency on foreign oil	Availability of fuel and refueling stations
Maintenance costs are similar or lower	NGVs permitted in cities with limited access for diesel trucks/buses		Availability of fuel can put limitations on vehicle range and usage
Tax incentives for vehicle purchase reduce the cost recovery time	Access to carpool lanes and special parking		

(Source: Pike Research)

4.1.1 Economics

Overall, everyone interviewed for this report agreed that economics is the most important driver of demand for NGVs. Environmental benefits and energy security typically followed closely. The exception involved those government agencies that are mandated to reduce their carbon footprint, for which environmental benefits and energy security issues take center stage (though economics is a close third).

4.1.1.1 Cost Recovery Analysis

The actual costs of NGVs compared to traditional vehicles vary wildly depending on the system. Some of the HD truck systems with large capacity LNG tanks can cost about $50,000; HD CNG truck systems are typically about $10,000 less than that. Passenger car CNG conversions may cost $6,000 to $10,000. Fuel costs play a huge role in how quickly those costs are recovered. Currently, CNG is priced over a dollar lower than diesel according to the DOE; at these levels, NG vehicles quickly recover their incremental cost. Without purchase incentives factored in, the current cost recovery just from CNG is approximately 3.6 years.

While there are some additional savings and costs associated with maintenance specific to NGVs, these have not been included in the example provided below.

Table 4.2 Incremental Cost Recovery Example

Metric	HD Diesel Tractor	HD CNG Tractor	MD CNG Truck	MD LPG Truck
Incremental Cost	N/A	$40,000	$12,000	$10,400
Clean Diesel Equipment	$8,500	N/A	N/A	N/A
Federal Tax Incentives	$0	$28,000	$5,000	$8,000
Miles Driven/Year	45,000	45,000	30,000	30,000
Fuel Economy	4 miles/gallon	4 miles/gge	13 miles/gge	11.3 miles/gallon
Gallons of Fuel Used per Year	11,250	11,250	3,077	3,540
Metric	**2010**	**2010**	**2010**	
Fuel Costs (Oct. 2010)	$3.07/g	$1.95/g	$1.95/g	$1.94/g (bulk)
Total Fuel Expense/Year	$30,700.00	$19,500.00	$4,500.00	$4,974.36
Savings over Diesel Costs	N/A	$11,200	$2,585	$2,110
Cost Recovery (years)		1.0	1.4	1.1

(Source: Pike Research)

This example shows that the incremental cost of the fuel system can generally be recovered within two years with the current federal Qualified Alternative Fuel Motor Vehicle (QAFMV) Tax Credit purchase incentives.

4.1.1.2 Relationship Between Alternative Fuel Demand and Gas/Diesel Prices

When diesel and gasoline pricing jumped in the 1970s and again in 2008, demand for alternative fuels also spiked. The relationship between increased fuel costs and increased demand can be expected to continue. In fact, most NGV trade organizations point to the rising costs of oil and gasoline as a major reason to boost the use of natural gas as a transportation fuel. The comparatively low cost for both diesel and gasoline in 2009 and 2010 has caused the economic argument for NGVs to become a more difficult prospect.

Individuals interviewed for this report often point out that the difference in fuel costs between natural gas and diesel has been so minimal that the cost advantage of fuel has not been as applicable in the past year. However, most also admitted that they expect natural gas to have the price advantage again soon (in fact, at the time of interviewing, most areas were seeing significantly lower natural gas costs in comparison to diesel).

4.1.2 Energy Security Issues

Energy security has different meanings depending on the region. In North America and Western Europe, NGVs are seen as a tool to reduce the dependence on imported oil (estimates are that 70% of the crude oil used in the United States is imported from overseas), thereby increasing energy security. In speaking with fleet managers, the issue of reducing imports of foreign oil almost always comes up, indicating that these concerns are also top of mind for fleet managers.

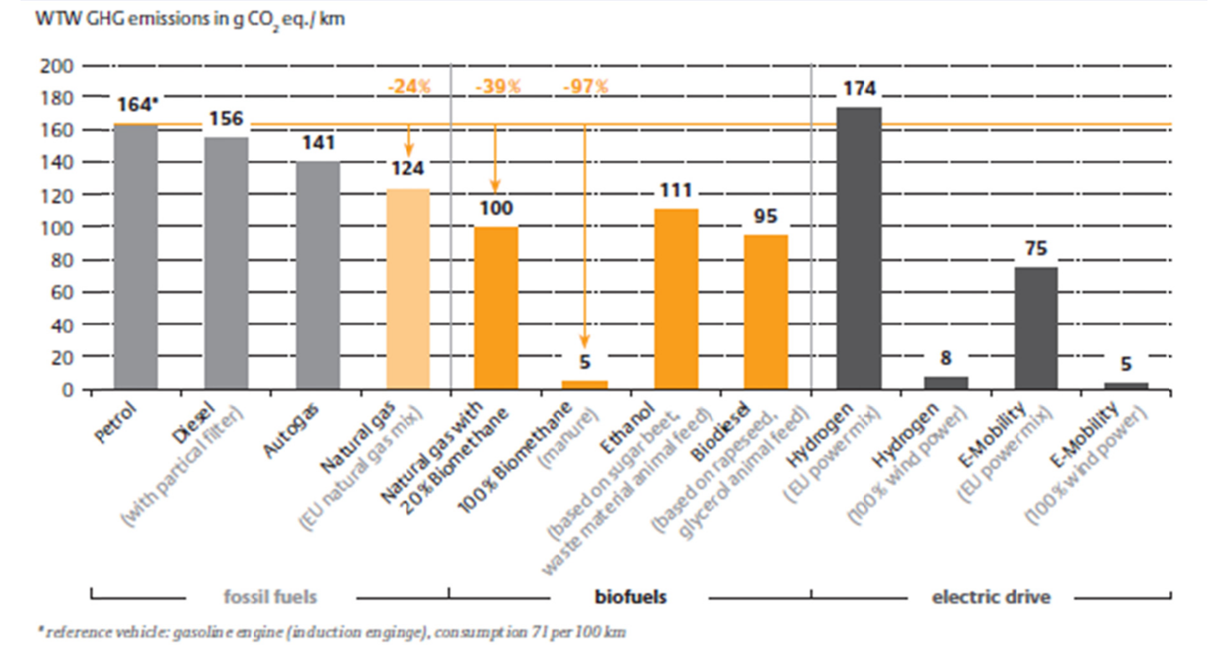
In oil-rich countries like Iran and Venezuela, NGVs serve two purposes: reducing the need for refining capacity for gasoline and increasing the amount of crude oil available for export. Iran, specifically, does not have refining capabilities and has to import gasoline at the same time that it exports crude oil.

4.1.3 Environmental Benefits

Using natural gas as a fuel offers benefits to OEMs who are increasingly under pressure to lower their GHG emissions. CNG emissions are substantially lower than that of gasoline (petrol), diesel, and to a lesser extent LPG (please refer to Figure 3.1 for details on CNG/LNG emissions and Figure 4.1 for well-to-wheel comparisons).

Many in the natural gas industry point to biomethane as an important step toward reducing GHGs, and the German energy agency, DENA, found that mixing just 20% biomethane can reduce GHG emissions by up to 39% over gasoline and 36% over new clean diesels. While Sweden leads in developing biomethane, other areas are working to develop high quality biomethane for transportation fuel.

Figure 4.1 Well-to-Wheel Greenhouse Gas Emissions for Various Fuels



(Source: DENA German Energy Agency GmbH)

Most fleet managers are being given a mandate to improve the environmental impact of the corporate fleet. Fleet managers interviewed for this report interpreted this mandate in two ways: a reduction in fuel usage and a reduction in emissions. While the reduction of fuel is mainly a cost issue, many recognize that less fuel burned means fewer emissions, particularly three specific emissions – NOx, particulate matter, and carbon. Diesel emission controls are likely the key sources for this focus because fleet managers are keenly aware of the selective catalytic reduction and particulate filters.

Fleet managers are generally looking for easy ways to demonstrate that their fleets are more environmentally friendly. Calculating the emissions of the fleet and the overall mileage of the fleet provides managers with quantitative evidence to attach to their efforts. There are some online tools mentioned by specific managers that provide these types of calculations. In addition, the National Association of Fleet Administrators, in conjunction with the Environmental Defense Fund, launched a new tool for calculating GHG emissions in mid-2009.

These calculations are not currently included in most fleet purchasing decisions, though many mentioned that they do have an impact on the decision. Fleet managers generally consider vehicles to be a tool for completing a job, and the tool has to be both the right one for the job and the most cost-effective. From that perspective, the NGV may not end up being a good fit for the fleet because refueling stations are not located in convenient places or the vehicle does not provide enough range to do the job.

4.1.4 Vehicle Availability

There are currently 28 light-duty models of CNG-powered vehicles available in Europe (primarily in Italy) from OEMs, compared to 68 LPG models. Currently, there is only one CNG model available in North America (from GM). In addition, NGVs in North America are primarily targeted at commercial fleets (the one vehicle available is a GM cargo van) due to low demand from consumers. Consumers in the United States are unlikely to seek NGVs because refueling infrastructure is not as robust as that of gasoline or diesel, requiring substantial behavior change to own the vehicles.

4.2 Global Warming and Peak Oil Awareness

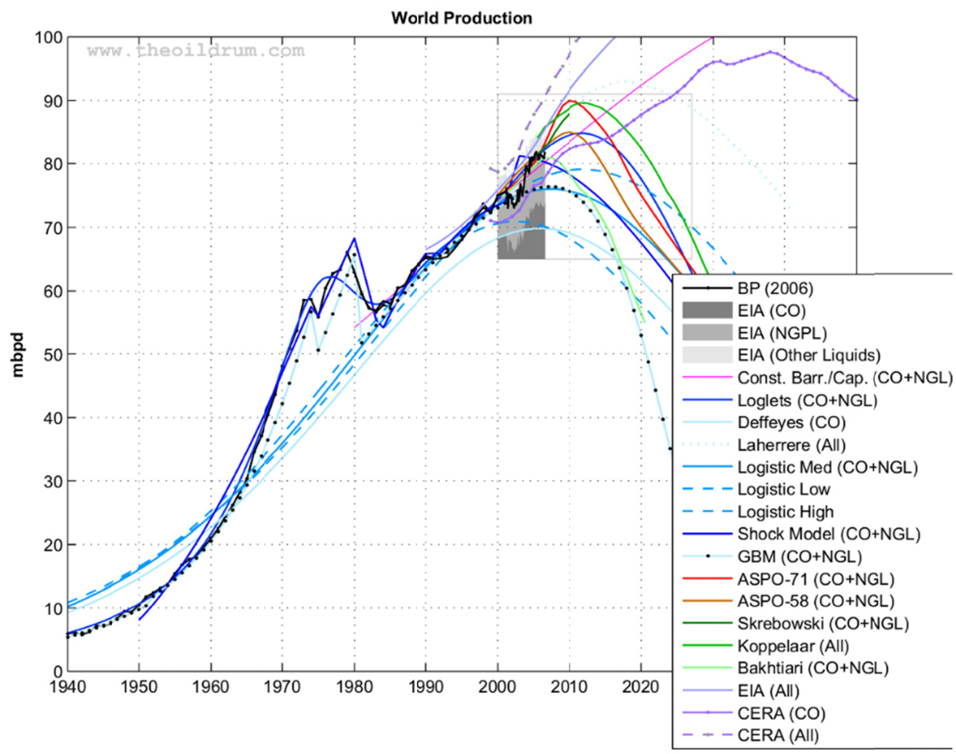
The issue of global warming has been discussed for several decades now. However, it came into much greater focus and acceptance with the development of the Kyoto Protocol in 1997 and its enactment in 2005 (without the United States). In 2006, Al Gore's speech became a high-profile film entitled *An Inconvenient Truth*, which won several awards (and contributed to a Nobel Peace Prize in 2007 for Al Gore himself). These events, along with many other news articles and speeches, have helped increase awareness of global warming and carbon emissions in the United States.

In Europe, emissions from vehicles have been limited since 1999, and automakers have been obligated to include labeling that discloses the emissions of vehicles since 2005. These actions have helped to increase awareness of global warming issues in that region.

Peak oil is the concern that the Earth is running out of crude oil. It refers to the point at which oil production is on the decline and cannot be increased. While peak oil is not as well-known as global warming, it is probable that most consumers understand that the supply of oil is not unlimited. Many peak oil advocates argue that oil production will peak and then begin to decline within the next decade, resulting in substantially higher gasoline and diesel prices.

It is difficult to make the leap to say that advocates of peak oil theories will help promote NGVs; yet, a move away from gasoline aligns with the goals of peak oil advocates. As oil prices rise, peak oil advocates will likely become more vocal. Note, though, that many continue to look to EVs or hydrogen fuel as a solution rather than NGVs, simply because NGVs still rely on a fossil fuel (a limited resource).

Figure 4.2 Peak Oil Curve, World Oil Production (Crude Oil + NGL) and Various Forecasts: 1940-2050



(Source: theoildrum.com)

4.2.1 T. Boone Pickens' Impact on the U.S. Market

T. Boone Pickens founded Mesa Petroleum in 1956. In the 1980s, Mesa Petroleum successfully acquired the then-much-larger Gulf Oil, which was part of a series of corporate takeovers that earned Pickens the dubious nickname of "corporate raider." He founded BP Capital Management, an energy-oriented investment fund firm, in 1996. During the same year, Pickens also launched Clean Energy, an energy firm that produces natural gas for transportation. Clean Energy owns 196 natural gas refueling stations across the United States and Canada, as well as two large LNG production plants. Additionally, Clean Energy is manufacturing biogas from a landfill in Texas that is being added to the national natural gas pipeline system.

Pickens is a major proponent of a new bill in the U.S. House of Representatives and Senate that will help promote the use of natural gas as a transportation fuel, H.R. 1835 and S.1408, (see Figure 4.3 for details). The bill, "New Alternative Transportation to Give Americans Solutions" (the NAT GAS Act), would provide tax incentives for NGVs purchased by consumers and fleets, as well as refueling stations built. There are similar bills in the Senate, notably one authored by Senator Harry Reid (Table 4.4 has comparisons of the different bills and incentives).

Those in the NGV industry generally laud Pickens as the major force helping to bring NGV awareness to the U.S. Congress. However, many also concede that much of the current focus is on establishing EV infrastructure and manufacturing, and the congressional lobbying effort of the natural gas industry appears to have trailed that of coal, nuclear, and

EV supporters.

4.3 Government Emissions Regulations

Governments across the globe have begun to regulate emissions. In North America, both the Environmental Protection Agency (EPA) and Environment Canada have enacted rules to limit the levels of nitrogen oxide (NOx) and particulate matter that can be exhausted from diesel engines. In other parts of the world, governments have joined the Kyoto Protocol, which has helped to develop emissions and pollution targets.

Additionally, upfitters converting diesel and gasoline engines to run on CNG and LNG are required to have the vehicles certified for use on the road by the EPA, the California Air Resources Board (to sell in California), Environment Canada, and the European Union. These certifications vary from country to country.

4.3.1 United States

4.3.1.1 CAFE Standards

The National Highway Traffic Safety Administration (NHTSA) sets the fuel economy standards for vehicles sold in the United States. Following the 1973 oil embargo, the NHTSA established the Corporate Average Fuel Economy (CAFE) regulations.

> *"First enacted by Congress in 1975, the purpose of CAFE is to reduce energy consumption by increasing the fuel economy of cars and light trucks."*
>
> *– NHTSA website*

The CAFE regulations have changed substantially since 1975, including in January 2009 when President Obama requested that the rules be updated for model year 2011 vehicles. Included in the new CAFE standard is a footprint-based approach. While there are still separate fuel economy standards for cars (30.2 mpg average) and light trucks (24.1 mpg average), there is also a combined light-duty fuel economy average of 27.3 mpg. The 2007 to 2010 model year rules stood at 27.5 mpg for cars and 19.1 mpg for light trucks, with a combined average fuel economy of 22.2 mpg. President Obama also requested rules for 2012 through 2016, which resulted in the NHTSA and the EPA issuing new requirements in April 2010 that raised the fuel economy for light duty vehicles to 35.5 mpg by 2016.

As part of the new requirements, OEMs have new limitations on GHG emissions measured in CO_2 grams/mile. Fourteen states including California and the District of Columbia began limiting CO_2 emissions from vehicles through the Clean Air Act, requiring OEMs to provide additional emissions equipment on vehicles sold in these states; the new requirements for model year 2012 bring the national policy in line with these states.

Table 4.3 Corporate Average Fuel Economy Regulations, United States: 2010-2016

Segment	Units	2010	2011	2012	2013	2014	2015	2016
Passenger cars	CO2, g/mi			263	256	247	236	225
	CO2 equiv. mpg			33.8	34.7	36	37.7	39.5
	CAFE mpg	27.5	30.2	33.3	34.2	34.9	36.2	37.8
Light trucks	CO2, g/mi			346	337	326	312	298
	CO2 equiv. mpg			25.7	26.4	27.3	28.5	29.8
	CAFE mpg	23.5	24.1	25.4	26	26.6	27.5	28.8
Combined Cars & Trucks	CO2, g/mi			295	286	276	263	250
	CO2 equiv. mpg			30.1	31.1	32.2	33.8	35.5
	CAFE mpg	22.2	27.3	29.7	30.5	31.3	32.6	34.1

(Source: EPA)

Specialty manufacturers (such as BMW) or small manufacturers (such as Porsche) that sold fewer than 400,000 vehicles in 2009 will receive Temporary Lead-time Allowance Alternative Standards (TLAAS), which allow 25,000 vehicles per year until 2015 to be calculated using 125% "of the vehicle's otherwise applicable foot-print target level" – in essence, allowing them more time to bring their fleet into compliance with the regulations.

NGVs are included in the CAFE regulations, though the calculation is different from that of traditional vehicles. One hundred cubic feet of gaseous fuels (such as CNG) is considered to be equal to 0.823 gallon equivalent of gasoline. This calculation provides the fuel economy for the vehicle. As an alternative fuel vehicle, the gallon equivalent of natural gas is treated as though it contains 0.15 gallons of fuel. This means that the fuel economy of the vehicle is then divided by 0.15, with a net result that is highly favorable according to CAFE rules (e.g., if it is calculated that the vehicle achieves 35 mpg, it would be treated as achieving 233.3 mpg under the CAFE calculation).

4.3.1.2 *EPA Regulations*

In addition to new CAFE standards, the EPA has been working to limit GHG emissions from vehicles. It passed new rules in 2000 for diesel engines that require NOx and particulate matter (soot) from diesel exhaust to be reduced by 95% and 90%, respectively, by 2010. All new heavy-duty diesel engines, regardless of weight category, are required to have emissions that do not exceed:

- Particulate matter: 0.01 gram per brake horsepower-hour (g/bhp-hr)
- Nitrogen oxide: 0.20 g/bhp-hr
- Non-methane hydrocarbons (NMHC): 0.14 g/bhp-hr

To meet these requirements, OEMs are forced to include expensive catalytic converters, Selective Catalytic Reduction, that reduce NOx emissions and a particulate filter that reduces particulates from engine emissions.

The EPA also had to institute new regulations on the amount of sulfur included in highway diesel (15 parts per million, down from 500 ppm before June 1, 2006). However, refiners were not uniformly required to switch to the new ultralow-sulfur diesel (ULSD) on June 1, 2006; mandated compliance varied by geography and size of refiner. However, all refiners were required to switch to ULSD by December 31, 2009.

In the fall of 2010, the EPA announced some potential new rules for M/HD trucks and buses. While these are not yet requirements, it appears that these rules would favor an NGV.

Table 4.4 Proposed EPA Truck Fuel Economy and Emissions Regulations (Oct. 2010)

	Combination Tractors	M/HD Pickups/Vans	Vocational Trucks
Fuel Economy	Phase in to 2017 limits of 11.4 gal/1,000 ton miles and 6.3 gal/1,000 ton miles depending on cab type and weight class	10% consumption reduction in gas vehicles; 15% consumption reduction in diesel vehicles	33.8 gal/1,000 ton miles for Class 3-5 trucks 20 gal/1,000 ton miles for Class 6-7 trucks 10.5 gal/1,000 ton miles for Class 8 trucks
Emissions	Phase in to 2017 limits of 117g CO2/ton-mile and 64g CO2/ton-mile depending on cab type and weight class	12% GHG reduction in gas vehicles; 17% GHG reduction in diesel vehicles	344g CO_2/ton-mile for Class 3-5 trucks 204g CO_2/ton-mile for Class 6-7 trucks 107g CO_2/ton-mile for Class 8 trucks

(Source: NHTSA/EPA)

NGVs must be certified by the EPA to be used on the road. This certification process can be very expensive and quite onerous. Many interviewed for this research felt that the EPA certification process was too difficult and too expensive. In this process, each engine has to be certified for each model year (e.g., a Chevrolet 5.9L V8 certified for 2008 has to be recertified for 2009, though the engine may have undergone no changes between the model years).

4.3.1.3 CARB Certification

In addition to EPA rules, OEMs and upfitters that wish to sell their NGVs in California must receive an additional certification from the California Air Resources Board (CARB).

In 2006, Assembly Bill (AB) 32 was signed into law which requires California to reduce GHG levels:

- By 2020, GHG levels are reduced to 1990 levels
- By 2050, GHG levels are reduced to 80% below 1990 levels

NG trucks are an important part of meeting these requirements, though many acknowledge that the state will have to have substantial investment in zero-emissions vehicles to meet the 2020 levels.

CARB is limiting the emissions from transit fleet vehicles (buses), based on total fleet emissions:

- Diesel PM emission total for a transit agency shall be no more than 20% of its diesel PM emission total on January 1, 2005 or equal to 0.01g/bhp-hr times the total number of current diesel-fueled active fleet buses, whichever is greater, and

- The NOx fleet average shall not exceed 2.4 g/bhp-hr or be void of 2001 and earlier model year engines.

In many cases, these rules are forcing transit agencies to move toward natural gas-powered buses. During interviewing, we heard from several bus manufacturers that this rule has effectively required transit agencies to purchase CNG/LNG buses when replacing vehicles.

4.3.2 Canada

Environment Canada, the ruling body for emissions in Canada, follows the United States in most cases. Its emissions and fuel economy rules are similar to those in the United States, including new diesel rules that match the EPA emissions rules. The vehicles available to consumers in Canada are also very similar to those in the United States, so it makes sense that the environmental rules would be similar.

4.3.3 Latin America

Mexico City currently has two programs to limit vehicle emissions: emissions testing and "Hoy no Circula" ("Don't Drive Today") – a program that began in 1989 with the aim of removing cars from the road on one day per week. There are exceptions for NGV drivers from Hoy no Circula restrictions. Many believe that drivers are circumventing Hoy no Circula days by purchasing a second, much less expensive and likely dirtier vehicle, which means the program is arguably having the opposite effect than intended. Mexico is also considering new taxes that encourage both ethanol and natural gas as a transportation fuel.

In Brazil, new emissions restrictions passed in September 2009 requiring a 35% reduction in car emissions and a 26% reduction in large vehicle emissions by 2013 for diesel and flex-fuel vehicles. Vehicles fueled by natural gas match these new requirements without substantial modification.

4.3.4 Europe

As part of the Kyoto Protocol, the European Union (EU) has committed to reducing GHG emissions by 8% by 2012. The United Kingdom and Germany went further, committing to a reduction of 12.5% and 21%, respectively. To achieve this dramatic result, Germany and the United Kingdom are relying heavily on EVs instead of NGVs. However, NGVs do play a role in Germany, as the country has rapidly built refueling stations and offers a subsidy on CNG fuel.

Similar to the United States, the EU has placed strict limitations on diesel engine emissions (slightly stricter than the U.S.' emissions limits). The next stage in the reduction occurred in 2009 (Euro V), and Euro VI will follow in 2014. The Euro VI limits are expected to have an impact on non-hybrid diesel engine pricing. To help consumers make more informed choices, EU countries require CO_2 emissions be labeled on vehicles. Labeling is often seen as confusing in the retail environment, and Europe has been testing color labels for vehicles to indicate the level of emissions and make comparisons easier.

4.3.5 China

In 2000, China introduced its first limits on emissions using the European standards. Until 1995, China was self-sufficient in terms of oil and did not import any; however, due to overwhelming demand for vehicles, oil imports have grown substantially. Consequently, fuel economy is becoming more critical within the country. In 2010, Chinese OEMs (and JVs) are required to provide fuel economy of the equivalent of 35.3 mpg. This is scheduled to grow to 42.2 mpg by 2015.

4.3.6 India

In 1998, India's Supreme Court issued a ruling that stated that the entire fleet of transit buses in the country had to be converted to CNG by 2001. While this ruling took longer to take effect, the expansion of the refueling infrastructure has resulted in growth in the NGV market. Meanwhile, India is also enacting emissions rules that are similar to the European standards, but trail in terms of the timeframe. Euro IV limits, which began in Europe during 2005, are set to take effect in 2010. In India, the limits do not apply to the entire country – only Delhi and the ten largest cities.

4.3.7 Japan

In 2003, Japan's Ministry of the Environment (MOE) developed strict emissions rules for diesel engines. Effective in 2009, the emissions limits of particulate matter and NOx have been reduced greatly – to 0.01 g/kWh and 0.7 g/kWh, respectively. Japan's limits fall between those of the EU and the United States, but have come into effect earlier.

Japan's fuel economy standards require that vehicles reach 23% better fuel economy than in 1995, meaning that vehicles must achieve 15 kilometers per liter of gas (35.3 mpg U.S.). By 2015, vehicles are required to achieve 18 kpl (42.3 mpg U.S.).

4.4 Government Incentives

4.4.1 United States

The United States currently provides tax incentives toward the purchase of NGVs, LPG vehicles, and other alternative fuel vehicles that use at least an 85% methane mix. These incentives vary for light-, medium-, and heavy-duty vehicles as part of the Qualified Alternative Fuel Motor Vehicle (QAFMV) Tax Credit. The incentives are all set to expire at the end of 2010, unless the new legislation (NAT GAS Act) is passed, which would extend and perhaps increase the incentives. There are currently two versions of the NAT GAS Act legislation in the works, as well as a bill introduced by Senator Harry Reid; moreover, the Senate Ways and Means Committee has made its own recommendations. It seems unlikely that these bills will be acted upon in the lame duck session in the fall of 2010, but most interviewed for this report expect some action to occur relatively quickly in 2011.

Table 4.5 Comparison of NAT GAS Act Bills

Issue	Current law	111th Congress NAT GAS Act- S. 1408 & Title I; S. 3535	111th Congress NAT GAS Act- HR 1835	Kerry/Lieberman American Power Act proposal	REID S. 3815	Draft Ways and Means proposal July 2010
Extension of Alternative Fuel Tax Incentive (Internal Revenue Code (IRC), §§ 6426,	Current law provides a 50 cent tax incentive for CNG (per 121 cubic feet) or LNG gallon when used as a fuel for	Section 101 Extends the alternative fuel incentive for CNG and LNG until December 31, 2019.	Section 101 Extends the alternative fuel incentive for CNG and LNG until December, 31 2027.	Not included	Not included	Section 503 Extends the alternative fuel incentive for CNG and LNG until December 31, 2011. The credit is to be made

Issue	Current law	111th Congress NAT GAS Act- S. 1408 & Title I; S. 3535	111th Congress NAT GAS Act- HR 1835	Kerry/Lieberman American Power Act proposal	REID S. 3815	Draft Ways and Means proposal July 2010
6427)	motor vehicles. Credit currently expired on 12/31/2009.					retroactive to 1/1/2010 if Congress has not done that prior to enactment.
Extension of Alternative Fuel Motor Vehicle Tax Credit (IRC §30B(e))	Income tax credit for the purchase of a qualified alternative fuel motor vehicle. Credit currently expires on 12/31/2010.	Section 102 Extends the natural gas vehicle credits until December 31, 2019.	Section 102 Extends the natural gas vehicle credits until December 31, 2027.	Section 4121 Extends natural gas vehicle credits for 10 years.	Section 1003 Makes up to $3.8 billion in financial rebates available to qualified owners who purchase a natural gas vehicle by 2013.	Section 401 Extends the natural gas vehicle credits until December 31, 2016.
Alternative Fuel Motor Vehicle Credit – Increased Credit Values. Modifies the values of the tax credits provided for qualifying natural gas vehicles. (IRC, §30B(e))	Under current law the purchaser or seller of a dedicated natural gas vehicle is eligible for an income tax credit: Credit is 50% or 80% of the incremental cost of the vehicle. The incremental cost caps vary depending on the weight classification of the vehicle. Credit	Section 105 Modification to the natural gas vehicle tax credits: Makes all new dedicated alternative fueled vehicles eligible for a credit equal to 80% of the incremental cost. Makes specific bi-fuel, alternative-fueled vehicles eligible for a tax credit equal to 50% of the incremental cost. Increases the light-duty vehicle purchase tax credit by 150% (from $5,000 to $12,500), and doubles the vehicle purchase tax credits for all	Section 104 Same as provision in section 105 of S. 1408.	Section 4121 Modification to the natural gas vehicle tax credits: Doubles the vehicle purchase tax credits for all vehicle weight classes. For light-duty vehicles (less than 8501 GVWR), the credit would only be available to commercial fleets that (1) operate at least 10 motor vehicles and (2) purchase more than two NGVs. Makes specific bi-fuel, alternative-fueled vehicles eligible for a tax credit.	Section 1003 Modification to the natural gas vehicle tax credits: Makes all new dedicated alternative-fueled vehicles eligible for a rebate equal to 90% of the incremental cost. Doubles the existing allowable vehicle incremental cost limits for all vehicle weight	Section 401 Modification to the natural gas vehicle tax credits: Makes all new dedicated alternative-fueled vehicles eligible for a credit equal to 80% of the incremental cost. Eliminates vehicle purchase tax credits for vehicles weighing less than 8501 pounds, but doubles the vehicle purchase tax credits for all other vehicle weight classes. Modifies the

Issue	Current law	111th Congress NAT GAS Act- S. 1408 & Title I; S. 3535	111th Congress NAT GAS Act- HR 1835	Kerry/Lieberman American Power Act proposal	REID S. 3815	Draft Ways and Means proposal July 2010
	values range from $2,500 to $32,000. Bi- fuel vehicles are **not** eligible for the credits.	other weight classes.		Modifies the definition of a mixed-fuel vehicle to also include a vehicle that (1) is capable of operating on CNG or LNG and (2) operates on not more than 35% petroleum-based fuel.	classes. Modifies the definition of a mixed-fuel vehicle to include a vehicle that (1) is capable of operating on either CNG or LNG and (2) operates on at least 75% CNG or LNG. Makes them eligible for 75% of the rebate a similar sized dedicated NGV would receive. Makes specific bi-fuel, alternative-fueled vehicles eligible for a rebate equal to 50% of the incremental cost.	definition of a mixed-fuel vehicle to include a vehicle that (1) is capable of operating on CNG or LNG and (2) operates on not more than 35% petroleum-based fuel.
Alternative Fuel Motor Vehicle – Inclusion of Bi-Fuel NGVs. Modifies the definition of a new qualified alternative	Not available today	Section 106 Expands the definition of qualified alternative- fuel vehicle to include bi-fuel, alternative-fueled vehicles that are capable of operating on	Section 105 Almost exactly the same as S. 1408 Section 106.	Section 4121 Makes certain bi-fuel, alternative-fueled vehicles eligible for a tax credit. A bi-fueled vehicle is defined as a vehicle that	Section 1001 A bi-fueled vehicle is defined as a vehicle that is capable of operating for more	Not Included

Issue	Current law	111th Congress NAT GAS Act- S. 1408 & Title I; S. 3535	111th Congress NAT GAS Act- HR 1835	Kerry/Lieberman American Power Act proposal	REID S. 3815	Draft Ways and Means proposal July 2010
fuel motor vehicle (IRC, §30B(e)) to include bi-fuel vehicles		natural gas and gasoline or diesel fuel, but only if such a vehicle has an operating range of not less than 200 miles when operating on natural gas. Clarifies that a converted or repowered vehicle is a new vehicle for the purposes of this section.		is capable of operating for more than 175 miles on one tank of CNG or LNG. To qualify for a tax credit of 80% of the applicable incremental cap, a light-duty NGV must meet the Tier 2/ Bin2 standard on both fuels.	than 175 miles on one tank of CNG or LNG. The maximum value of the rebate for a bi-fuel vehicle is 50% of the rebate amount otherwise provided for a similar size dedicated NGV.	

(Source: Pike Research)

The U.S. Office of Energy Efficiency and Renewable Energy has a volunteer program called Clean Cities:

> *"The mission of Clean Cities is to advance the energy, economic, and environmental security of the United States by supporting local decisions to adopt practices that reduce the use of petroleum in the transportation sector."*

Source: Mission via Clean Cities website ."

The Clean Cities coalition helps cities with programs and funding for alternative-fuel vehicles and infrastructure, and has been instrumental in the development of NGV programs in cities around the United States through grants and expertise.

The American Recovery and Reinvestment Act (ARRA, the 2009 federal stimulus program) also includes funding that can be applied to NGVs: Up to $15 billion of ARRA has been designated for alternative fuels, including $300 million for green school buses, $300 million for an alternative-fuel vehicle program to be administered by Clean Cities, and $8.4 billion for alternative-fuel transit buses and infrastructure.

In addition, some states offer state-level incentives. These incentives vary substantially depending on whether each state's focus is on NGVs, PEVs, or biofuels.

Table 4.6 Vehicle Incentives by State

PHEV and EV Incentives	Light-Duty Vehicle Purchase/Conversions Incentives	Commercial Vehicle Conversion/Purchase Incentives
Alabama	No current state-level incentives.	
Alaska	No current state-level incentives.	Conducting an analysis on the feasibility of using CNG in the state.
Arizona	NG, LPG, and H_2 vehicles have access to HOV lanes, and a reduction in annual license taxes by reducing assessable value of the vehicle from 60% MSRP to 1% in the year of purchase, and 15% each year thereafter.	75% of state and municipal fleets must be AFVs; 50% of school districts' fleets must be AFVs.
Arkansas	No current state-level incentives.	
California	Alternative and Renewable Fuel and Vehicle Technology Program provides grants and loans to increase the use of alternative and renewable fuels. Motor Vehicle Registration Fee program provides grant funding for AFV and refueling infrastructure that reduces air pollution. NGV, LPG, and H_2 vehicles have access to HOV lanes.	Low Emission School Bus Program provides grant funding to replace school buses with those that reduce particulate matter by 85%; NGVs qualify.
Colorado	75% cost rebate (no cap) for light-duty passenger vehicle, light-duty truck, or medium-duty truck natural gas conversions.	55% cost rebate ($350,000 per year cap) for light-duty passenger vehicle, light-duty truck, or medium-duty truck natural gas conversions for state and municipal fleets.
Connecticut	No current state-level incentives.	Connecticut Clean Fuel program provides funding to government fleets for AFVs; Connecticut Clean School Bus Program provides grant funding for reimbursing retrofit of existing school buses (funding scheduled to run out September 2010).
Delaware	Alternative fuel tax exemption for state and federal fleets.	
District of Columbia	Vehicles with at least 40 mpg city rating are exempt from the excise tax imposed on an original certificate of title. Vehicles with at least 40 mpg city rating are eligible for a reduced vehicle registration fee of $36 for two years.	
Florida	No current state-level incentives.	
Georgia	10% AFV purchase/conversion cost tax credit, up to $2,500 (includes NGV and LPG).	
Hawaii	No current state-level incentives.	
Idaho	Alternative fuel tax exemption for state	

PHEV and EV Incentives	Light-Duty Vehicle Purchase/Conversions Incentives	Commercial Vehicle Conversion/Purchase Incentives
	and federal fleets.	
Illinois	Tax rebate for 80% of the incremental cost of purchasing an AFV (up to $4,000) and 80% of the cost of federally certified AFV conversions (up to $4,000).	Illinois Clean School Bus program provides grant funding for reimbursing the retrofit of existing school buses.
Indiana	Grants of up to $20,000 for installation of alternative fuel stations (funds are not currently allocated for this program).	$2,000 grants for each OEM AFV purchased and up to $2,000 for each AFV conversion are available to counties, cities, towns, townships, or school corporations to purchase OEM AFVs and for the cost of AFV conversions.
Iowa	No current state-level incentives.	
Kansas	40% conversion cost for biogas-fueled vehicles: up to $2,400 for LD; $4,000 for MD; and $40,000 for HD vehicles.	
Kentucky	No current state-level incentives.	
Louisiana	50% tax credit for conversion to AFV (NGV, LPG, H_2); 10% cost tax credit up to $3,000 for new AFV purchase.	
Maine	Reduced state fuel taxes on NG, LPG, and H_2.	
Maryland	No current state-level incentives.	
Massachusetts	No current state-level incentives.	
Michigan	No current state-level incentives.	
Minnesota	No current state-level incentives.	
Mississippi	No current state-level incentives.	75% of state fleets required to achieve 40 mpg (highway) by July 1, 2014.
Missouri	20% tax credit for installing AFV refueling infrastructure ($20,000 cap), includes ethanol, NG, LPG, H_2.	
Montana	$500 credit for conversion to AFV.	$1,000 credit for vehicles over 10K pounds GVW converted to AFV.
Nebraska	No current state-level incentives.	Alternative Fuel Tax refund issued for buses capable of carrying more than 7 passengers and operating within municipalities.
Nevada	Reduced fuel taxes on CNG, LNG, and LPG.	
New Hampshire	No current state-level incentives.	State and Clean Cities provides competitive funding on a cost-reimbursement basis for AFVs, advanced technology vehicles, and alternative fueling infrastructure in ozone nonattainment or maintenance areas.

PHEV and EV Incentives	Light-Duty Vehicle Purchase/Conversions Incentives	Commercial Vehicle Conversion/Purchase Incentives
New Jersey	NG, LPG, and H_2 vehicles have access to HOV lanes.	Rebate for AFV purchase to government fleets of up to $4,000 for LD (<8,500 pounds GVW), $7,000 for medium-duty (8,500-14,000 pounds GVW) HEV/PHEV/BEV purchase; tax rebate of up to $12,000 for heavy-duty (>14,000 lbs GVW).
New Mexico	No current state-level incentives.	
New York	Tax credit for 50% of alternative fuel infrastructure installation (expires Dec. 31, 2010).	New York City Private Fleet Alternative Fuel/Electric Vehicle Program helps private companies and non-profit organizations operating vehicles in New York City to acquire AFV and advanced technology vehicles. Funds are awarded on a competitive basis for up to 50% of the incremental cost of purchasing new light-duty AFVs, and up to 80% of the incremental cost for purchasing new or converting medium- and heavy-duty AFVs.
North Carolina		Diesel emission reduction grants for AFVs and refueling infrastructure.
North Dakota	Tax credit to biogas producers for 1% of wages and salaries paid for first three years; 0.5% in fourth and fifth year.	
Ohio	No current state-level incentives.	School Bus Retrofit program provides grant funding for reimbursing retrofit of existing school buses.
Oklahoma	50% of conversion cost to AFV income tax credit or 50% of incremental cost of AFV; 10% of total vehicle cost, up to $1,500, if the incremental cost of a new AFV cannot be determined or when an AFV is resold, as long as a tax credit has not been previously issued for the vehicle. Tax credit of up to 75% on refueling infrastructure for NG, LPG, and H_2. $2,500 credit for residential CNG refueling system.	
Oregon	$1,500 tax credit for purchase of AFV; $750 tax credit for converting to AFV.	
Pennsylvania	No current state-level incentives.	
Rhode Island	No current state-level incentives.	
South Carolina	State income tax credit equal to 20% of the federal fuel cell, hybrid electric vehicle, and alternative fuel vehicle credits.	
South Dakota	No current state-level incentives.	
Tennessee	No current state-level incentives.	

PHEV and EV Incentives	Light-Duty Vehicle Purchase/Conversions Incentives	Commercial Vehicle Conversion/Purchase Incentives
Texas		Grants available to fleets to offset the incremental cost of diesel replacement projects (Must operate a fleet of at least 100 vehicles and place 25 or more qualifying vehicles in service for use entirely in Texas during a given calendar year to be eligible). Incentives available for diesel replacement with LPG vehicles.
Utah	35% of vehicle purchase price ($2,500 cap) for OEM CNG vehicles. $750 credit for all other AFVs that meet air quality and fuel economy requirements. NG, LPG, and H_2 vehicles have access to HOV lanes.	$2,500 in ground transportation fees for purchase or conversion to AFV.
Vermont	Clean Energy Development Fund provides funding for NGV purchases and NG refueling infrastructure.	
Virginia	NG, LPG, and H_2 vehicles have access to HOV lanes.	
Washington	Sales tax and emissions inspections waived on dedicated AFVs (NG, LPG, and H_2 vehicles).	
West Virginia	No current state-level incentives.	Additional 10% reimbursement for school bus replacement with AFV (including CNG, LPG).
Wisconsin		Taxi fuel tax refund for alternative fuels.
Wyoming	No current state-level incentives.	

(Source: NGV America, DOE Office of Energy Efficiency & Renewable Energy)

4.4.2 Canada

Canada currently has the incentive of no tax (GST) on natural gas fuel. Similar to the United States, Canada previously provided tax incentives for NGVs, though these expired in 2008 and 2009 and there has been no push to replace them. The Canadian Natural Gas Vehicle Alliance (CNGVA) is working to develop more robust incentives for HD trucks/buses in cities where it makes sense.

4.4.3 Europe

In many countries in Europe, CNG is subsidized, which helps to maintain lower fuel costs than for diesel or gasoline. Taxes on natural gas are substantially lower than traditional diesel and gasoline, which means vehicle fuel costs are substantially for CNG than others. Additionally, infrastructure costs for refueling stations receive grants to help establish a stronger network of stations.

4.4.4 Japan

The Japanese national government provides incentives for NGVs of 50% of the purchase price. In addition, Japanese cities have local incentives that include grants to purchase

NGVs. These programs vary by city.

Japan's motor tax incentive tool is currently being used to remove older vehicles from the roads. The program charges a 10% surcharge tax on diesel vehicles that are 11 years old and on gasoline or LPG vehicles that are 13 years old.

For HD vehicles, if trucks in the 3.5-ton GVW class meet 2009 emissions standards and are compliant with 2015 fuel efficiency standards, their tonnage and acquisition taxes can be reduced by 75% until 2012. If their emissions are 75% lower than 2005 standards and are compliant with 2015 fuel efficiency standards, their tonnage and acquisition taxes can be reduced by 50%.

4.4.5 China

China has a program called the Clean Development Mechanism (CDM) to fund environmental projects. The CDM program appears to have backfired to some degree due to increased upfront investment required from companies which limits interest. It is also not clear whether NGVs qualify for this program. As such, there are no financial incentive programs for the purchase of NGVs at this time. Much of the natural gas in China is being used as industrial and heating fuel rather than transportation fuel, and refueling stations that are built are often funded by government programs.

4.4.6 Other Regulatory Incentives

Pakistan is currently working to promote NGVs by reducing tariffs on compression equipment imported to set up refueling infrastructure, helping to reduce costs for constructing refueling stations.

Cities, provinces, and states across the globe are enacting a variety of other incentives for NGVs. Many of these include the use of high-occupancy vehicle lanes (HOVs), waivers from vehicle emissions tests, and special parking. In the United States, these are considered to be strong incentives for NGV adoption. Meanwhile, NGVs in several European cities are permitted to travel in city centers where diesel trucks have been banned or have to pay a substantial fee.

Section 5

KEY INDUSTRY PLAYERS

5.1 Original Equipment Manufacturers

5.1.1 Fiat

Fiat is the largest manufacturer of CNG vehicles in Europe. In 2010, the company offered 10 bi-fuel CNG and gasoline models: the 500, Grande Punto, Doblo, Multipla, Panda, Punto 5, Punto Ages, Bravo, IDEA, and Qubo. In 2007 and 2008 (prior to the collapse of automotive sales due to the economy), Fiat was selling almost 5,000 CNG vehicles per month, with sales in Europe, Latin America, and India. Fiat is currently selling a "tetra-fuel" version of its Siena in Brazil, a vehicle capable of running on 100% alcohol, 25% alcohol, pure gasoline, or CNG. When launched in 2007, the vehicle was expected to sell at a rate of about 200 per month, but more than 7,000 were sold within the first year alone.

Fiat claims to have the lowest CO_2 emissions of any European manufacturer. The company now plans to bring its technology for small gas ICEs and diesel ICEs to the United States, and will be the lead for Chrysler in developing small car platforms and small ICEs. In the fall of 2010, Chrysler began to indicate that a CNG vehicle from Fiat may be coming, but this has yet to be confirmed; no particular model has been discussed and an introduction is not expected until 2012 or 2013 at the earliest.

5.1.2 Ford Motor Co.

During the mid-1990s, Ford Motor Co. provided natural gas versions of its F-250 pickup truck, E-Series vans and truck chassis, as well as its Crown Victoria car. More recently, the company partnered with upfitters to provide an OEM-approved conversion. Ford currently offers an engine upgrade to prep the vehicle for conversion to either CNG or LPG (option code 91G). This is available for:

- 2.0L 4-cylinder Transit Connect Taxi
- 5.4L 8-cylinder F-Series pickup, E-Series van
- 6.8L 8-cylinder F-Series Super Duty, E-Series van

Ford is expected to ship a total of approximately 3,500 to 4,000 of the prepped 5.4L and 6.8L engines in 2010. The Transit Connect Taxi will be available by the end of 2010, but had yet to begin shipping as of this report's publication. Other Ford vehicles are being converted by upfitters without the engine prep package, including the Crown Victoria, Lincoln Town Car, Ford Focus, and Ford Fusion. In Europe, Ford builds a bi-fuel version of its Focus and CMax (it also offers a bi-fuel Focus Wagon with LPG and petrol only).

5.1.3 General Motors

GM left the NGV market in 2004 (it sold pickups and vans). Similar to Ford, GM has been working with upfitters that offer NGV conversions for its pickup trucks, vans, the Chevrolet Impala, and the Chevrolet Cobalt. In Europe and Latin America, GM sells CNG vehicles under the Opel and Chevrolet brands.

For the 2011 model year, GM has begun selling CNG versions of the Chevrolet Express and GMC Savana full-size vans. The vans will be manufactured with an upgraded 6.0L V8 engine, and then shipped to Productive Concepts International in Indiana for fuel system installation before delivery to the dealer. GM is marketing these vans as complete CNG products rather than available for conversion.

5.1.4 Honda

Honda is the only major manufacturer that currently offers a CNG vehicle in the United States, the Civic GX. The vehicle is manufactured in Ohio, and is available for retail consumers in California, Oklahoma, New York, and Utah – areas with an established refueling infrastructure and repair network. The Honda Civic GX is also available to fleet customers in an additional 29 states. Honda has pursued HEV and fuel cell technology to a much greater extent than natural gas. As a result, the Civic GX is its only available CNG vehicle.

Many of those we spoke with for this report indicate that they have had the Civic GX in their fleet over the years. Pike Research is expecting that Honda will sell approximately 1,000 Civic GXs in 2010.

5.1.5 Hyundai Motor Co.

Hyundai Motor Co. has introduced two CNG vehicles in India: the Accent and Santro. Both are converted versions of its original gasoline engines and both are available only in Delhi. Hyundai is also selling CNG vehicles in South America, with the Atos and Accent designed specifically for taxi service.

Hyundai provides engines to a joint venture with Westport called Juniper Engines, Inc. that sells small industrial CNG engines. These engines generally target the forklift and stationary market.

5.1.6 Mercedes-Benz

In Europe, Mercedes will offer a bi-fuel version of the 2011 E-Class with CNG and petrol by the end of 2010. While some have speculated that this vehicle would be brought to the United States and to India, the India plan has officially been scrapped. It seems unlikely that Mercedes would bring the E-Class to the United States before the California and New York refueling station infrastructures are more established and vehicle incentives are set into law.

5.1.7 Renault

Renault offers a CNG version of its light-duty panel van, the Kangoo, in Europe. It also provides CNG versions of its trucks that use the Westport Cummins B Gas Plus and C Gas Plus CNG engines. The company is not expected to make a rapid move into the CNG market for passenger vehicles, given that its strong regional markets are not big CNG markets. However, Renault does offer LPG versions of the Megane and Scenic, both of which could easily be converted to CNG if the demand proved worthy.

5.1.8 Toyota Motor Corp.

Toyota offers a few models of CNG vehicles in Asia (including Thailand and India). It is widely anticipated that Toyota will make an announcement regarding a new CNG vehicle in the next couple of years. In Europe, the company offers two bi-fuel models – Aygo and Yaris – with LPG and petrol.

5.1.9 Volkswagen

VW currently sells a CNG version of its popular Passat wagon, Touran van, and its Caddy EcoFuel van (all bi-fuel vehicles) across Europe. A CNG version of its small car, the Bora, is available in parts of Latin America. The Passat has been one of the best-selling CNG vehicles in Europe. VW also sells one CNG model under the Skoda brand in Europe: the Octavia CNG.

5.2 Heavy-Duty Trucks/Buses

5.2.1 Autocar

Autocar LLC is an HD truck manufacturer focused on refuse, yard trucks, and other vocational trucks. The company is a subsidiary of Grand Vehicle Works Holdings, which purchased Autocar from Volvo Trucks in 2001. It has between 250 and 300 employees.

Autocar competes with Mack Trucks for the lead in the refuse truck market in North America, and is the sales leader for natural gas refuse trucks with sales of approximately 400 vehicles per year. However, Mack Trucks holds the lead in refuse trucks overall.

5.2.2 Capacity of Texas, Inc.

Capacity of Texas is a “yard truck” manufacturer, building vehicles that move trailers around shipping yards. The company currently manufactures CNG and LNG versions of its trucks that use the Cummins Westport ISL G engine to meet the 2010 EPA and CARB certification rules. The vehicles have a GVW of 242,000 pounds.

5.2.3 Cummins Westport Inc.

Diesel engine manufacturer Cummins and Canadian natural gas engine builder Westport formed a joint venture to build CNG, LNG, and HCNG engines based on the Cummins engines. The joint venture currently offers four versions of the engines, including the ISL G Series that is certified to meet 2010 EPA and CARB rules. These engines are designed to work in M/HD truck applications and to work with CNG, LNG, and biogas.

Cummins Westport is not only the largest OEM of NGV engines in the United States, but also the only manufacturer to build engines for the transit bus market. Its engines have essentially no competition in North America from other OEMs for natural gas, though several retrofitters do compete with Cummins Westport.

Outside the United States, Cummins Westport’s position is no less strong, though there is additional competition from OEMs who are choosing to build NGVs based on their own engine technology. Westport recently formed a joint venture with Weichai Power to develop NG engines for China and other Asia Pacific markets.

5.2.4 Emissions Solutions Inc.

Emissions Solutions Inc. is a gaseous fuel engine manufacturer and converter for M/HD trucks. Its engines are certified as meeting 2010 EPA and CARB rules. The company’s conversion services include all tanks and engine replacement for fleet customers. In addition, Emission Solutions has partnered with International Truck and Engine Corp. to provide CNG versions for new trucks and buses.

5.2.5 Foton

Foton is a Chinese bus manufacturer that currently builds CNG buses for the Middle East and Asian markets. The company is the largest provider of CNG buses to the Karachi, Pakistan market.

Foton is preparing a version of its CNG bus to be sold in North America, and recently sent one to be tested for EPA certification. This vehicle will be powered by the Cummins Westport CNG engine. The Chinese-made chassis and body will have American components and parts in order to qualify for the "Buy American" requirement placed on the funding requirements for government purchases. This will allow Foton to compete for transit bus orders in the U.S.

Foton is also planning a CNG box truck for the U.S. market in 2011 or 2012. Foton's launch in the United States has been delayed slightly, but is expected to begin ramping up quickly in 2011.

5.2.6 Freightliner

Freightliner is one of the brands owned by Daimler Trucks North America (Sterling, Thomas-Built Buses, and Western Star are others). Freightliner and Daimler currently offer the Business Class M2 112 in both LNG and CNG versions. These vehicles feature Cummins Westport engines.

Freightliner is one of the top truck brands (along with Navistar International and Ford) for cab-and-chassis trucks. Daimler Trucks North America employs 14,000 people in the United States, with sales of $24.93 billion in 2009.

5.2.7 Gillig

Gillig is the second largest transit bus manufacturer in the United States, holding approximately 27% market share with sales of approximately 1,200 to 1,400 per year. Gillig produces LNG and CNG versions of its transit bus and utilizes Allison Transmissions' hybrid system for its hybrid buses. In 2008, Gillig employed 700 people and had $77.8 million in revenue.

5.2.8 Iveco

Iveco recently announced a CNG version of its EcoDaily, a bi-fuel panel truck (light-duty). It is also manufacturing CNG buses for a variety of transit services around Europe. At the end of 2008, Iveco had a fleet of about 5,000 CNG buses operating in Europe. In addition, the company offers its Stalis CNG, an HD truck chassis often used for refuse trucks, using its Cursor 8 CNG engines. Iveco trucks use stoichiometric mixture combustion, which the company claims provides its CNG trucks with "near fuel cell levels" of emissions.

5.2.9 Mack Trucks

Mack Trucks is a manufacturer of refuse, construction, and over-the-road HD trucks. While the company focuses mainly on diesel products, it does offer CNG versions of its TerraPro Cabover refuse trucks.

Mack Trucks holds the dominant market share in the refuse truck market (close to 50%). As part of the Volvo Group, the company previously had a CNG engine supplied by Volvo, but now uses Cummins Westport ISL G engines for its CNG refuse trucks.

5.2.10 Navistar/International Truck and Engine Corp.

Emissions Solutions provides a CNG-converted version of some International Truck and Engine models, though there are no Navistar/International Truck and Engine Corp. OEM versions of CNG trucks at present. The current Navistar trucks have all exceeded the 2007 EPA certification rules. Thus, Navistar/International Truck and Engine Corp. has built up enough credits to continue selling diesel engines into 2011 without changes to the engine. It has been working to develop its own natural gas engine, but has yet to bring it to market. Whether it will continue to work toward this goal, or whether it will partner with another supplier like Cummins Westport for the engines, is unclear.

5.2.11 New Flyer Bus

New Flyer is a bus manufacturer in North America that offers a variety of drivetrains in its transit buses, including hybrid, fuel-cell, full electric, and natural gas. It was the first bus manufacturer in the United States to offer natural gas-powered versions, and continues to offer buses powered by Cummins Westport engines. New Flyer was also one of the first companies to explore FC-powered buses. New Flyer is now working with ISE Corp. to test a CNG hybrid electric bus in California.

New Flyer Bus employs 2,300 people and had revenue of $961.3 million in 2008.

5.2.12 Volvo

In 2008, Volvo discontinued its CNG light-duty wagons (sold primarily as taxis). Volvo is working with conversion companies, including Alternative Fuel Vehicles, to produce bi-fuel versions of its S70 and V50 for Sweden, Switzerland, and Italy.

Volvo trucks are currently manufactured with diesel engines, but several upfitters are working to convert Volvo trucks to CNG or LNG.

5.2.13 Westport

Westport is a Canadian manufacturer of natural gas engines. It has partnered with several companies to provide engines for a variety of applications. The Westport HD is a heavy-duty engine for Class 8 trucks based on the Cummins ISX diesel engine. Westport also partners with OMVL SpA of Italy to manufacture industrial CNG engines for smaller applications (forklifts, etc.).

The joint venture with Cummins currently holds the largest market share in the HD NGV engine market. Additionally, Westport has a joint venture with Beijing Tianhai Industry Co. Ltd. (BTIC Westport Inc.) to manufacture and sell LNG tanks in the Chinese markets. Westport also partners with Weichai Power, Ltd. (Weichai Westport Inc.) to develop and manufacture CNG and LNG engines for China.

5.2.14 Weichai Power, Ltd.

Weichai Power is the world’s largest producer of diesel engines, producing more than 300,000 HD diesel engines annually. In fact, the company holds 36% of the HD vehicle engine market share in China. In 2008, Weichai entered into a joint venture with Westport to develop and manufacture natural gas engines for the HD market in China. Weichai Power had sales of $5.29 billion in 2009.

5.3 Key Suppliers/NGV Converters

5.3.1 Advanced Fuels Technologies, Pty Ltd.

Advanced Fuels Technologies (AFT) is an Australian company that manufactures storage tanks for CNG and LNG conversions, particularly in the heavy-duty vehicle market (trucks and buses). While AFT largely works on projects in Southeast Asia (including Thailand and China) and Australia, it has also worked with converters in Europe and North America.

5.3.2 Altech-Eco Corp.

Altech-Eco Corp. is part of Transeco Energy Corporation, an NGV station builder located in Ashville, N.C. Altech-Eco holds EPA certification for converting 2010 Ford Focus vehicles to either dedicated or bi-fuel CNG. It is currently working in conjunction with Ford and dealers to deliver the Focus directly to dealers and maintain the Ford vehicle warranty; the emissions warranty comes from Altech-Eco.

Altech-Eco has additional models available for conversion, including the 2010 Ford Fusion, Ford E-Series van, Ford F-250/350, and Transit Connect. Altech-Eco is thought to employ about 60 people, and is estimated to complete 4,000 and 6,500 conversions per year.

5.3.3 BAF Technologies

BAF Technologies is an engine converter located in Dallas, Texas. It provides CNG, LPG, LNG, and dual-fuel (CNG and diesel) systems for light-duty and heavy-duty vehicles and has both EPA and CARB certification. BAF Technologies works with Ford to deliver converted vehicles to the dealer so that the conversion is invisible to the end customer. The company uses components manufactured by Bosch and other suppliers. In September 2009, BAF Technologies was sold to Clean Energy Fuels for $8.3 million (Clean Energy Finance already owned $3.8 million of BAF Technologies' debt).

BAF Technologies is developing bi-fuel vehicles for 2011, and has some of the highest volumes of NGV deliveries in the United States.

5.3.4 Baytech Corp.

In 2010, Landi Renzo purchased Baytech Corporation as part of an effort to enter the U.S. market. The Baytech network of installers provided Landi Renzo with access to a nationwide group of installers for their products. Baytech Corp. installs a wide variety of engine conversions for light-, medium-, and heavy-duty GM, Ford, and Isuzu trucks for the North American market. Its systems include CNG, LNG, and LPG, and they meet all the CARB and EPA requirements to qualify as LEV, ULEV, and SULEV.

5.3.5 The Bosch Group

Bosch is the one of largest (in terms of sales) automotive suppliers in the world. While the company provides an array of components to global auto manufacturers, it supplies injectors, engine control units, bi-fuel control systems, and other components (such as pressure regulators, tank valves, and more) for the NGV market. The company works with most major auto manufacturers, including GM, Volkswagen, Chrysler, Toyota, and others. In addition, Bosch works globally and produces bi-fuel components for the Latin American, European, and Chinese markets.

Bosch Group employs 280,000 people worldwide and its sales totaled $66.4 billion in 2008. In the United States, the company employs approximately 24,000, with sales totaling $8.3 billion in 2008.

5.3.6 Clean Energy Fuels Corp.

Clean Energy Fuels is a natural gas company that provides infrastructure for NGVs, including CNG and LNG shipping and refueling stations. Clean Energy Fuels was founded by T. Boone Pickens and operates 184 natural gas refueling stations across North America. The company also has a biogas plant in Texas to develop landfill natural gas for the national pipeline. Additionally, Clean Energy Finance (a subsidiary of Clean Energy Fuels) provides financing for a variety of natural gas projects. In September 2009, it agreed to purchase BAF Technologies (an engine converter).

Clean Energy Fuels has been one of the leading natural gas companies building refueling stations at no charge to fleet customers so long as they agree to a fuel contract. This strategy of giving away the station as a tool to sell the fuel has helped Clean Energy become one of the most prolific refueling infrastructure companies in the United States.

5.3.7 FAB Industries

FAB Industries is a tank/storage system supplier for LNG, CNG, and hydrogen. It works with a variety of converters throughout North America to adapt heavy-duty trucks and buses. The company focuses its marketing on the design and manufacture of storage systems for mass transit buses.

FAB Industries had sales of approximately $3.5 million in 2009, and employs roughly 35 people.

5.3.8 Fuel Systems Solutions, Inc.

Fuel Systems Solutions is a holding company for a few natural gas refilling suppliers, including BRC and IMPCO Technologies, both of which provide components for converting vehicles to CNG and LNG fuels. Additionally, BRC provides some components for natural gas refilling stations.

In the fall of 2010, Fuel Systems Solutions acquired converter EvoTek, LLC. It is unclear whether EvoTek had EPA and CARB certifications for both Ford and GM conversions for 2010.

Fuel Systems Solutions purchased the assets of FuelMaker, which manufactured the home refilling system Phill, among other smaller CNG refilling systems. Fleet refilling systems and home refueling systems represent very attractive elements of the natural gas market. FuelMaker's past experience points to a potential strength for Fuel Systems Solutions in the infrastructure marketplace for fleets.

In 2009, Fuel Systems Solutions' revenue totaled $425.3 million, and the company employed about 1,760 people around the world.

5.3.9 GNC Galileo

GNC Galileo is an Argentina-based company that supplies natural gas compression equipment for refueling stations around the world, as well as vehicle conversion equipment and natural gas transportation equipment. It has become one of the largest CNG compression manufacturers, due largely to Argentina's large CNG station network.

5.3.10 Kraus Global

Kraus Global is a Canadian company that supplies dispenser equipment for CNG, LNG, LPG, and hydrogen refilling stations. It focuses on OEMs and refilling equipment, including the nozzles and meters/registers for measuring the fuel. Despite being located in Canada, Kraus Global sells most of its products outside North America. Prior to 2005, the company also manufactured gas compressors; however, as competition from manufacturers in Latin America and Asia (strong natural gas markets) increased due to low-cost compressors, Kraus Global left that market to focus on the dispenser business.

5.3.11 Landi Renzo

Based in Italy, Landi Renzo is a leading supplier of CNG equipment. The company currently supplies most OEMs in the alternative fuel market in Europe, including Fiat, GM, Mercedes, Toyota and Nissan. It is also a leader in the LPG market in Europe. Landi Renzo SpA had revenue of €270.8 million in 2009, up 25% from 2008.

In 2010, Landi Renzo entered the U.S. market and purchased Baytech Corp. to gain access to a wide installation network. In that process, it was able to purchase the certifications for both EPA and CARB for GM vehicle conversions.

5.3.12 Magneti Marelli

Magneti Marelli is an Italian automotive components supplier and aftermarket parts and service provider that serves Europe, Brazil, and Argentina. The company is part of the Fiat group. Magneti Marelli produces a variety of vehicle components, including NG components such as fuel rails with injectors, manifolds, engine control units, pressure regulators, and throttle bodies. These components are used in bi-fuel systems in both OEM Fiat vehicles and conversions.

Magneti Marelli had revenue of €5 billion in 2007, 28,000 employees, 46 production sites (56 production units), 9 R&D Centres and 27 Application Centres. The company has a presence in 16 countries (Italy, France, Germany, Spain, Poland, Czech Republic, Russia, Turkey, the United States, Mexico, Brazil, Argentina, China, Japan, Malaysia and South Africa). Magneti Marelli supplies all the leading OEMs in Europe, North and South America, and Asia. Bosch is a major competitor.

5.3.13 OMVL SpA

OMVL is an automotive supplier that manufactures alternative fuel parts for OEM vehicles from Citroen, Fiat, Ford, and Volkswagen. It manufactures many different components of CNG engines, including pressure regulators, injectors, and vaporizers. The company has plants in Iran, Argentina, and Brazil.

5.3.14 Natural Drive

Natural Drive is a conversion company in Arizona that holds EPA certification and works with conversion companies to produce engine computer calibration kits. Natural Drive is working with Productive Concepts International for the installation of its kits into GM vans. For the most part, Natural Drive is a software company that works with installers to ensure that vehicle computers are set to run on natural gas and LPG.

In early August, Fuel Systems Solutions announced it had completed the purchase of PCI for $11.1 million. The likely impact is that PCI will shift to using IMPCO Technologies equipment for the conversions. Natural Drive’s relationship with PCI is (according to GM press releases) still intact. It is expected that Fuel Systems Solutions may either terminate the agreements with Natural Drive or expand the relationship.

5.3.15 Productive Concepts International

Located in Indiana, Productive Concepts International is a CNG conversion company that partners with GM to deliver the GMC Savana and Chevrolet Express CNG vans. Manufactured by GM in Missouri, the vans are transferred to PCI's facility for integration of the CNG equipment.

In early August, Fuel Systems Solutions announced that it completed the purchase of PCI for $11.1 million. This will likely mean that PCI will shift to using IMPCO Technologies equipment for the conversions.

5.3.16 Prins Autogassystemen BV

Prins provides LNG, CNG, and liquid petroleum gas components for both the light-duty and heavy-duty markets. It manufactures gaseous fuel injectors that work with both LNG and CNG for a wide range of engine types. In addition to working with OEMs, Prins works with upfitters and converters to simplify the conversion of vehicles to LNG, CNG, or LPG.

Prins is one of the key suppliers to smaller auto and truck manufacturers in Asia and the Middle East. It partners with Proton (Malaysia), Saipa, and Zamyad (both Iranian). Prins also works with OEMs in specific countries in Europe, including Ford of Europe, Cadillac in Europe, Chrysler in the Netherlands, Lada of Germany, and Volvo in Sweden.

5.3.17 Roush

Roush is an automotive engineering, aftermarket, testing, and prototyping company with a division that conducts LPG conversions. The company converts Ford's E-Series van and F-Series pickup trucks to LPG, and maintains a very close relationship with Ford, delivering vehicles directly through Ford dealers. Roush has the leading share of the LPG vehicle market in North America.

The company is privately held, with sales of $125.2 million in 2008 and 2,400 employees.

Section 6

MARKET FORECASTS

6.1 Global Natural Gas Vehicle Forecast: 2010-2016

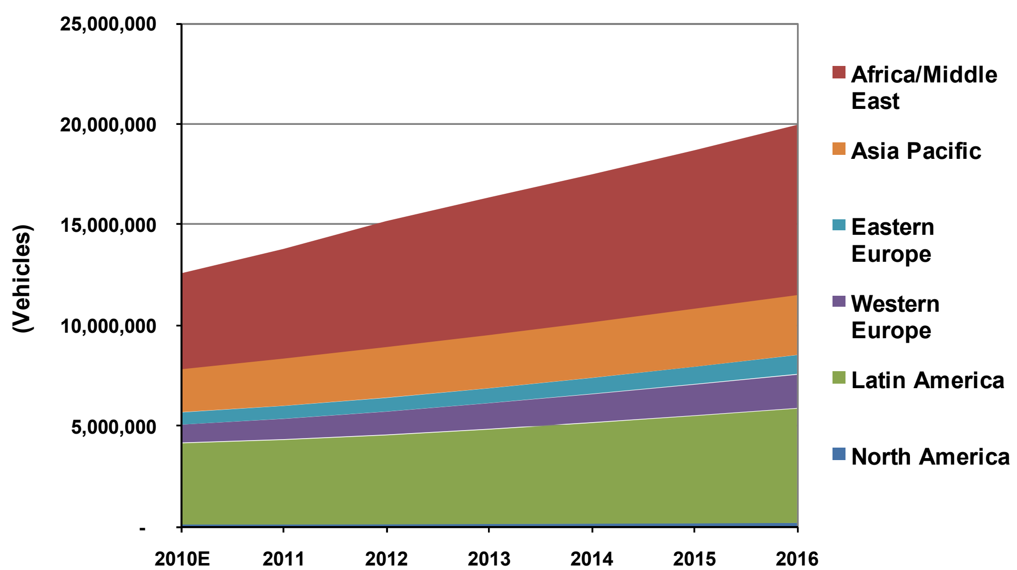
There are currently about 12.57 million NGVs globally, with the majority located in the Africa/Middle East and Latin American markets. In general, the NGV market is volatile, as many countries with weaker economies or political instability look to push NGVs as a defense against oil prices. There are a variety of strains on the marketplace in such regions, both on the supply side for fuel and on the retail side for station owners trying to eke a profit out of a very low cost fuel. However, the incentives to go to NGV remain strong and the vehicles continue to be adopted as governments, fleets and consumers look for an emissions solution and a hedge against oil prices.

The worldwide fleet of NGVs will continue to grow during the next five years due to strong continued sales in specific regions as NGVs replace gasoline or diesel vehicles. The net result will be a growing cumulative fleet of NGVs at a rate of 8.3% CAGR by 2016, resulting in 20.3 million NGVs globally.

The Africa/Middle East market is expected to remain the largest region for NGVs. By 2016, this region will have 8,766,650 NGVs on the road, thanks in no small part to continued growth in the production of natural gas keeping the cost of fuel low. This growth (10.9% CAGR between 2010 and 2016) will come mostly at the expense of gasoline and diesel vehicles, as opposed to existing CNG vehicles.

Latin America is the second largest market for NGVs, and will see positive growth of 5.9% CAGR in its number of NGVs.

Chart 6.1 Cumulative Natural Gas Vehicles Forecast: 2010-2016



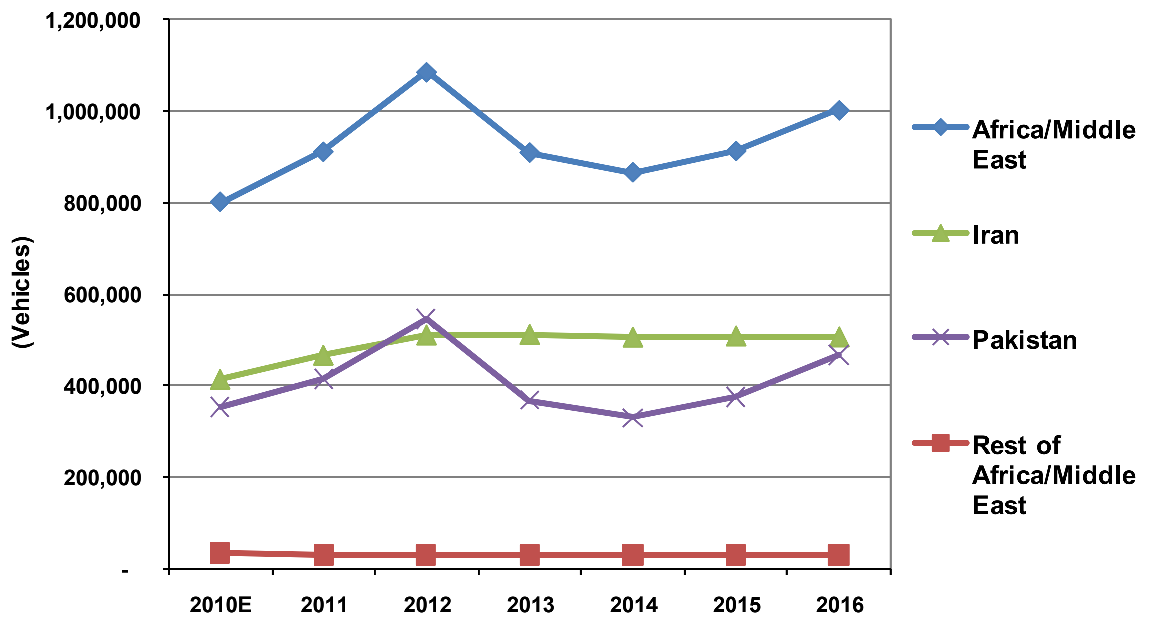
(Source: Pike Research)

6.1.1 NGV Sales Forecast, Middle East/Africa: 2010-2016

Over the past decade, the Pakistani market has proven to be volatile, and the next several are expected to be the same. While currently on an upswing, sales are expected to peak in 2012 as gas prices climb. A combination of expected restrictions on natural gas development and poor reporting of new discoveries from far regions of the country will cause the higher prices. Pakistan NGV sales are anticipated to peak at 546,137 vehicles in 2012 (similar to 2007 sales in the market), then fall to 330,263 NGVs sold in 2014 before rebounding again, resulting in a CAGR of 4.8% between 2010 and 2016.

Iran will be much more stable, but sales are expected to be relatively stagnant after peaking in 2012-2013. Due to the fuel's low level of profitability, the country has trouble attracting new refueling stations. As a result, Iran's 1,631 vehicles per station will climb to 3,070 vehicles per station in 2016. This high ratio will result in longer lines and growing frustration among consumers. Vehicle sales, while still high when compared to other regions (504,986 vehicles in 2016 on 3.8% CAGR between 2010 and 2016), are expected to see little growth after 2012, unless the situation for station owners improves.

Chart 6.2 Natural Gas Vehicle Sales (Including Conversions), Africa/Middle East: 2010-2016

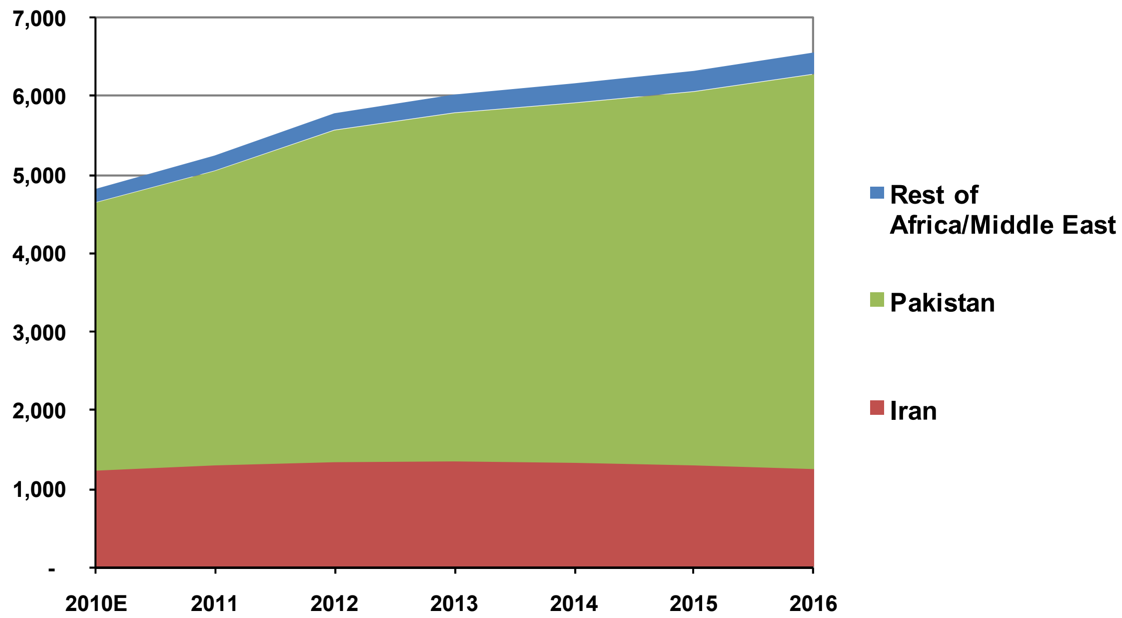


(Source: Pike Research)

Pakistan has the greatest number of refueling stations in the world and that number is expected to grow until 2016 (6.7% CAGR), driven by the already large population of vehicles in the country and the growing need for refueling points. By 2016, Pakistan is expected to have 5,036 stations, up dramatically from 3,416 in 2010.

In contrast, Iran has comparatively few stations, with just 1,234 (for 2.0 million NGVs). As mentioned, Iranian station growth will be followed by anticipated losses as station operators give up on natural gas. Iran's refueling station CAGR will be 0.2% between 2010 and 2016, resulting in 1,253 stations.

Chart 6.3 NGV Refueling Stations, Africa/Middle East: 2010-2016



(Source: Pike Research)

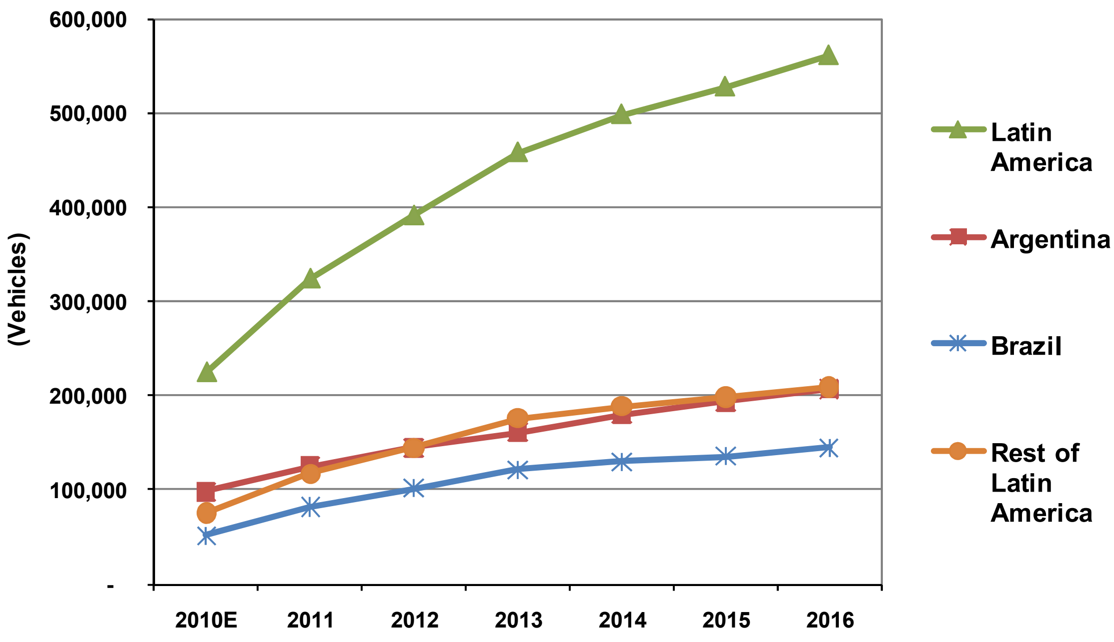
6.1.2 Latin America Forecasts: 2010-2016

In the past several years, the Latin American markets have seen strong growth in NGVs, thanks to increased availability and affordability of the fuel. Argentina continues to show strong growth and there is no reason to expect this to slow. As a result, Argentina is projected to see sales grow from 97,898 in 2010 to 207,130 in 2016 (13.3% CAGR).

Brazil will experience similar early growth, but its market for NGVs is expected to slow slightly as ethanol producers push to maintain competitive rates for locally grown fuel. However, this is a modest concern and overall NGV sales growth in Brazil will be strong (18.8% CAGR between 2010 and 2016). The Brazilian market for NGVs will be 144,726 vehicles by 2016.

Other parts of Latin America are expected to see strong growth in NGV sales, including Chile, Columbia, Peru, and Bolivia. While these countries currently represent small markets, they have gas available and have seen growing numbers of NGVs. Pike Research expects these to be strong markets for growth, but also expects them to remain small through the end of the decade.

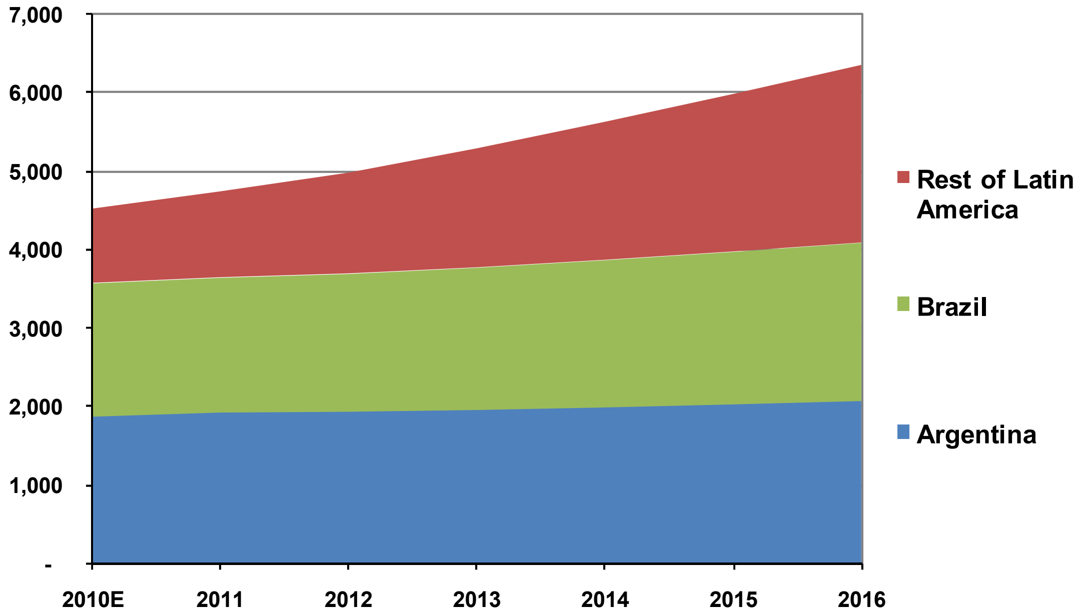
Chart 6.4 Natural Gas Vehicle Sales (Including Conversions), Latin America: 2010-2016



(Source: Pike Research)

While the large NGV countries of Brazil and Argentina are looking at modest refueling station growth between 2010 and 2016 (2.9% and 1.7% CAGR, respectively), other areas within Latin America are expected to build stations at a rate that keeps pace with vehicle sales. Overall, the region will have a station for every 893 NGVs by 2016, but as one might expect, the parts of Latin America with lower vehicle counts will have fewer vehicles per station (620 in 2016).

Chart 6.5 NGV Refueling Stations, Latin America: 2010-2016



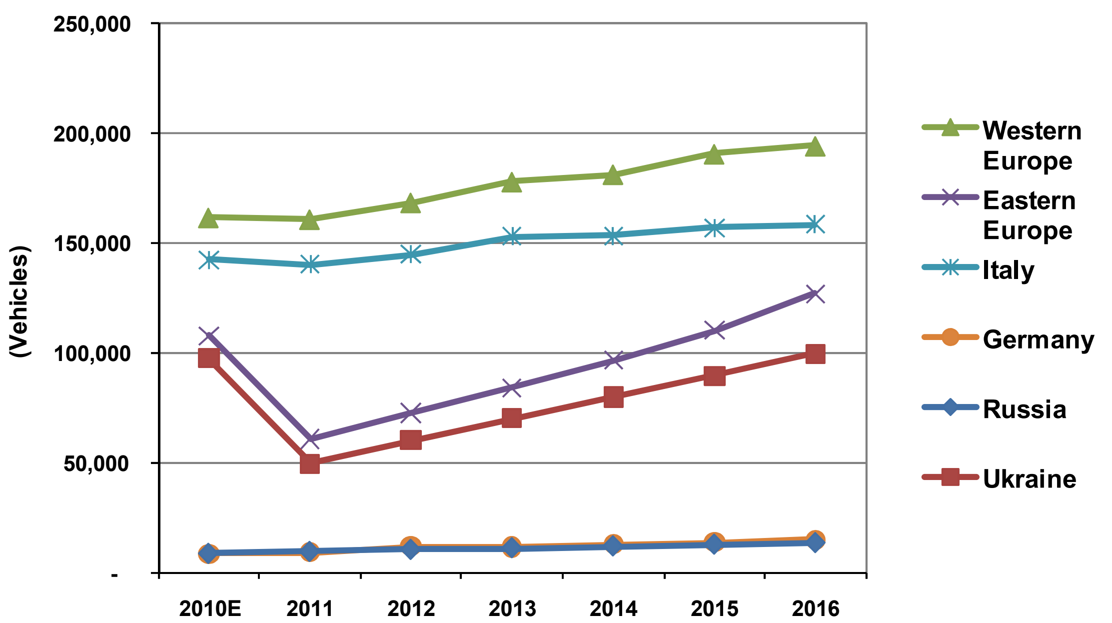
(Source: Pike Research)

6.1.3 NGV Sales Forecast, Eastern and Western Europe: 2010-2016

In Western Europe, continued strong OEM support for CNG and growth in government support for refueling infrastructure will result in growth of the market overall. Lead by Italy, Western Europe is expected to see moderate growth of 3.1% CAGR, which will result in sales of 194,208 vehicles in 2016. Italy is expected to remain the largest market for NGVs, thanks to support from domestic OEM, Fiat. Other markets within Europe will also see strong growth due to less expensive CNG than gasoline or diesel, though the fuel will remain a niche market (German sales are expected to be 14,924 in 2016, the largest European market outside of Italy).

In Eastern Europe, the Ukrainian market has been highly volatile in the last few years. As a result, Pike Research is expecting that after another big sales year in 2010 (97,613 vehicles), the sales in Ukraine will decline, then rebound by 2016 (99,655 vehicles). While there is a substantial amount of natural gas available, thanks to the pipelines from Russia, the Russian government is looking to reduce dependence on Ukraine with new pipelines. This will make the Ukraine more susceptible to price fluctuations and supply decreases from Gazprom.

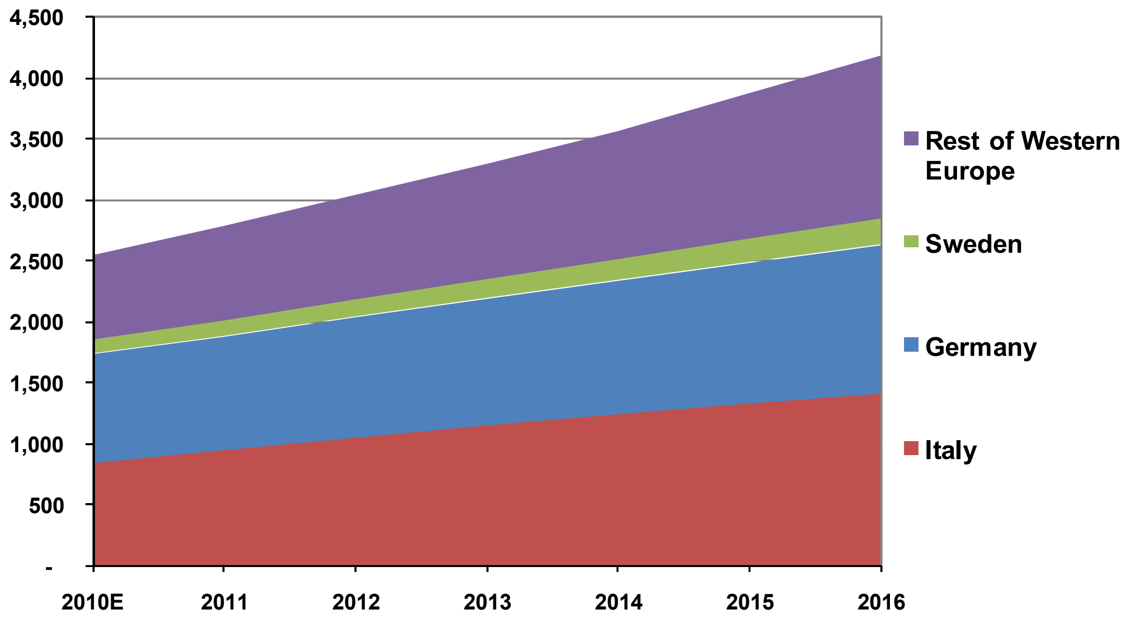
Chart 6.6 Natural Gas Vehicle Sales (Including Conversions), Eastern and Western Europe: 2010-2016



(Source: Pike Research)

Western Europe is expected to have the strongest refueling station growth with 8.6% CAGR between 2010 and 2016. Germany and Italy's support of CNG vehicles will result in strong growth in these countries (5.2% and 8.9%, respectively). The German government is using incentives and grants to develop a wider network of refueling stations to spur development of the vehicles (particularly for fleet vehicles).

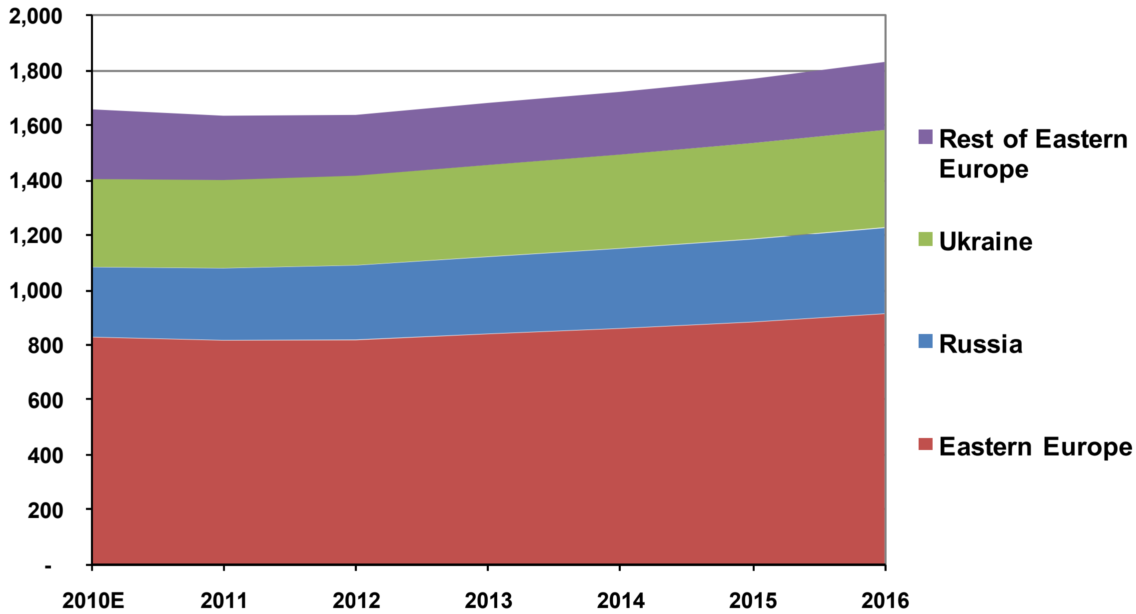
Chart 6.7 NGV Refueling Stations, Western Europe: 2010-2016



(Source: Pike Research)

Eastern European refueling infrastructure growth is expected to be relatively modest (1.6% CAGR between 2010 and 2016). While the Ukrainian vehicle market is strong, the number of refueling stations are not as prevalent (320 stations in 2010), likely due to installation costs and low profitability of stations in that country.

Chart 6.8 NGV Refueling Stations, Eastern Europe: 2010-2016



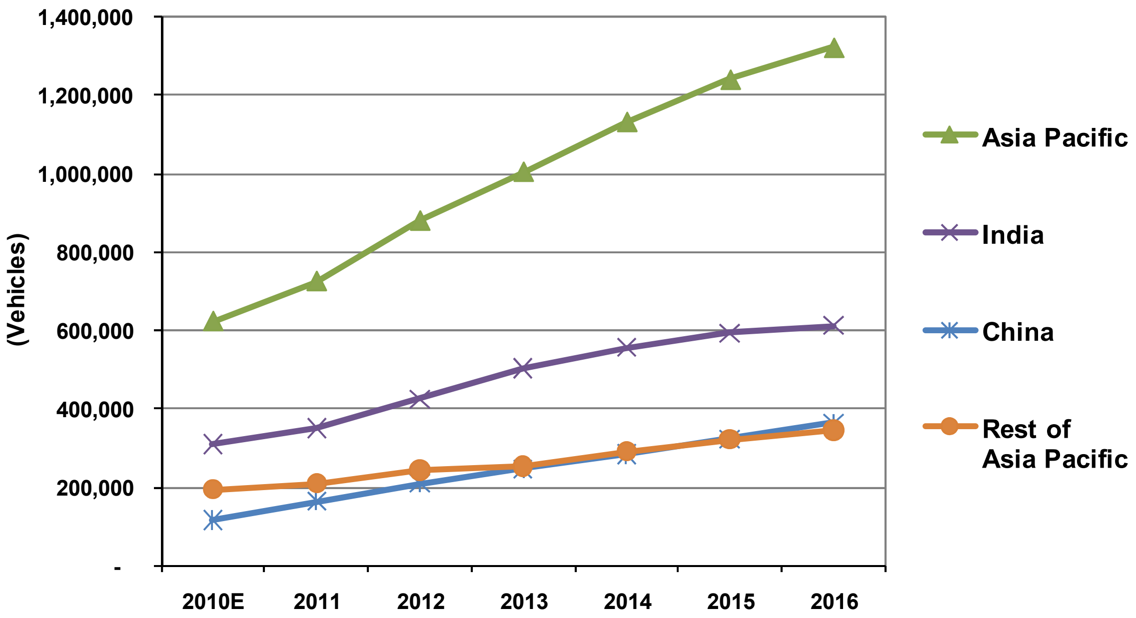
(Source: Pike Research)

6.1.4 NGV Sales Forecast, Asia-Pacific: 2010-2016

The Asia-Pacific market is the second largest market for NGVs, and is expected to become the largest market by 2016 (1,322,084 vehicles in 2016). This growth will be in part due to India's continued acceptance of CNG as a vehicle fuel for government and corporate fleets. The lower cost for CNG and the government crackdown on vehicle emissions will result in 12.0% CAGR in India to become the largest NGV market in the world (612,390 vehicles in 2016).

China continues to see strong vehicle sales overall, and the NGV market is anticipated to benefit from this. In addition, the increasing scrutiny on emissions from diesels will see the Chinese market for CNG and LNG trucks grow. The NGV market in China is expected to grow at 20.8% CAGR between 2010 and 2016, resulting in a 364,049 NGV market in 2016.

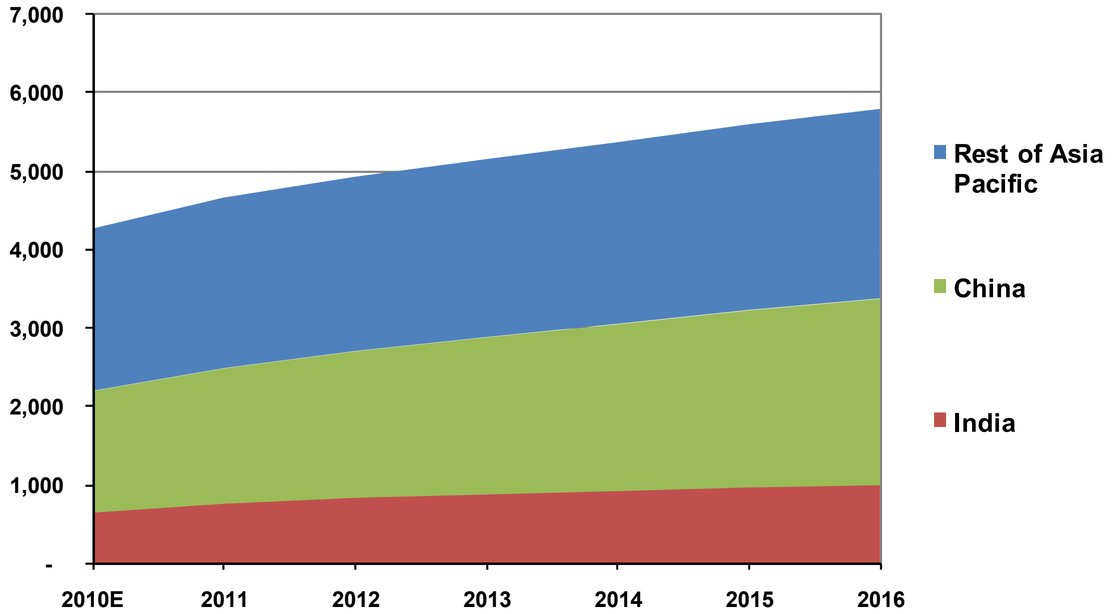
Chart 6.9 Natural Gas Vehicle Sales (Including Conversions), Asia Pacific: 2010-2016



(Source: Pike Research)

Because many of the refueling stations in Asia-Pacific are government funded and most will support fleet vehicles, the growth of refueling stations is anticipated to be strong (5.2% CAGR between 2010 and 2016). By 2016, China will trail only Pakistan for the number of NGV refueling stations (2,376 in China and 5,036 in Pakistan). India is anticipated to have growth of 7.5% CAGR for refueling stations as the stations are spread out to other cities and more broadly within India's largest cities.

Chart 6.10 NGV Refueling Stations, Asia Pacific: 2010-2016

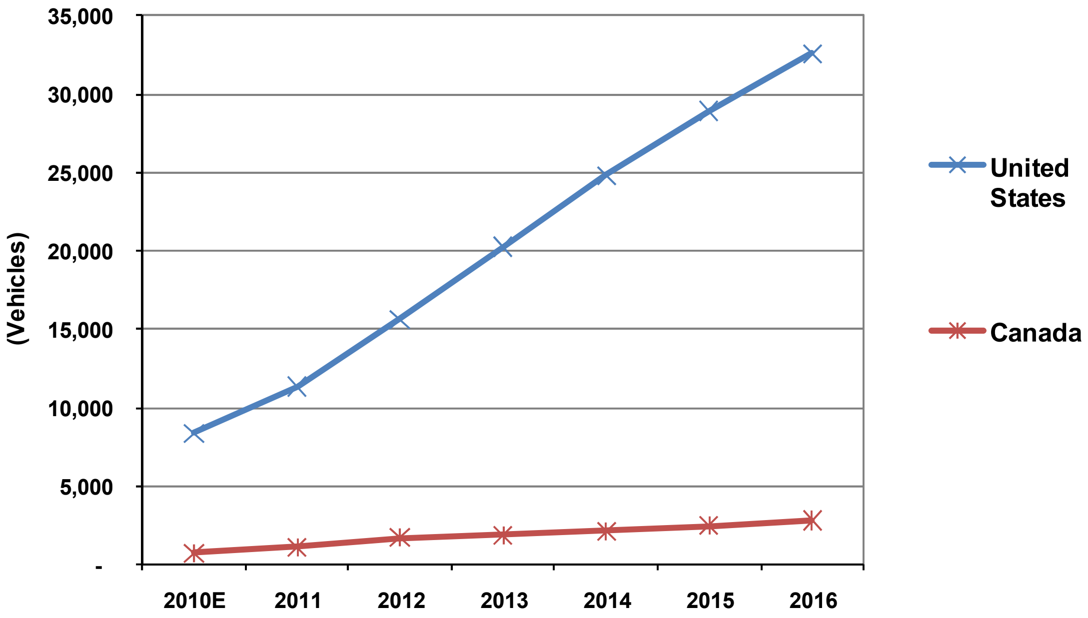


(Source: Pike Research)

6.1.5 NGV Sales Forecast, North America: 2010-2016

Growth of NGVs in the United States is highly dependent on government incentives. Assuming that the incentives that are currently being debated do end up passing in some form, then growth is expected to be strong (25.4% CAGR between 2010 and 2016). This growth is also supported by continued legislation towards reduced diesel emissions and acceptance by fleets of natural gas a vehicle fuel. In Canada, where the incentives are not broadly available, the NGV market is expected to grow at a similar rate (25.2% CAGR), albeit remain a very small market (2,821 vehicles by 2016).

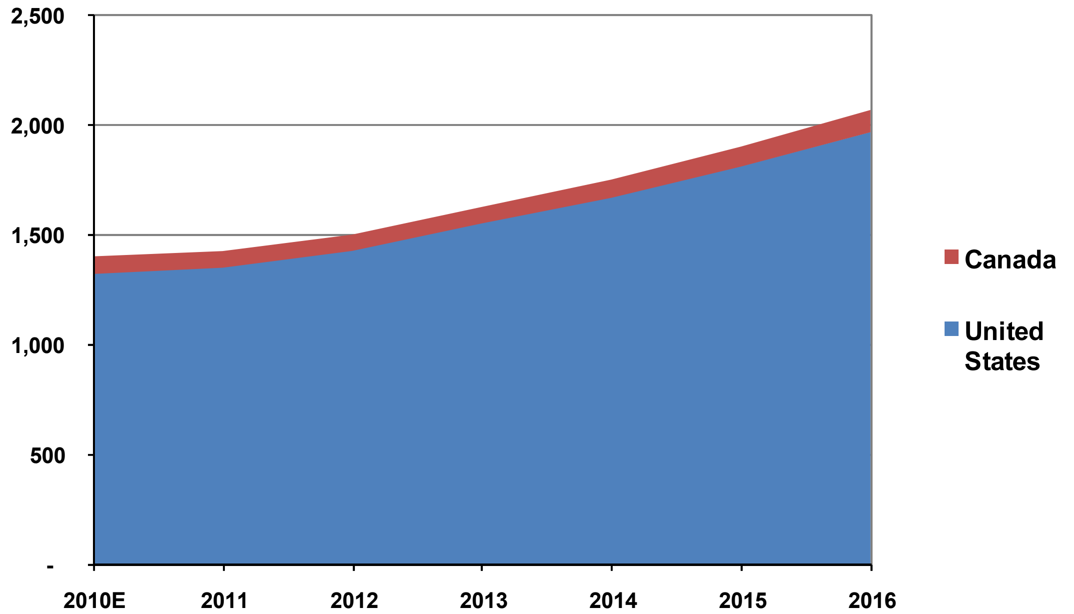
Chart 6.11 Natural Gas Vehicle Sales (Including Conversions), North America: 2010-2016



(Source: Pike Research)

Similar to the vehicle market, the refueling infrastructure in the U.S. will see strong growth (6.8% CAGR) thanks to incentives and profitability of the gas. The number of stations are anticipated to reach 1,972 by 2016 in the U.S. While open to the public, most of these stations will serve fleets.

Chart 6.12 NGV Refueling Stations, North America: 2010-2016



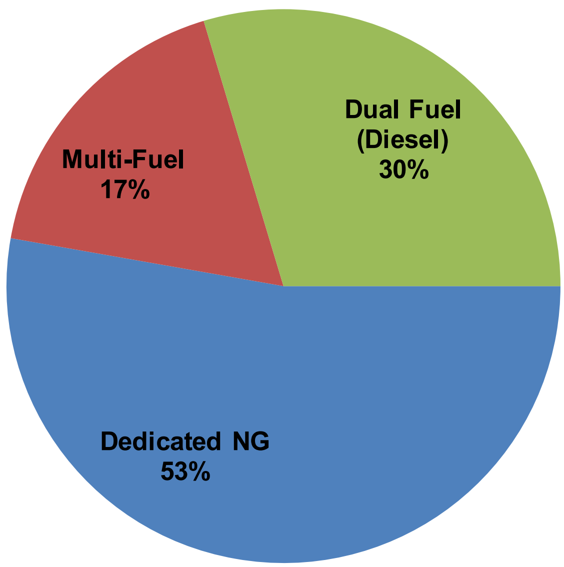
(Source: Pike Research)

6.2 Multi-fuel Vehicles

In Latin America, the majority of NGVs are multi-fuel (typically bi-fuel) vehicles. However, 83% of the NGVs in North America are likely to be dedicated or dual-fuel (using diesel as an ignition source). This is because the U.S. government purchase incentives have only applied to dedicated or dual-fuel, not bi-fuel vehicles. As a result, there are only a few conversion companies that offer bi-fuel vehicles and no OEMs offer bi-fuel vehicles in the United States.

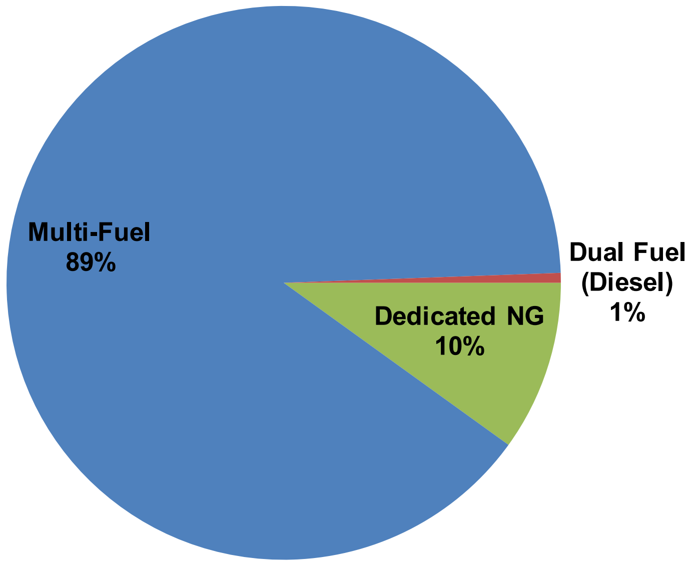
At the moment, the mix of bi-fuel vehicles in the United States is on the precipice of growth. The issue of incentives is addressed in some versions of the NAT GAS Act, and there appears to be renewed interest from conversion companies. However, it is too early to tell whether the bi-fuel market in North America has legs.

Chart 6.13 Multi-Fuel Vehicles, North America: 2010



(Source: Pike Research)

Chart 6.14 Multi-Fuel Vehicles, Latin America: 2010



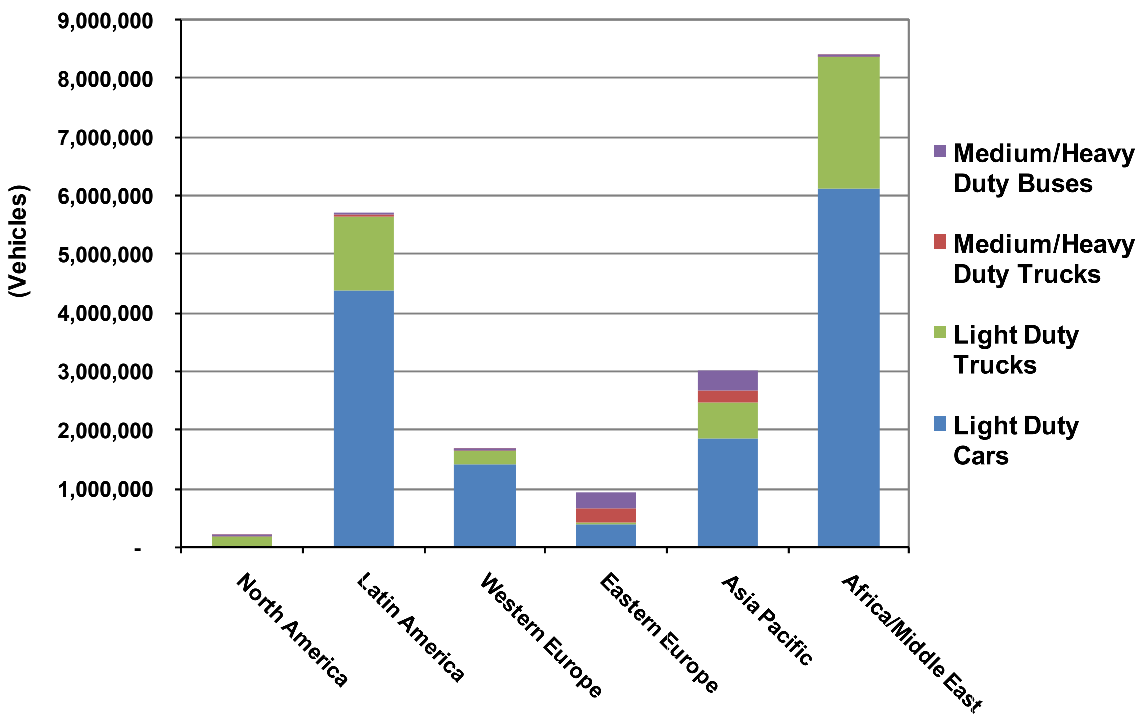
(Source: Pike Research)

6.3 NGV by Vehicle Segment Forecast

In all regions except North America and Eastern Europe, the NGV market will be dominated by the passenger car segment. In North America, light trucks draw the most interest and are expected to continue to do so through 2016 (175,292 LD trucks sold; 86% of North American NGVs). In Eastern Europe, passenger cars have the largest share of the market, but are closely followed by natural gas M/HD buses and M/HD trucks (370,010 cars, or 40% sold in 2016; 285,516 M/HD buses, or 31%; 220,573 M/HD trucks, or 24%).

Interestingly, the M/HD truck segment is expected to be the fastest growing segment, albeit also the smallest segment in most regions. Between 2010 and 2016, the M/HD truck segment will see CAGRs of between 6.5% in Latin America and 12.3% in Western Europe. The increasing regulation of emissions from large diesel trucks will certainly help push the interest in NGVs during the middle years of the decade.

Chart 6.15 Natural Gas Vehicle Segments (including Conversions), World Markets: 2016



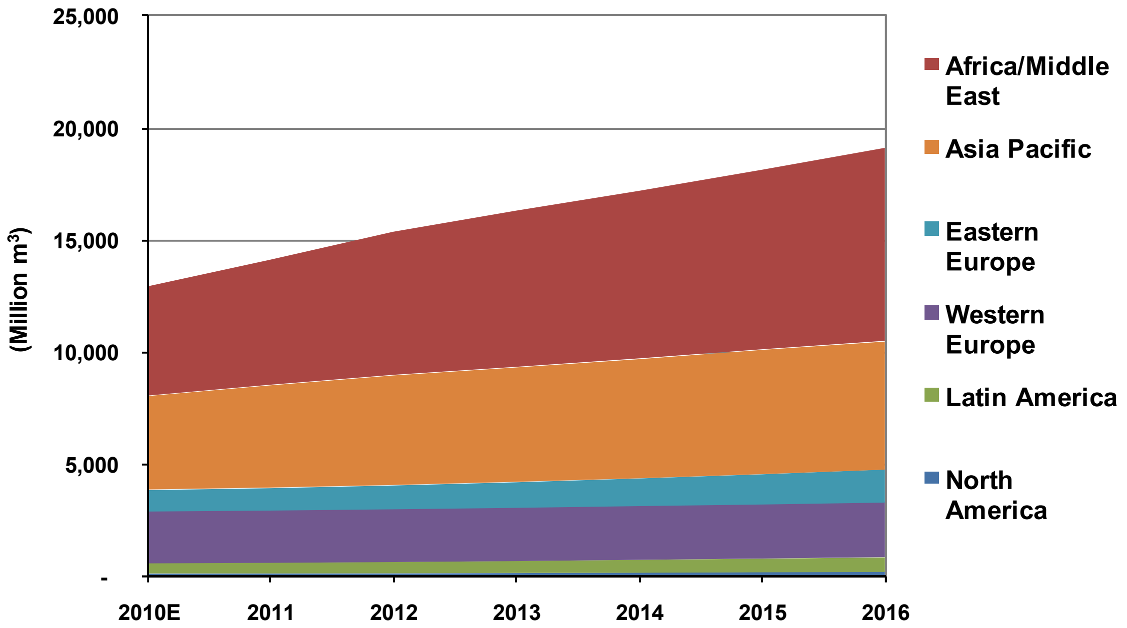
(Source: Pike Research)

6.4 Natural Gas Used for Transportation Forecast: 2010-2016

In 2010, NGVs are expected to use 12,294 million cubic meters of natural gas, which is about 3.459 billion gge used globally in 2010. Africa/Middle East will use the most natural gas for fuel, as would be expected based on the number of NGVs in use in this region. Notably, North America will see very strong growth in the need for natural gas for transportation (8.5% CAGR between 2010 and 2016), given that its fastest-growing NGV segments (M/HD trucks and LD trucks) consume a lot of fuel.

The United States used 591.7 billion cubic meters of natural gas in total in 2009, compared to 107 million cubic meters used for transportation. This is less than 0.5% of the country's total natural gas usage.

Chart 6.16 Natural Gas Used for Automotive Transportation, World Markets: 2010-2016



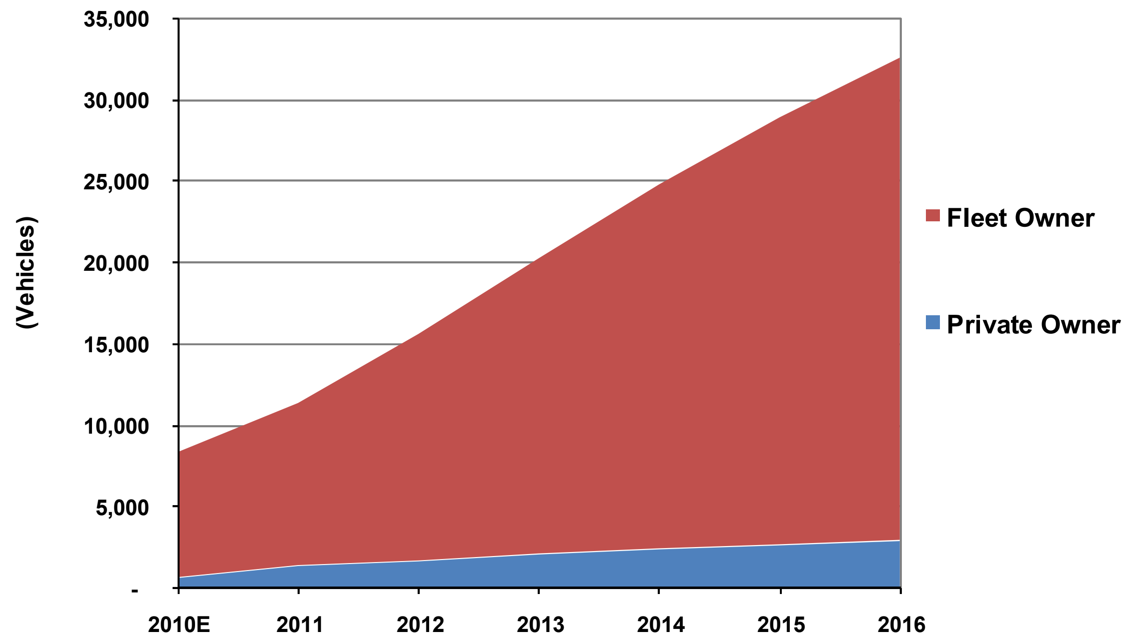
(Source: Pike Research)

6.5 Fleet versus Private Owner Forecast: 2010-2016

Currently, the market for NGVs in North America is almost entirely composed of fleets. Consumers have few choices when it comes to purchasing an NGV, and in fact most have access only to aftermarket conversions. Pike Research is anticipating a 27.7% CAGR between 2010 and 2016 for private owners as infrastructure and new models become more widely available (including potentially new Fiat CNG models and a Toyota model). However, the consumer market for NGVs in the United States is expected to remain very small, reaching 2,970 vehicles by 2016.

At the same time, the fleet market for NGVs is expected to maintain steady growth following slightly slower growth in 2011. Overall, the fleet market will grow at a rate of 25.5% between 2010 and 2016 to reach 29,649 NGV sales.

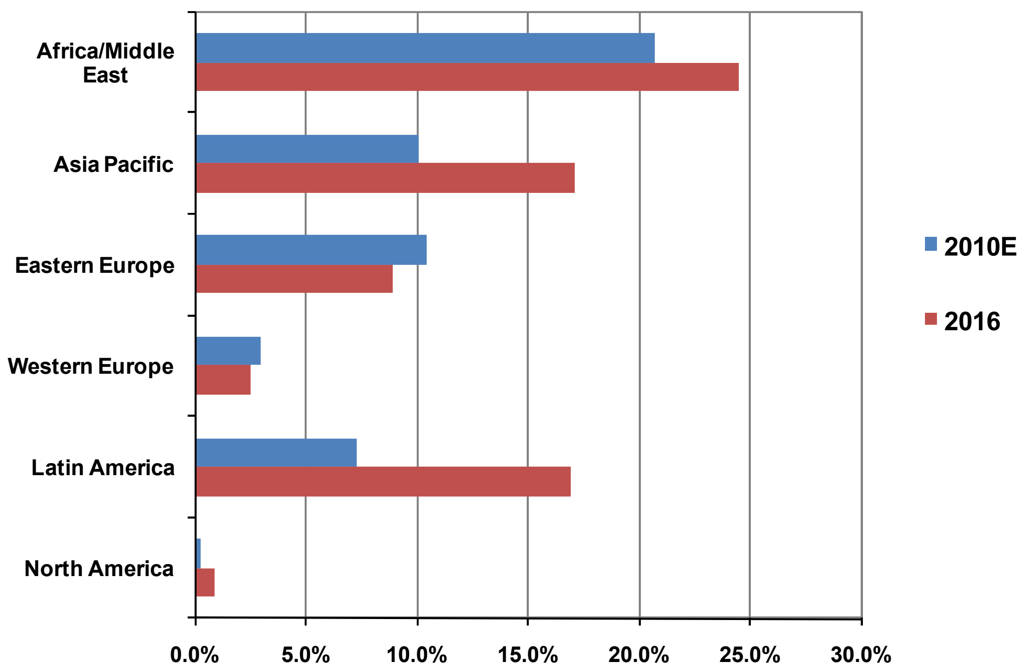
Chart 6.17 NGV Sales, Fleet Versus Private Owner, United States: 2010-2016



(Source: Pike Research)

Not surprisingly, in regions where NGVs sell well, Fleet purchases compose the majority of the sales. In Africa/Middle East, NGVs will account for 24% of fleet sales by 2016, up from 21% in 2010. Asia Pacific is expected to increase its mix of NGVs in fleets as the region comes under greater scrutiny to reduce emissions. In North America, fleet sales are expected to reach 3,754,772 vehicles by 2016, of which 29,649 will be NGVs (amounting to less than 1% of fleet vehicles sold). The one area that will be strong in North America is the bus segment.

Chart 6.18 NGV Percentage of Total Fleet Sales by Region, World Markets: 2010-2016



(Source: Pike Research)

6.6 Taxi Fleet Forecasts: 2010-2016

As the world's population becomes increasingly urban, the largest cities will see continued growth of their transportation industries. Many NGVs are targeted toward these fleets. The taxi market is a special market simply because of its size, and many of the largest taxi fleets are located in strong NGV markets and offer an additional opportunity to NGV adoption. Of the top five taxi fleets, three (Mumbai, Karachi, Sao Paulo) are in the world's strongest NGV markets, where NGV infrastructure may already be available to them.

Table 6.1 Top Largest Global Taxi Fleets: 2010-2016

Segment	Units	2010	2011	2012	2013	2014	2015	2016
Mexico City, Mexico	Vehicles	126,391	127,840	129,307	129,900	130,496	131,394	132,212
Shanghai, Beijing, Guangzhou, China	Vehicles	69,323	71,231	71,885	72,709	73,543	74,218	74,719
Mumbai, India	Vehicles	54,197	55,440	56,330	57,105	57,760	58,423	58,923
Tokyo, Japan	Vehicles	49,362	49,513	49,665	49,741	49,817	49,893	49,963
Karachi, Pakistan	Vehicles	45,043	45,560	45,873	46,189	46,507	46,827	47,119
Sao Paulo, Brazil	Vehicles	34,364	35,546	36,769	37,613	38,130	38,480	38,800
London, UK	Vehicles	19,989	20,429	20,617	20,759	20,901	20,997	21,089
Hong Kong, China	Vehicles	18,993	19,255	19,343	19,454	19,565	19,655	19,718
Paris, France	Vehicles	15,679	15,727	15,799	15,847	15,872	15,920	15,965
New York City, USA	Vehicles	13,451	13,595	13,678	13,782	13,844	13,887	13,927
Dhaka, Bangladesh	Vehicles	9,499	9,572	9,601	9,631	9,660	9,690	9,718
Chicago, USA	Vehicles	6,608	6,679	6,720	6,771	6,802	6,822	6,842
Dubai, United Arab Emirates	Vehicles	5,953	6,089	6,173	6,258	6,344	6,432	6,516
Buenos Aires, Argentina	Vehicles	3,168	3,192	3,217	3,232	3,246	3,261	3,277
Los Angeles, USA	Vehicles	2,313	2,331	2,345	2,363	2,374	2,381	2,388
Johannesburg, Africa	Vehicles	1,854	1,875	1,888	1,901	1,914	1,928	1,940
San Francisco, USA	Vehicles	1,383	1,398	1,406	1,417	1,423	1,428	1,432

(Source: Pike Research)

6.7 Summary and Conclusions

The NGV market remains highly regionalized, with different factors affecting different regions. India is growing rapidly, but seems to have a good balance of vehicles and stations that will help propel it to lead the market in terms of NGV sales. In the Middle East and Europe, the volatility we see in the sales market is due to access to fuel. Consumers are struggling with the constraints of refueling infrastructure that has not kept pace with vehicle sales, and gas companies and governments are struggling to balance supply demands.

In the United States, NGVs will continue to rely on the government to keep the market growing; whether in the form of regulations, incentives, or both, the NGV market is not yet competitive enough with new clean diesel and hybrids to survive without this influence. The NAT GAS Act incentives will be critical to the fleet market, but are unlikely to have any impact on the consumer market.

We are starting to see more consolidation in the market as Fuel System Solutions, Landi Renzo, and gas companies continue to make purchases that broaden their products across the supply chain. This consolidation will likely continue as OEMs in this small market are unlikely to commit to NGVs without upfitters. However, larger players like Magneti Marelli and Bosch are unlikely to make the move into the acquisition game as they are expected to remain focused on components.

While the variety of alternative fuels and EV technologies does not eliminate the need for NGVs, it will most certainly impact the market. Natural gas and EV technologies have some very similar attributes: both have limited range compared to similar gasoline engines; both have a substantially higher cost than gasoline engines; and both have government-supported backing. As a result, both technologies are well-suited for fleet operations. Although differences exist between these types of vehicles and their usage, it is clear that EVs will take a piece of the market that could be a good fit for NGVs.

Section 7

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Section 8

Acronym and Abbreviation List

Alternative Fuel Vehicle .... AFV

American National Standard for Natural Gas Vehicle Containers NGV2

American National Standards Institute .... ANSI

American Recovery and Reinvestment Act of 2009 .... ARRA

Asia Pacific Natural Gas Vehicle Association .... ANGVA

Battery Electric Vehicle (All Battery-Powered) .... BEV

Billion Cubic Feet .... bcf

British Thermal Unit .... BTU

California Air Resources Board .... CARB

Canadian Natural Gas Vehicle Association .... CNGVA

Canadian Standards Association .... CSA

Carbon Dioxide .... CO_2

Clean Development Mechanism (China) .... CDM

Code of Federal Regulations .... CFR

Compound Annual Growth Rate .... CAGR

Compressed Natural Gas .... CNG

Corporate Average Fuel Economy .... CAFE

Cubic Meters .... M^3

Degree Celsius .... °C

Degree Fahrenheit .... °F

Department of Energy .... DOE

Engine Control Unit .... ECU

Environmental Protection Agency .... EPA

European Union .... EU

Federal Motor Vehicle Safety Standards .... FMVSS

Fuel Cell .... FC

Gasoline Gallon Equivalent .... GGE

General Motors .... GM

Goods and Services Tax (Canada) .... GST

Grams per Kilowatt Hour .... g/kWh

Greenhouse Gases .... GHGs

Gross Combined Weight .... GCW

Heavy-Duty .... HD

High Occupancy Vehicle Lanes (Carpool Lanes) .... HOVs

Horsepower .... HP

Hybrid Electric Vehicle .... HEV

Hydrogen Compress Natural Gas .... HCNG

Hydrogen Fuel Initiative .... HFI

Internal Combustion Engine .... ICE

Internal Revenue Service .... IRS

International Association of Natural Gas Vehicles .... IANGV

Kilometers per Hour .... kph

Light-Duty Vehicle LV

Liquefied Natural Gas .... LNG

Liquefied Petroleum Gas .... LPG

Lithium Ion .... Li-ion

Low Emissions Vehicle .... LEV

Medium/Heavy-Duty Truck .... M/HD

Methane CH4

Mile per Gallon .... mpg

Miles per Hour .... mph

Ministry of Environment (Japan) .... MOE

Model Year .... MY

National Highway Traffic Safety Administration .... NHTSA

Natural Gas Vehicle .... NGV

Natural Gas .... NG

NGV America (Trade Organization) .... NGVA

Nitrogen Oxide .... NOx

Office of Energy Efficiency and Renewable Energy .... EERE

Original Equipment Manufacturer (Automaker) .... OEM

Over-the-Road – Semi-Tractor Trailer Trucks .... OTR

Particulate Matter .... PM

Plug-in Hybrid Electric Vehicle .... PHEV

Pounds per Square Inch (Pressure) .... psi

Pounds .... lbs

Sport Utility Vehicle .... SUV

Super Ultra Low Emissions Vehicle .... SULEV

Ultra Low Emissions Vehicle .... ULEV

Ultra Low Sulfur Diesel .... ULSD

United Kingdom .... UK

United Parcel Service of America .... UPS

United States .... U.S.

Volkswagen .... VW

Zero-Emissions Vehicle .... ZEV

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Scope of Study

Pike Research has prepared this report to provide participants at all levels of the NGV market, including vehicle OEMs, suppliers, trade associations, and gas providers, with a study of the market for NGVs and refueling technologies. The major objective is to determine the state of the industry and likely future growth of NGV demand in the overall consumer automobile market. In addition, the report provides a review of major demand drivers, as well as key industry players within the competitive landscape.

The report's purpose is not to present an exhaustive technical assessment of the vehicles and technologies covered. Rather, it aims to provide a strategic examination from an overall tactical business perspective. Pike Research strives to identify and examine new market segments to aid readers in the development of their business models. All major global regions are included and the forecast period extends through 2016.

Sources and Methodology

Pike Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Pike Research's analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Pike Research's analysts and the firm's staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Pike Research's reports. Great care is taken in making sure that all analysis is well-supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

Pike Research is an independent market research firm whose goal is to present an objective, unbiased view of market opportunities within its coverage areas. The firm is not beholden to any special interests and is thus able to offer clear, actionable advice to help clients succeed in the industry, unfettered by technology hype, political agendas, or emotional factors that are inherent in cleantech markets.

NOTES

CAGR refers to compound average annual growth rate, using the formula:

CAGR = (End Year Value ÷ Start Year Value)$^{(1/steps)}$ – 1.

CAGRs presented in the tables are for the entire timeframe in the title. Where data for fewer years are given, the CAGR is for the range presented. Where relevant, CAGRs for shorter timeframes may be given as well.

Figures are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in year 2009 U.S. dollars unless otherwise noted. Percentages may not add up to 100 due to rounding.

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