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

Natural Gas Vehicle Industry Overview

Executive Summary

Published by America's Natural Gas Alliance

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

The Final Reports of Modules 1 through 5 are the work of TIAX LLC as a market assessment sponsored by ANGA with the support of participating AGA companies.

Executive Summary

Driving Into a Cleaner, Safer Future

America needs to increase its energy independence now

America urgently needs a new alternative energy solution. We must reduce our dependency on foreign sources of energy and implement an alternative transportation fuel that is reliable, safe, and affordable. The U.S.'s annual import bill approaches $350 billion, more than double what the federal government spends on education.[1] The transportation sector uses the bulk of our imported oil. Vehicles consumed 4.7 billion barrels of petroleum in 2010, even more than the 4.2 billion barrels of petroleum the country imported that year.[2]

Increasing use of domestic natural gas as a clean alternative fuel will help prevent North America from relying on regions of the world whose interests run counter to our own. Given events in the Middle East like the Gulf War and the prolonged conflict in Iraq as well as OPEC's continual control of petroleum supplies, we can practically gauge the health of U.S./Middle East diplomatic relations by the price at the pump.

Our current transportation portfolio carries societal costs

It's not just the price at the pump that should worry us. It's also the hidden costs we don't see when we slide our credit cards across the magnetic reader. Each time a driver refuels, the indirect cost of energy security adds an additional $0.46 per gallon or an average of $8.31 per vehicle.[3] You can see the costs of this premium in decreased national economic output, loss of national gross product, economic strain and volatility, oil supply shocks, prices spikes, supply disruption, and import costs.

Each time a driver refuels, the indirect cost of energy security adds an additional $0.46 per gallon or an average of $8.31 per vehicle.[3]

In addition, every transportation fuel carries a societal cost based on impacts from criteria pollutant emissions. Another societal cost of our transportation fuel results from GHG emissions. Monetization of these societal costs provides a means to assess the societal benefits of the alternative fuels considered. Across multiple vehicle segments, the societal costs for NGVs are lower than those for conventional transportation fuels. The net savings (of direct and societal costs) exceed $50,000 for some high fuel use applications and are comparable to saving 15 percent of lifetime costs. The savings for other applications may be less but are still significant.

The more we increase the use of domestic natural gas, the more these societal costs can be reduced.

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1 Brian Riedel, "Federal Spending By the Numbers," June 1, 2010, http://www.heritage.org/research/reports/2010/06/federal-spending-by-the-numbers-2010, (October 12, 2011).
2 Energy Information Administration. "Annual Energy Review." October 19, 2011.
3 U.S. EPA, NHTSA. "Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards: Regulatory Impact Analysis." EPA-420-R-10-009, p. 8-16. April 2010.

ES1 Energy Security Premium

The effect of imported overseas petroleum:

Energy Security Premium[4] **$0.46 per gallon transportation fuel**
Decreased economic output Loss of national gross product Economic strain and volatility Supply shocks and price spikes Supply disruption Import costs

ES2 Criteria Pollutants + GHG Costs

Our current total transportation portfolio bears societal costs:

Air Pollution Costs[5,6,7,8] **$9,072 per ton NOx** **$270 per ton CO** **$7,401 per ton VOC** **$283,274 per ton PM2.5**	**GHG Costs**[9,10] **$23.13 per ton**
Impacts from Criteria Pollutants	Impacts from GHG Emissions

Current societal costs are estimated to add up to $0.99 per day for each 2010 passenger car on the road.[11,12,13,14,15,16] With an on-highway vehicle population of 255 million in the U.S., the costs related to transportation fuel pollution total upwards of $252 million dollars a day.[17]

Natural gas vehicles (NGVs) have less impact on energy and the environment, and the difference is dramatic. Conventionally-powered passenger cars carry a societal cost estimated at $5,100 per vehicle over their lifetime, while NGVs cost $2,000 to $2,500.

For medium-duty vans, hybrid package delivery vans, hybrid beverage trucks, transit buses, refuse haulers, and 18-wheeled tractor-trailers using diesel the societal costs are even greater. Over the lifetime of an 18-wheeler, these costs are estimated at $70,000. In comparison, the costs associated with an 18-wheeler using natural gas are $21,000 to $34,000. Regardless of a vehicle's size, the lifetime societal costs of NGVs will be lower than those of conventional vehicles.

> *Regardless of a vehicle's size, the lifetime societal costs of NGVs will be lower than those of conventional vehicles vehicles.*

4 U.S. EPA, NHTSA. "Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards: Regulatory Impact Analysis." EPA-420-R-10-009, p. 8-16. April 2010.
5 Costs for NOx and VOCs include both direct emissions of these pollutants and their indirect emissions (as precursors to PM); all costs are given in 2010 U.S. dollars.
6 U.S. EPA, NHTSA. "Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards: Regulatory Impact Analysis." EPA-420-R-10-009, p. 7-118. April 2010.
7 TIAX communication with N. Fann, EPA Office of Air Quality Planning & Standards, August/September 2010.
8 CEC. "Reducing California's Petroleum Dependence, Appendix A: Benefits of Reducing Demand for Gasoline and Diesel (Task 1)." P600-03-005A1, p. 3-27. September 2003.
9 U.S. Government. "Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis, Under Executive Order 12866," p. 39. Interagency Working Group. February 2010.
10 U.S. EPA, NHTSA. "Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards: Regulatory Impact Analysis." EPA-420-R-10-009, p. 7-128. April 2010.
11 Costs for NOx and VOCs include both direct emissions of these pollutants and their indirect emissions (as precursors to PM); all costs are given in 2010 U.S. dollars.Costs for NOx and VOCs include both direct emissions of these pollutants and their indirect emissions (as precursors to PM); all costs are given in 2010 U.S. dollars.
12 U.S. EPA, NHTSA. "Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards: Regulatory Impact Analysis." EPA-420-R-10-009, p. 7-118. April 2010.
13 TIAX communication with N. Fann, EPA Office of Air Quality Planning & Standards, August/September 2010.
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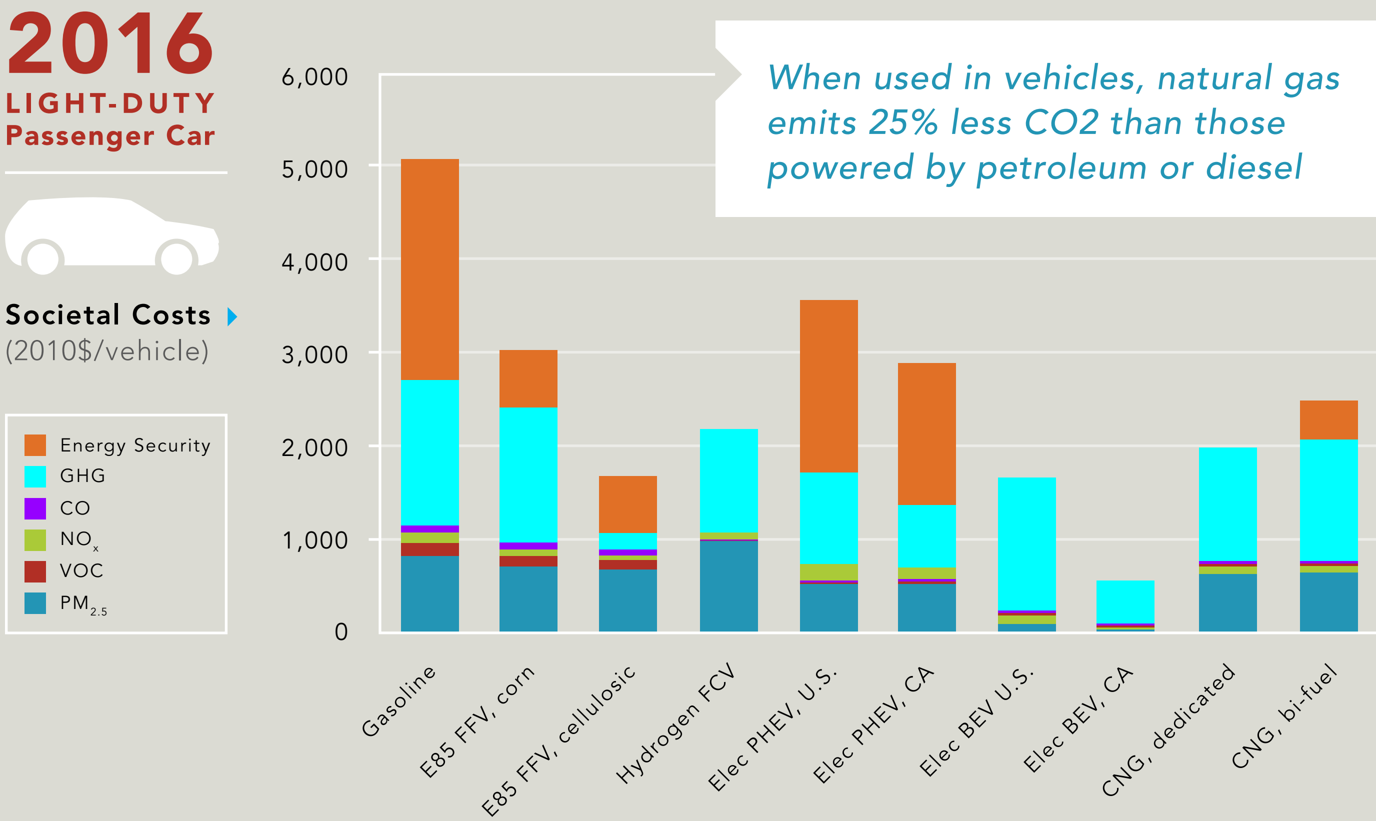
16 U.S. EPA, NHTSA. "Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards: Regulatory Impact Analysis." EPA-420-R-10-009, p. 7-128. April 2010.
17 Research and Innovative Technology Administration, "Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances (2008)," http://www.bts.gov/publications/national_transportation_statistics/html/table_01_11.html (October 6, 2011).



The advantages and opportunities of alternative fuels

Although driving small vehicles reduces fuel consumption, all vehicles in every class have gotten heavier and more powerful, small and large vehicles alike. However, many Americans want their minivans, SUVs, and trucks. As we continue to use energy in transportation, we need to find alternatives to the way we fuel our cars.

No matter what your political affiliation, we all agree on a basic problem: We must change our energy consumption. Former President George W. Bush explained that affordable energy is the key to our future:

"Keeping America competitive requires affordable energy. And here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world. […] By applying the talent and technology of America, this country can dramatically improve our environment, move beyond a petroleum-based economy and make our dependence on Middle Eastern oil a thing of the past." [18]

The Obama Administration shared these sentiments, and President Barack Obama stated:

"Our dependence on foreign oil threatens our national security, our environment and our economy. We must make the investments in clean energy sources that will put Americans back in control of our energy future, create millions of new jobs, and lay the foundation for long-term economic security." [19]

Fortunately, our overseas dependency on foreign sources of energy from geopolitically unstable regions of the world is a problem we can solve. We already recycle, tote canvas bags to the grocery store, and try to run our appliances in evening hours. Doesn't it logically follow then that the transportation industry offers consumers an amazing opportunity to impact their country, environment, and wallet with one purchasing decision?

18 President George W. Bush, "State of the Union Address: January 31, 2006," The Washington Post, http://www.washingtonpost.com/wp-dyn/content/article/2006/01/31/AR2006013101468.html, (October 3, 2011).
19 The White House, "Learn: Clean Energy Economy," http://m.whitehouse.gov/issues/energy-and-environment/new-foundation/learn, (October 3, 2011).

A better source of energy security and economic stability exists inside our borders

North America has a better energy source inside its borders, and the U.S. could pass Saudi Arabia and overtake Russia as the world's largest energy producer.[20] We can accelerate our energy independence by augmenting our petroleum supply with North American natural gas. NGVs and a natural gas fueling infrastructure can be the solution to our energy problems that minimizes damage to the environment. Switching to natural gas will also save North America millions of dollars in security costs related to defending access to international petroleum resources in geopolitically unstable regions of the world.

Natural gas is not a new fuel. We've used it since practically the beginning of time—the Chinese discovered natural gas in 600 BC and, around the first century, the first recorded use of natural gas in the home occurred in Persia (now Iran). In North America, natural gas use dates back as early as 1626.[21] It heats our homes and businesses, has many industrial applications, and generates electricity. Natural gas already accounts for 23.4% of the U.S. energy supply.[22]

Natural gas has served as a transportation fuel for more than six decades. It has mainly been applied to commercial vehicles like school buses and truck fleets that return to a central base at the end of a day. Fleet operators can economically build and maintain fueling stations at these central stations. It's also no coincidence that school buses have been a successful application, given the positive attribute of lower emissions.

We can accelerate our energy independence by augmenting our petroleum supply with North American natural gas.

Natural gas is an economical fuel option

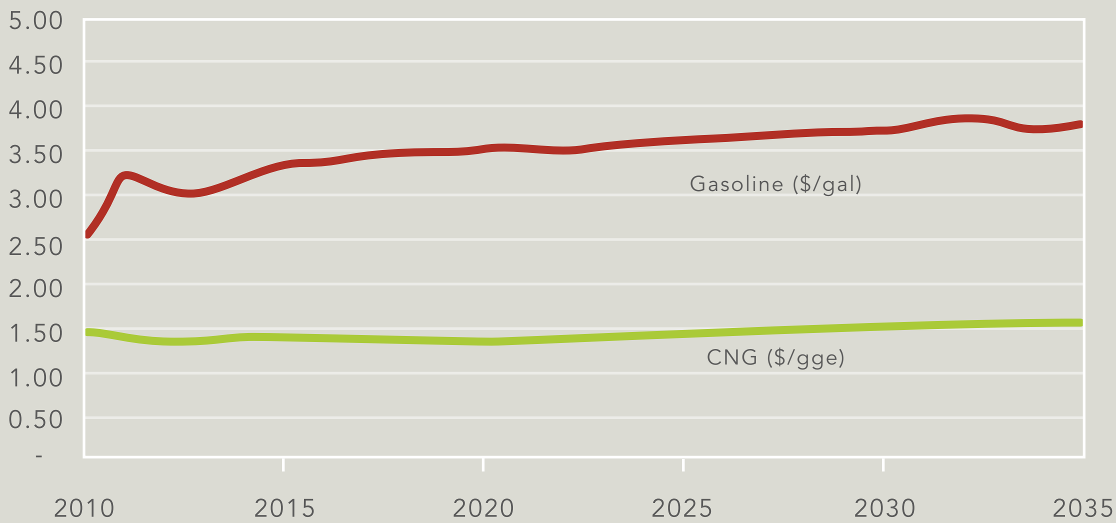
Despite the lack of a large natural gas fueling infrastructure for the public, consumption as a transportation fuel has increased steadily since 1997. During this period, the price of petroleum rose while the price of natural gas fell. As the exhibit below shows, this trend is continuing. Over the next 25 years, natural gas is expected to become even cheaper relative to petroleum.

The fuel cost differential between natural gas and gasoline is expected to reach over \$2.00 per gasoline gallon equivalent (GGE) and over \$3.00 per diesel gallon equivalent (DGE) between natural gas and diesel. For the average North American, who fills up his or her tank weekly, refueling with natural gas rather than petroleum would save approximately \$32 per gas station visit. In a year, that's a \$1,664 savings.

ES4

GGE Fuel Price At Pump
(2010\$ per GGE)

Notes
1) Fuel prices are derived from the reference case in U.S. EIA "Annual Energy Outlook," 2012
2) Prices include federal and state taxes
3) Prices are adjusted for vehicle efficiency



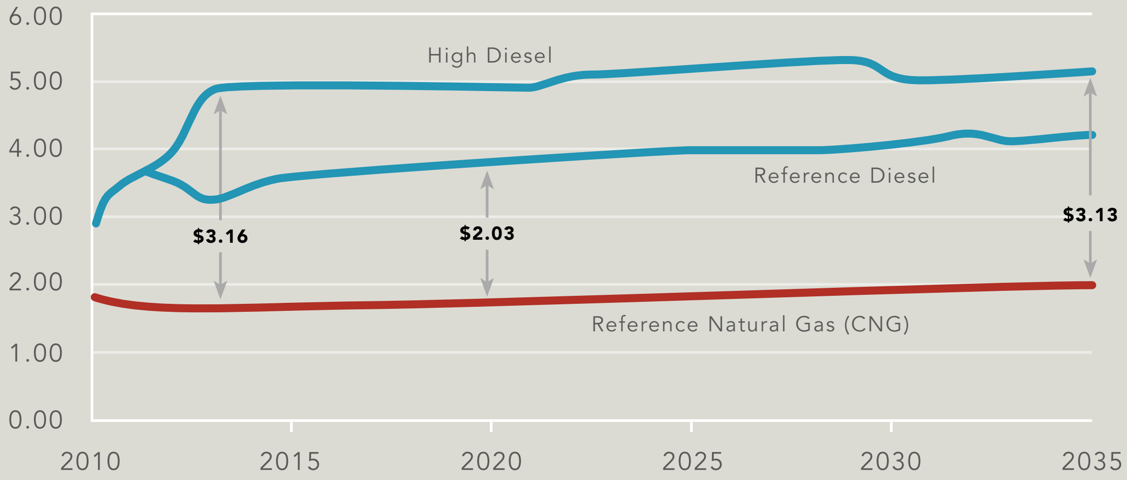
20 "History Zone", Pacific Gas & Electric, http://www.pge.com/microsite/safety_esw_ngsw/ngsw/more/history.html (October 3, 2011).
21 U.S. Energy Information Administration, "U.S. Primary Energy Flow by Source and Sector, 2009," www.eia.gov, http://www.eia.gov/totalenergy/data/annual/pecss_diagram.cfm, (October 3, 2011)
22 Energy Information Administration. "Annual Energy Outlook 2011" assessed at http://www.eia.doe.gov/forecasts/aeo/ on April 28, 2011.

ES5

DGE Fuel Price At Pump
(2010$ per DGE)

Notes
1) Fuel prices are derived from U.S. EIA "Annual Energy Outlook," 2012
2) Prices include federal and state taxes
3) Prices are adjusted for vehicle efficiency

Fuel price differentials at the pump of over $3 per equivalent gallon are possible in the near future.[23]



Conventional fuel retailers, fleet fueling operators, and average drivers are accustomed to fueling vehicles with liquid fuels. Though natural gas is different from conventional fueling, it's simple to use and is widely used in transportation.

While liquid fuels like gasoline or diesel must be transported to stations via over-the-road trucks, compressed natural gas (CNG) is a natural gas fuel that is typically transported via an underground pipeline and then compressed to a higher pressure. While some investment is required to build a natural gas fueling infrastructure, it can use an already existing network of pipelines to reach stations. Additionally, CNG fueling stations can be designed to accommodate any situation—public or fleet fueling.

Natural gas is in abundant supply and offers price stability

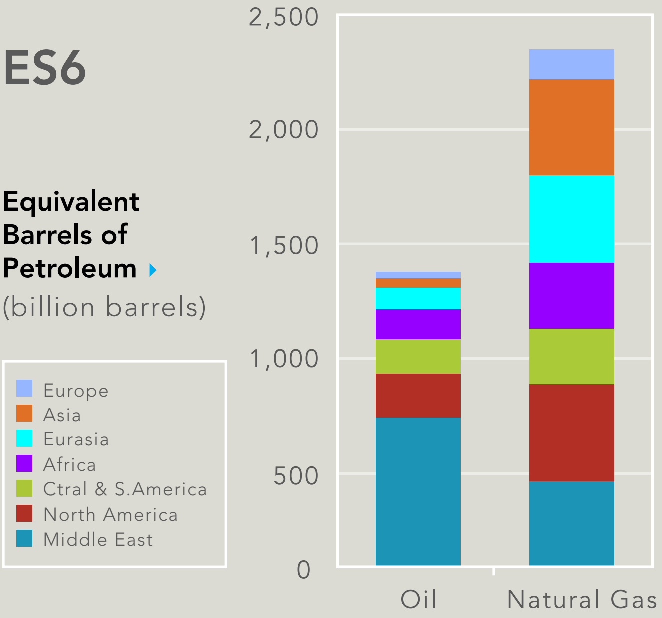
Now is the time for natural gas. Recent explorations for natural gas have found abundant supplies in North America, making natural gas even more plentiful than petroleum. Current global supplies of natural gas could sustain world demand, at current consumption, for 121 years versus 46 years for petroleum.[24]

There is enough natural gas in the U.S. and Canada to supply the current economy-wide uses of 24.3 trillion cubic feet (TCF) per year and support these markets as they expand.[25]

Current global supplies of natural gas could sustain world demand, at current consumption, for 121 years versus 46 years for petroleum.[24]

ES6

Equivalent Barrels of Petroleum
(billion barrels)



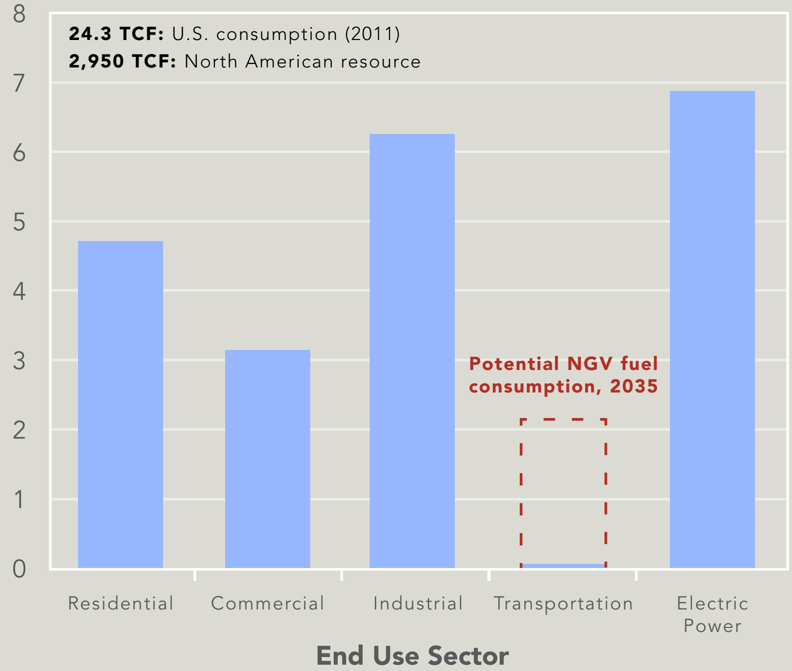
23 Energy Information Administration, "International Energy Outlook 2010-Natural Gas," DOE/EIA-0484(2009), July 27, 2010; http://www.eia.doe.gov/oiaf/ieo/nat_gas.html
24 Energy Information Administration, "World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States," Release date: April 5, 2011, http://www.eia.doe.gov/analysis/studies/worldshalegas/
25 Energy Information Administration. "Natural Gas Consumption by End Use." http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm. Accessed January 2011.

ES7 Natural Gas Transportation Consumption

	2008	2035
Natural Gas Vehicles in U.S. (Millions)	0.13	16
Consumption (Trillion Cubic Feet-TCF)	0.05	2.2

ES8 Natural Gas Consumption (TCF)

Source [27]



The existing U.S. natural gas vehicle population is approximately 130 thousand (.05% of the on-highway vehicle population), and it consumes 364 million DGE of natural gas annually. If we made a commitment to NGVs, by 2035 we could have 16 million vehicles in the U.S. That amounts to 6% of the 2012 on-highway vehicle population, and it would displace 10% of the 2012 on-highway conventional/transportation fuel consumption.[26] At the same time, we could also increase the number of residences, businesses, and industries using natural gas for electricity.

Because North America is subject to changes in foreign energy policy, we constantly wrestle with fluctuating supply and volatile prices for foreign sources of energy from geopolitical unstable regions of the world. However, the abundance of our current and projected natural gas supplies would lead to stable prices for regionally sourced fuel. Price certainty would also allay some of our fears about domestic security. Among other benefits, this would translate into millions of dollars in fuel savings, fewer dollars leaving North America to pay for imports, and a smaller trade imbalance.

Replacing 6% of the vehicles on the highway with natural gas vehicles would displace 10% of conventional/transportation fuel consumption.

Natural gas is a safe, environmentally superior fuel

You might ask, since natural gas is a fuel, doesn't that mean it is harmful to the environment? With natural gas, our clean energy future may be closer than we think. When it's used to generate electricity, natural gas burns cleaner than other fossil fuels and releases fewer pollutants. It is an essential partner to the development of renewables because it provides clean, reliable power when the sun sets in the evening or the wind dies down.

26 See Scenario Analysis report of overall TIAX assessment for details and assumptions

27 See Market Segmentation and Scenario Analysis reports of overall TIAX assessment for NGV population and fuel consumption estimates and projections. Data from Energy Information Administration, "Natural Gas Consumption by End Use," http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm, accessed September 11, 2012; Energy Information Administration, "Natural Gas Year-in-Review 2009," July 2010; Massachusetts Institute of Technology, "The Future of Natural Gas," Interim Report, p. 7. 2010.

Natural gas is the answer that green energy proponents are searching for: it's a high octane, low carbon fuel. From a well to wheels analysis natural gas can emit 23% less CO_2 than gasoline passenger cars.[28] But that's just the beginning of its clean-energy profile. Using natural gas results in 46% reduction in NO_x emissions compared to pre 2010 diesel vehicles and virtually no sulfur dioxide, mercury, or particulate pollution. In most cases, natural gas can be a substitute for gasoline or diesel without many of the energy and environmental drawbacks.[29]

But to get an accurate picture of the environmental costs of different fuels, you need to look beyond tailpipe emissions. Using domestically sourced natural gas would mean we wouldn't have to use oil tankers to transport oil thousands of miles from the Middle East to North America.

The U.S. Environmental Protection Agency (EPA) has cited natural gas as a safe transportation fuel for several reasons including reduced flammability relative to petroleum, presence of onboard gas detectors, existence of tank safety valves, and periodic DOT tank inspections. Since it is non-toxic, natural gas poses no threat to land or water. In the event of a release, natural gas disperses rapidly (it is lighter than air) thus reducing ignition risks relative to gasoline.

Similarly, liquefied natural gas (LNG) readily evaporates if it is released in the air. If an LNG vehicle or station were damaged in a way that punctured fuel tanks, any spilled fuel would evaporate into the atmosphere much faster than gasoline or diesel, both of which pool on the ground.

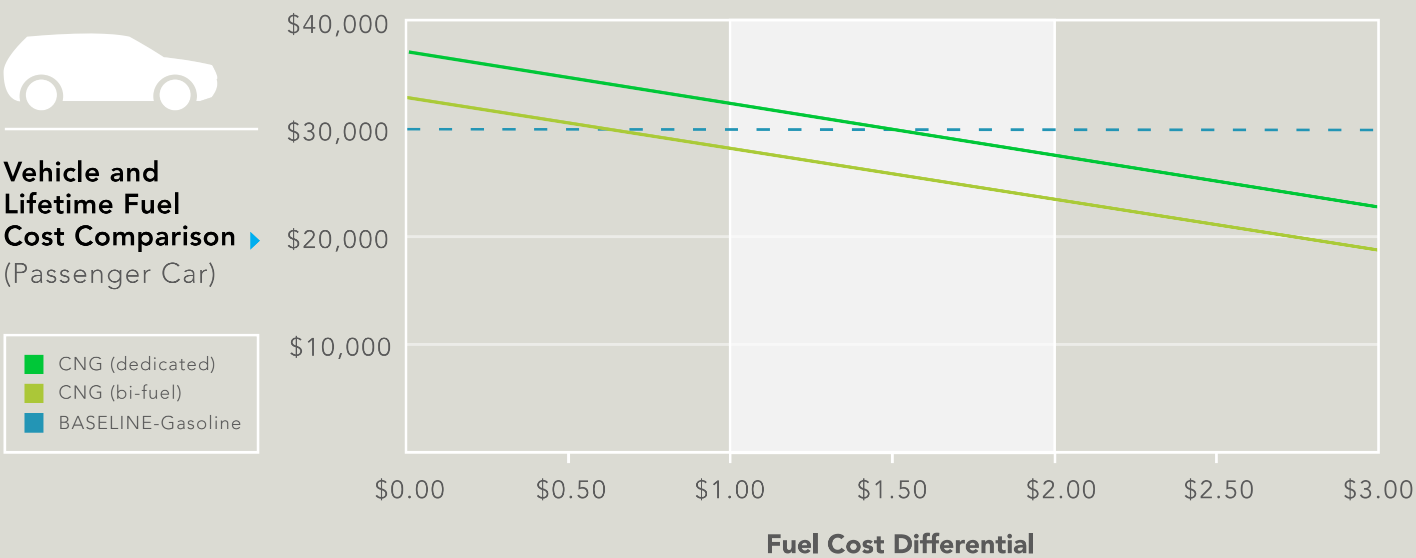
Because natural gas has been used in the North American vehicle fleet for many years, consumers are unlikely to face the specter of dramatic new, unforeseen dangers if market penetration increases.

NGVs have a lower total cost of ownership versus conventional vehicles

Natural gas is an economical and versatile fuel option. Even assuming a conservative fuel price differential at the pump of $1.50 per equivalent gallon, lifetime ownership costs for NGVs are generally lower than those of conventional vehicles. Lower fuel prices offset the higher costs of fuel storage in vehicles, enabling NGV owners to have reasonable payback periods.[30] As demand for petroleum increases, prices do the same. However, because of our vast natural gas supplies, increases in natural gas vehicles on the road will have little impact on the price of natural gas.

ES9

Vehicle and Lifetime Fuel Cost Comparison (Passenger Car)



28 U.S. Department of Energy, "Energy Efficiency and Renewable Energy: Alternative Fuels and Advanced Vehicles Data Center," http://www.afdc.energy.gov/afdc/vehicles/natural_gas_emissions.html, (November 17, 2011).ANGA, "Why Natural Gas: Clean," http://anga.us/why-natural-gas/clean, (October 3, 2011).

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

30 Lifetime costs include the cost of fuel over the vehicle's first-owner operating lifetime and reflect the vehicle application's operating characteristics. Hydrogen vehicle and fuels costs are projections only (not yet commercialized). See Comparative Analysis report of overall TIAX assessment for calculation details and assumptions.

NGV adoption is progressing in the commercial and consumer markets

Commercial Adoption

Several corporations and municipalities have already switched their fleets from petroleum to natural gas fuel (CNG in all applications), and they're already seeing savings in transportation costs and a reduction in harmful emissions. Among them:

UPS: By switching a portion of its fleet to compressed natural gas (CNG) vehicles and converting existing trucks, UPS reduced its carbon emissions significantly. It started this process in 2000, and its CNG trucks have traveled over 165 million miles since. A study by the National Renewable Energy Laboratory found UPS' CNG trucks yielded much lower emissions than the cleanest operating diesel trucks.[31]

Kansas City: In 1996, Kansas City, Missouri instituted a fleet-wide alternative fuel program for the city's large rigs and public transportation. The city started with six CNG-powered vehicles and has expanded to approximately 2,700. By switching much of their fleet to CNG, the city displaces nearly a half a million gallons of foreign oil each year. Kansas City has experienced not only 15% savings in fuel costs, but has also significantly lowered emissions. The EPA estimates the use of CNG in Kansas City will yield 90-97% lower carbon monoxide output, 35-60% lower nitrogen oxides emissions, and reductions in carbon dioxide output of 25%.[32]

Seattle: Seattle has quickly expanded its natural gas fleets to include both heavy-duty vehicles—garbage trucks—and light-duty taxis. In 2009, Waste Management of Seattle invested $29 million in 106 new CNG-fueled vehicles to replace diesel-run trucks. An independent environmental review determined Waste Management's equipment upgrade will reduce smog-causing NOx emissions by 97%, diesel particulate matter by 94%, and greenhouse gases by 20%.. It's also good news for residents—natural gas vehicles run cleaner and quieter.[33]

Seattle opened Washington's first large scale, public access CNG fueling station near the Sea-Tac Airport. The station is convenient for the 74 natural gas and hybrid vehicles in use at the airport as well as the fleet of taxis operated by the Seattle-Tacoma International Taxicab Association. All 166 Ford Crown Victoria cabs operated by the association are CNG-fueled. It's estimated that the cabs will produce 149 fewer tons of carbon monoxide and 24 fewer tons of nitrogen oxides each year than comparable petroleum-powered vehicles.[34]

With respect to NGVs, though the world is changing, the U.S. is not.

Consumer Adoption

Consumers already drive NGVs today, though the limited vehicle choices and uncertainty about refueling options holds many people back. Honda manufactures and sells limited volumes of the Civic Natural Gas, one of the cleanest vehicles in the world, and more manufacturers are re-entering the North American market, including Ford, GM, and Chrysler. As consumer demand increases, the market will expand, just as it has globally. Worldwide, consumers can choose from more than 40 models, and there are more than 12 million NGVs in operation. In the U.S., that number is just 120,000. With respect to NGVs, though the world is changing, the U.S. is not.

NGVs offer proven benefits and are the new frontier of North American prosperity

Natural gas means domestic jobs. By increasingly using NGVs in transportation, we will foster domestic jobs, create new manufacturing and construction opportunities, and stimulate economy-wide spending through consumer fuel savings.

Expanding North America's fueling infrastructure would add over 3.7 million jobs. Some, though not all, of these jobs would be temporary, but they are just the kinds of opportunities that Americans, specifically unemployed construction workers, need today.

31 ANGA, "Issues and Policies: Case Studies," http://anga.us/issues--policy/transportation/case-studies-, (October 3, 2011).
32 Ibid.
33 Ibid.
34 Ibid.

ES10 Building the natural gas transportation infrastructure will create jobs

Source [35]

	Light-Duty CNG	Medium and Heavy-duty CNG	Heavy-Duty LNG
Total number of new stations built by 2035	12,800	12,100	700
Spending Changes and employment impacts in transportation fuel sectors			
Job impacts (Full Time Employees) per station:	0.81	0.24	19.78
Overall job impacts (FTEs):	10,400	2,900	13,800
Capital and infrastructure expansion			
Job impacts (FTEs) per station built:	112	179	166
Overall job impacts (FTEs):	1,430,000	2,170,000	116,000

During this economic downturn, new shale plays across North America enabled the natural gas community to add jobs. According to IHS Global Insight, an independent research source, natural gas companies directly employed roughly 622,000 Americans in 2008 and indirectly sustained an additional 2.2 million jobs. But the economic benefits of natural gas extend well beyond job creation. In 2008 alone, natural gas contributed $385 billion to the U.S. economy and generated over $70 billion in direct income for workers. Its overall impact on the U.S. economy was $172 billion.[36]

Natural gas contributed $385 billion to our nation's economy and generated over $70 billion in direct income for workers.

In Canada, the natural gas industry has had a greater relative impact on the domestic economy. Every province has people whose jobs are related to natural gas. According to IHS Global Insight, nearly 600,000 Canadians worked in jobs supported by natural gas in 2008, contributing $106 billion to the nation's GDP. This economic impact exceeds the total GDP of all but four Canadian provinces that year. It accounts for 3.5% of all Canadian jobs and roughly 6.7% of Canada's overall GDP.[37]

According to IHS Global Insight, nearly 600,000 Canadians worked in jobs supported by natural gas in 2008, contributing $106 billion to the nation's GDP.

Natural gas jobs are filling the void left by the manufacturing, management, and technology sectors in Pennsylvania, Louisiana, and Alberta.

Pennsylvania: The Marcellus Shale, which is considered by experts to be the second largest shale gas formation in the world, is responsible for much for the state's natural gas job growth. A recent influx of natural gas activity in the state has quickly expanded the number of well-paying employment opportunities, ranging from manual labor to highly technical work. A 2010 Penn State study concluded that the Marcellus Shale could generate over $8 billion in economic value this year, $1 billion in state and local tax revenue and almost 100,000 jobs in 2011, just in Pennsylvania.[38]

35 Employment impacts based on IMPLAN Input-Output model and Jack Faucett Associate estimates. See Overview report of overall TIAX assessment.
36 ANGA, "Why Natural Gas: U.S. Benefits," http://anga.us/why-natural-gas/jobs/us-benefits, (October 3, 2011).
37 ANGA, "Why Natural Gas: Canada Benefits," http://anga.us/why-natural-gas/jobs/canada-benefits, (October 3, 2011).
38 ANGA, "Why Natural Gas: State-by-State," http://anga.us/why-natural-gas/jobs/us-benefits/state-by-state, (October 3, 2011).

Louisiana: The Haynesville Shale has helped boost the Louisiana economy during tough economic times. According to Dr. Loren Scott & Associates, which looked at about 70% of the exploration in the state, natural gas activities in the shale generated $10.6 billion in new economic activity and created more than 57,000 new jobs. It also generated $5.7 billion in new household earnings for Louisiana residents.[39]

Alberta: Over 16% of Alberta's employment was attributable to natural gas, with British Columbia (4.8%) the second largest beneficiary of Canada's natural gas abundance. Saskatchewan was third (4.5%). Natural gas supports 27.7% of Alberta's GDP, or $80 billion in total economic impact.[40]

Jump-starting NGV adoption

Even without broad adoption in the commercial transportation market and a minimal presence in the consumer market, natural gas is has made a significant economic impact in North America. Just imagine the opportunity we have to strengthen national security, grow our economy, reduce pollution, and lower greenhouse gas emissions if we make NGVs more widely available and affordable. This challenge will involve all of us but particularly the four major stakeholders in the NGV industry—end users, natural gas supply chain companies, vehicle and engine manufacturers, and government—all working together. There are some challenges to this goal but they are not insurmountable.

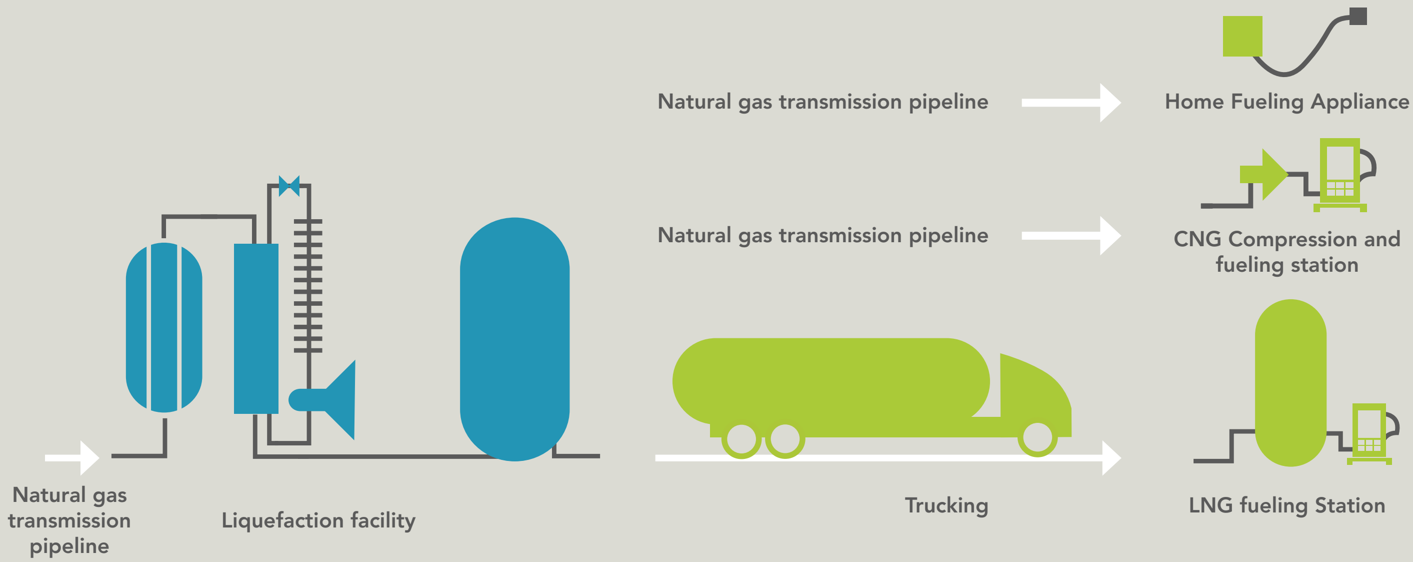
The average driver in the U.S. drives 29 miles per day, based on this statistic, early localized infrastructure can support this emerging consumer market, but it will take a paradigm shift in the consumer mindset.[41]

To drive demand, consumers need to be educated on vehicle and fueling options

Consumers and commercial stakeholders are becoming more interested in natural gas. General consumer interest in alternative vehicles is also growing, but consumers are driven by both price and convenience. NGVs will not become a viable transportation option without an efficient and affordable fueling infrastructure, affordable vehicles, and a level playing field among alternative vehicles if government incentives are necessary.

Uncertainty about the fueling infrastructure is the main concern swaying customer purchase decisions and keeping vehicle manufacturers from building more NGVs. It's a chicken and egg problem: consumers who consider buying an NGV don't see natural gas fueling stations lining the highway or visible at main intersections, so they assume that refueling will be inconvenient. But without a critical mass of NGVs on the road, the need for a fueling infrastructure does not seem critical.

ES11



39 ANGA, "Why Natural Gas: State-by-State," http://anga.us/why-natural-gas/jobs/us-benefits/state-by-state, (October 3, 2011).
40 ANGA, "Why Natural Gas: Canada Benefits," http://anga.us/why-natural-gas/jobs/canada-benefits, (October 3, 2011).
41 U.S. Department of Transportation Federal Highway Administration. "2009 National Household Travel Survey." http://nhts.ornl.gov. Accessed August 2012.

Building the fueling infrastructure

North America is in the process of establishing an efficient and affordable natural gas fueling infrastructure. Companies like UPS and Seattle Waste Management have been able to transition to natural gas quickly because they have dedicated fleets that return to a base. It's economical for them to develop small or large private fueling facilities for their exclusive use. Accommodating light and medium duty vehicles will require some changes in vehicle fueling systems, like an in-home fueling device—a home-based gas utility or personal fueling device approximately the size of a small chair that sits outside or inside—and accessible public fueling stations.

During this intermediate phase, government will work in partnership with the natural gas industry and fuel providers to begin developing a public natural gas fueling infrastructure that includes corridors connecting stations throughout regions.[42] This partnership is already underway. Through the American Recovery and Reinvestment Act of 2009, the Department of Energy funded 25 different projects for alternative fuel, infrastructure, and advanced technology vehicles, and 19 of these 25 projects included natural gas. These commitments include support for 140 new fueling stations.

Building the vehicles

When consumers make the decision to buy an NGV, these vehicles need to be readily available on showroom floors. The manufacturing process must begin with engine manufacturers who provide efficient technology for natural gas, develop, and commercialize a wider selection of natural gas engines to meet the increasing demand.

One way to ease into this new era is to design and adopt natural gas passenger cars and light-duty trucks as bi-fuel vehicles—using both natural gas and gasoline. These vehicles do not compromise tailpipe or evaporative emission performance. They are designed to meet daily driving requirements with natural gas and use gasoline for extended driving. Reducing onboard natural gas storage capacity reduces vehicle costs, and ensures a faster payback on initial NGV purchase costs. For the U.S. and Canadian retail consumer market, bi-fuel NGVs coupled with a small home fueling compressor would provide overnight access to natural gas and allow consumers to avoid daily trips to a natural gas fueling station. For heavy-duty trucks, dedicated natural gas systems make the most economic sense, as long as the fuel systems are properly sized to the particular needs of the fleet, thereby minimizing unnecessary incremental cost and weight.

Vehicle manufacturers must be financially motivated to continue to provide high quality NGVs that meet the same reliability and durability standards as gasoline and diesel products.

The newest NGV offerings have focused on the medium-duty market and targeted at the commercial working sector. In the future, we need to offer a wider selection of vehicles for the consumer market.

Creating a level playing field

The U.S. and Canada both have robust environmental policies to reduce air pollutant and GHG emissions associated with fuel production and vehicle operation. These policies have been marginally effective. Now, we need stronger energy policy or strategy supported by stakeholders to increase the use of natural gas in the transportation sector and reduce North America's dependency on foreign sources of energy from geopolitcally unstable regions of the world.

The integration of both environmental and energy policies can reduce petroleum use and emissions. These policies can also highlight the favorable lifetime economics and environmental aspects of NGVs to increase consumers' interest in alternatives to petroleum. The government can also play a role in leveling the playing field relative to other alternative fuels and vehicles, allowing for more market based adoption and avoidance of picking alternative fuel winners and losers. If policy makers decide to continue to offer purchase incentives for alternative fueled vehicles, they should do so on a level playing field.

The players in the natural gas ecosystem—vehicle manufacturers, government, and fuel suppliers—are ready to work together to make natural gas vehicles widely available, affordable, and simple to maintain. The missing piece is consumer demand and a desire to increase energy security. Now it is your turn; it's time to find out about the natural gas vehicle waiting for you. It's time for natural gas.

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42 See Compressed Natural Gas Infrastructure and Liquefied Natural Gas Infrastructure reports of overall TIAX assessment for additional discussion of natural gas fueling infrastructure development.

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

Natural Gas Vehicle Industry Overview

Legal Disclaimer

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Lower heating value energy conversion factors*

Diesel	129,488 Btu/gal
Gasoline	113,602 Btu/gal
Natural gas	113,602 Btu/GGE or 129,488 Btu/DGE (983 Btu/cubic foot)

*Argonne National Laboratory, "Greenhouse Gas and Regulated Emissions and Energy Use in Transportation," 1.8c. Note that lower heating values for fuels will vary by refinery. Lower heating value does not include the latent heat of vaporization of water vapor, whereas the higher heating value does. Lower heating value is used to represent the energy available for internal combustion engines, and higher heating value is used to represent energy available for external combustion engines (e.g., gas fired boiler for space heating).

Abbreviations

AGA American Gas Association
ANGA America's Natural Gas Alliance
B20 Blend of 20 percent biodiesel and 80 percent diesel
BCF Billion cubic feet
BEV Battery electric vehicle
CA California
CAFE Corporate Average Fuel Economy
CNG Compressed natural gas
CO Carbon monoxide
DEF Diesel exhaust fluid (urea)
DGE Diesel gallon equivalent (equals 131.7 cubic feet of natural gas)
DPF Diesel particulate filter
E10 Blend of 10 percent ethanol, 90 percent gasoline
E85 Blend of 85 percent ethanol, 15 percent gasoline
EIA Energy Information Administration
EPAct Energy Policy Act
EPA Environmental Protection Agency
FCV Fuel cell vehicle
FTE Full-time equivalent
gal Gallon
GGE Gasoline gallon equivalent (equals 115.6 cubic feet of natural gas)
H2 Hydrogen
HEV Hybrid electric vehicle
LNG Liquefied natural gas (1 gallon LNG equals 0.58 DGE)
LDC Local distribution company (gas utility)
LPG Liquefied petroleum gas
M85 Blend of 85 percent methanol, 15 percent gasoline
MPG Miles per gallon
NGV Natural gas vehicle
NHTSA National Highway Safety Transportation Administration
NOx Oxides of nitrogen
OEM Original equipment manufacturer
OECD Organization for Economic Co-operation and Development
OPEC Organization of Petroleum Exporting Countries
PHEV Plug-in hybrid vehicle
PM Particulate matter
RFS Renewable Fuel Standard
SCAQMD South Coast Air Quality Management District
SCFM Standard cubic feet per minute
SCR Selective catalytic reduction
TCF Trillion cubic feet
U.S. United States
VOC Volatile organic compound

Preface

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

TIAX's overall approach relies on six key stages:

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

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

Drawing on the respective expertise of each team member, TIAX presents an integrated assessment of the U.S. and Canadian NGV market in a collection of eight reports. Each report is capable of standing alone while integrating the data, ideas, and themes of the other seven reports. The collection of reports in this TIAX analysis of the NGV market is funded by America's Natural Gas Alliance (ANGA) and further supported by participating members of the American Gas Association (AGA).

Introduction

The NGV market and its prospects for a long-term, sustainable future are described from the perspectives of four major stakeholders: End Users, Natural Gas Supply Chain Companies, Vehicle and Engine Manufacturers, and Government, all of whom have significant opportunities in the NGV market.

The four major stakeholders that have a key role in bringing about these changes in transportation are: 1) end users, 2) natural gas supply chain companies, 3) vehicle and engine manufacturers, and 4) government.

• **End users** purchase and operate vehicles and provide the market demand for natural gas vehicles (NGVs). Acceptance of NGVs by end users will depend on the value proposition offered by the vehicles, including lifetime economics, attribute tradeoffs, vehicle availability, fueling convenience, and other incentives.

• **Natural gas supply chain companies** include gas producers, pipeline companies, local distribution companies (gas utilities/LDCs), and fueling station operators. Together, they establish and operate the infrastructure needed to supply natural gas to the transportation market. Having the most knowledge of and greatest familiarity with natural gas, these companies may also greatly benefit the NGV market by helping in the education and training of and outreach to other industry players, which aids in the distribution of market risk.

• **Vehicle and engine manufacturers** provide NGV and engine offerings to meet the requirements of the end users. Because these requirements vary by vehicle application, NGVs may be better suited to some applications than others.

• **Government** is entrusted with the general welfare of society and can undertake measures to correct market failures, including the classic example of environmental costs that are not included in full product costs that negatively impact society as a whole.

Other needed stakeholders in the NGV industry include vehicle component and infrastructure equipment suppliers, who enable the four major stakeholders to operate in the NGV market.

Chapter 1

What do we pay for our current transportation energy?

The high cost and risk of foreign energy dependency

Our transportation system relies on imported fuel

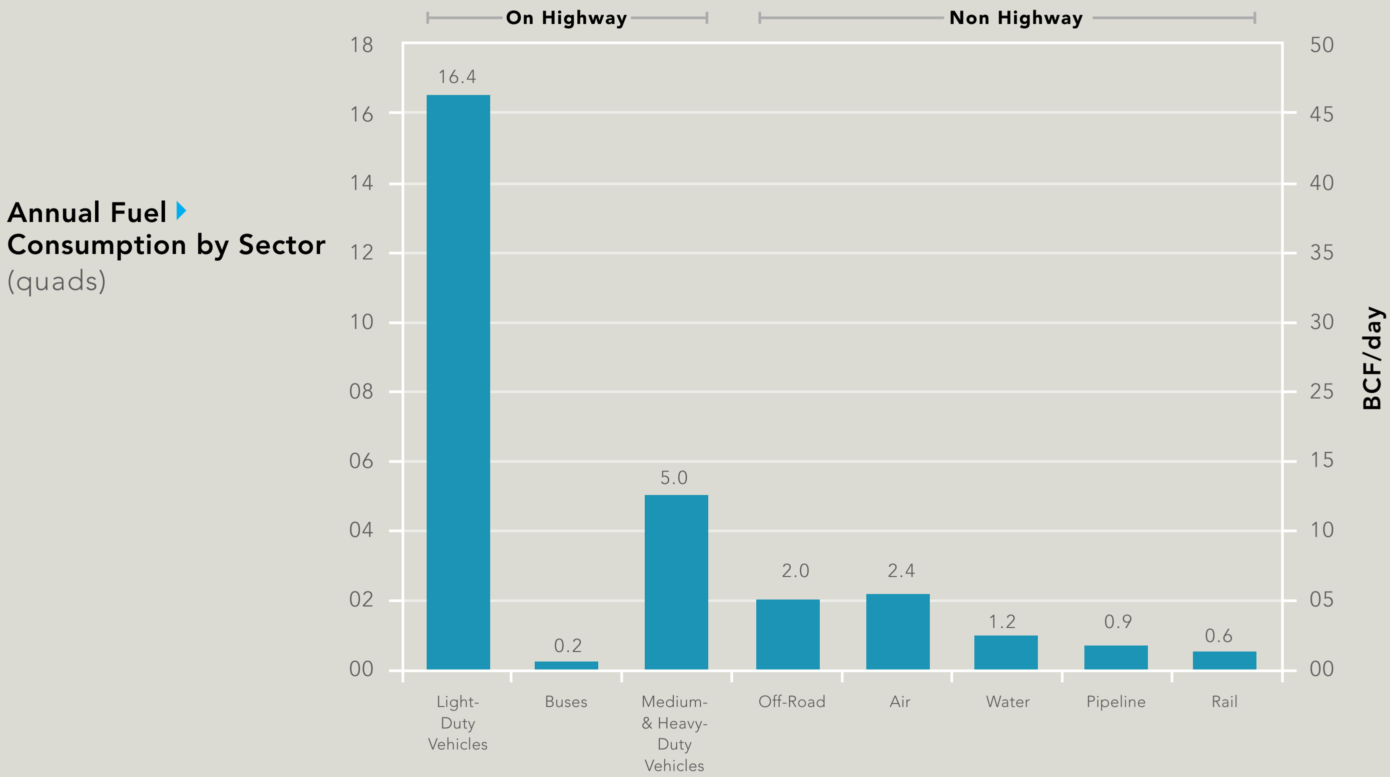
The transportation sector, specifically vehicles that operate using gasoline or diesel, uses mostly foreign sources of energy. In 2010, vehicles consumed a total of 4.7 billion barrels of petroleum, 4.2 billion barrels of which were imported.[1]

Passenger and light-duty trucks dominate energy use, but off-road and non-highway uses consume significant energy per vehicle. Vehicles vary in their fuel consumption and efficiency. The North American vehicle fleet is very diverse, composed of relatively standardized vehicles such as pickup trucks and passenger cars, as well as highly specialized vehicles such as beverage trucks and refuse haulers. Within the on-road market, the light- and medium-duty vehicle market segments are predominantly composed of mass-produced vehicles in a few common configurations. Heavy-duty, on-road vehicles are built for specific applications and are generally built-to-order for each customer, as is equipment in the off-road and non-highway sectors.

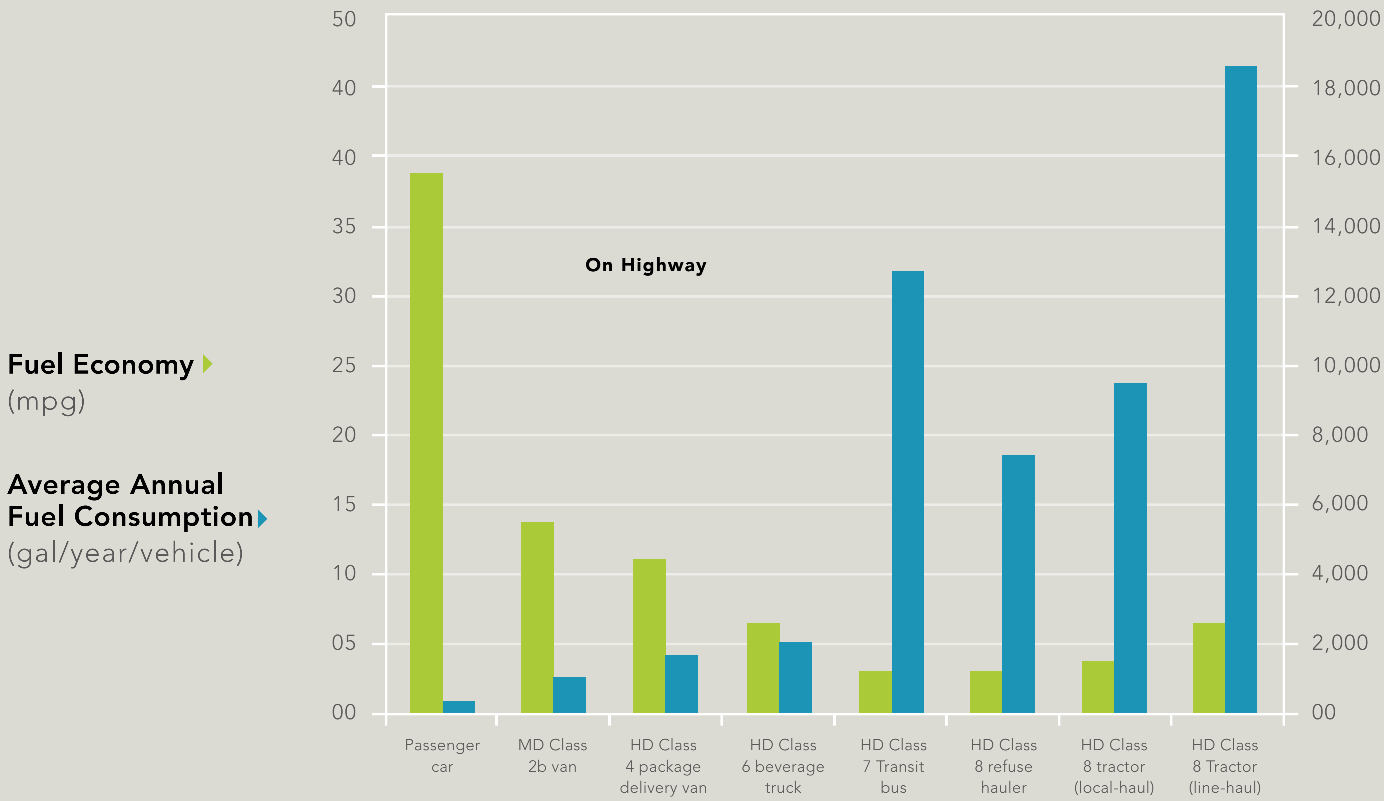
As the graphics below show, in the on-road segment, light-duty vehicles are the most fuel-efficient vehicles and use the least fuel per vehicle on an annual basis. Medium- and heavy-duty vehicles are less fuel efficient and consume more fuel annually per vehicle, especially in specific applications, making their total cost of ownership very sensitive to fuel price. Passenger and light-duty trucks dominate energy use, but off-road and non-highway uses consume significant energy per vehicle/application.[2] Despite increasing fuel efficiency of light, medium, and heavy-duty vehicles, the U.S. transportation system continues to rely significantly on foreign sources of energy from geopolitically unstable regions of the world and cannot be satisfied with domestic sources alone.

1 Energy Information Administration. "Annual Energy Review." October 19, 2011.
2 U.S. Census Bureau Foreign Trade Division. "U.S. Imports of Crude Oil." http://www.census.gov/foreign-trade/statistics/historical/petr.pdf. Accessed October 2010.

Passenger and light-duty trucks dominate energy use; non-highway uses consume significant energy per vehicle/application[3]



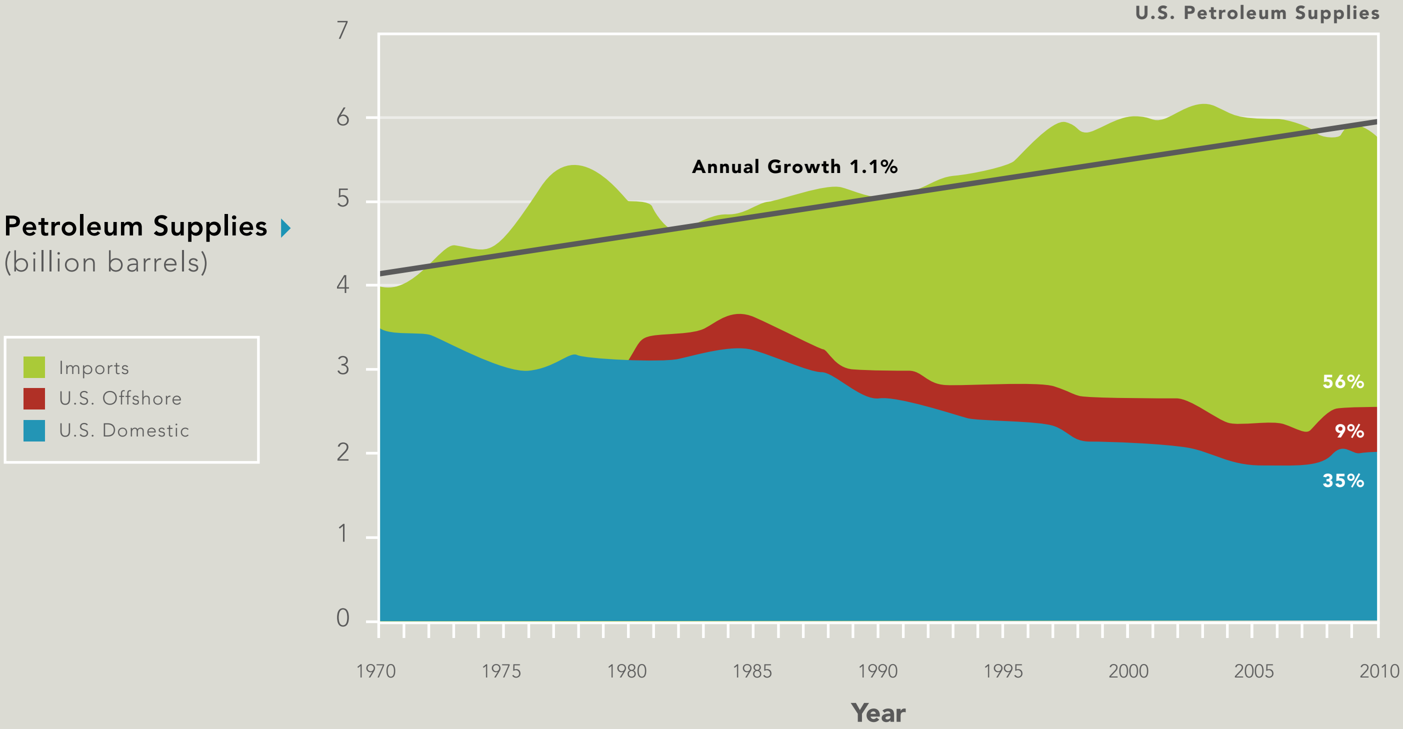
Light-duty vehicles have low annual mileage and high fuel economy; heavy-duty vehicles have high annual mileage and lower fuel economy[4]



3 2008 data from DOE Transportation Energy Data Book - http://cta.ornl.gov/data/index.shtml

4 See Market Segmentation report of overall TIAX assessment for additional descriptions of these market segments.

U.S. petroleum supplies[5]



For commercial and fleet vehicle operators, whose total cost of doing business is significantly influenced by small changes in fuel price, both volatility of, and increase in, petroleum prices can have a large negative impact. From the consumer perspective, this cost is reflected in the price per gallon at the retail pump. Because fuel price to date has generally represented a small fraction of total lifetime vehicle costs, private vehicle use has been relatively insensitive to fuel price.

If alternative fuel vehicle technology can be proven economically and become more available, conventional fuel prices will eventually move consumers to lower costs alternatives. Leveraging and communicating the potential of natural gas is a critical component of this shift. With abundant domestic natural gas, proven technology, and overall lower ownership costs, consumers will move natural gas into the marketplace and allow the North American economy to hedge against widespread impacts of unstable sources of foreign energy.

5 Data from Energy Information Administration, "Crude Oil Production," http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm, accessed September 11, 2012; Energy Information Administration, "U.S. Crude Oil Supply & Disposition," http://www.eia.gov/dnav/pet/pet_sum_crdsnd_k_a.htm, accessed September 11, 2012.

Chapter 2

How can NGVs and a supporting natural gas infrastructure enable energy independence?

A reliable source of energy security and economic stability exists inside our borders

North America can reduce its dependence on imported petroleum by tapping into the supply of natural gas. Several recent developments make this the right time to look at natural gas as a viable and sustainable option for widespread use in transportation. First, recent discoveries of abundant and domestic natural gas supplies have resolved questions relating to supply constraints. Secondly, NGV technologies are maturing. Thirdly, the United States and Canada are experiencing a widespread push for increasing energy security.

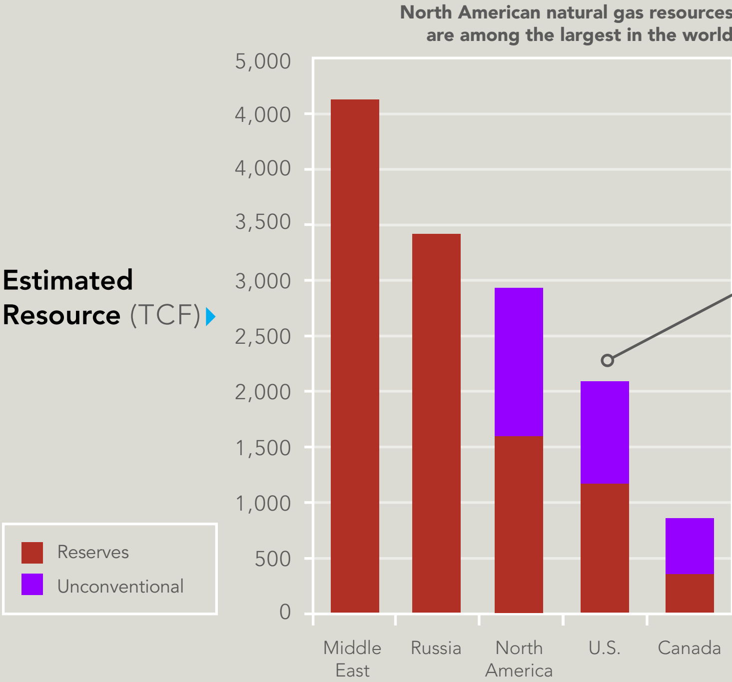
From mature supply and rising prices to abundance and affordability

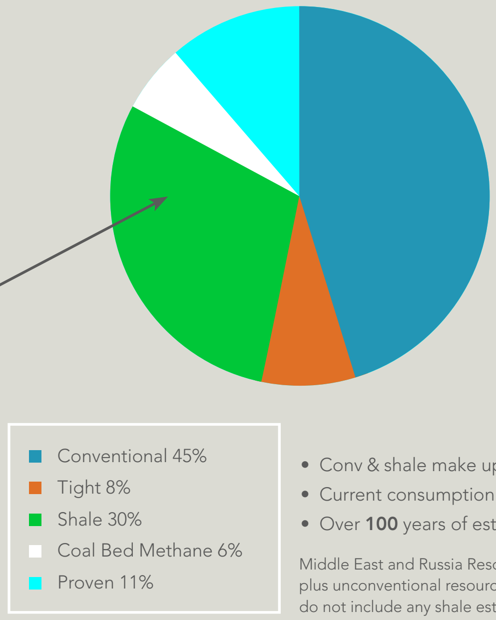
Not long ago, it appeared that conventional North American domestic natural gas supplies had begun to reach maturity. This perceived limited supply drove up prices, and demand stagnated as consumers switched to other energy sources. Due to high prices, suppliers (particularly in the U.S.) sought new natural gas sources, including planned liquefied natural gas (LNG) terminals, and increased exploration. This lack of North American supply was seen as a non-starter for considering natural gas as an alternative to foreign petroleum in the transportation sector. At this time, natural gas was being used for residential, commercial, and power generation markets. However, expanding its use in transportation would only take away from using clean natural gas in these segments.

Natural gas supply changed radically beginning in the early 2000s with the introduction of advanced drilling technologies and pressure pumping services that could economically produce natural gas from the vast resources in North America. Overnight, the supply went from projections of shortages to oversupply. This changed the opportunity for using natural gas as a transportation fuel. Currently, North America's natural gas resources are among the largest in the world, approaching 3,000 trillion cubic feet (TCF). Current U.S. consumption is about 24 TCF[6], suggesting over 100 years of supply.

6 Energy Information Administration. "Natural Gas Consumption by End Use." http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm. Accessed September 11, 2012.

U.S. and Canadian natural gas resources are among the largest in the world[7]





- Conv & shale make up **75%** of estimate
- Current consumption **24 TCF**
- Over **100** years of estimated supply

Middle East and Russia Resources include proven plus unconventional resources but do not include any shale estimates.

The abundance of natural gas makes it an attractive transportation fuel option

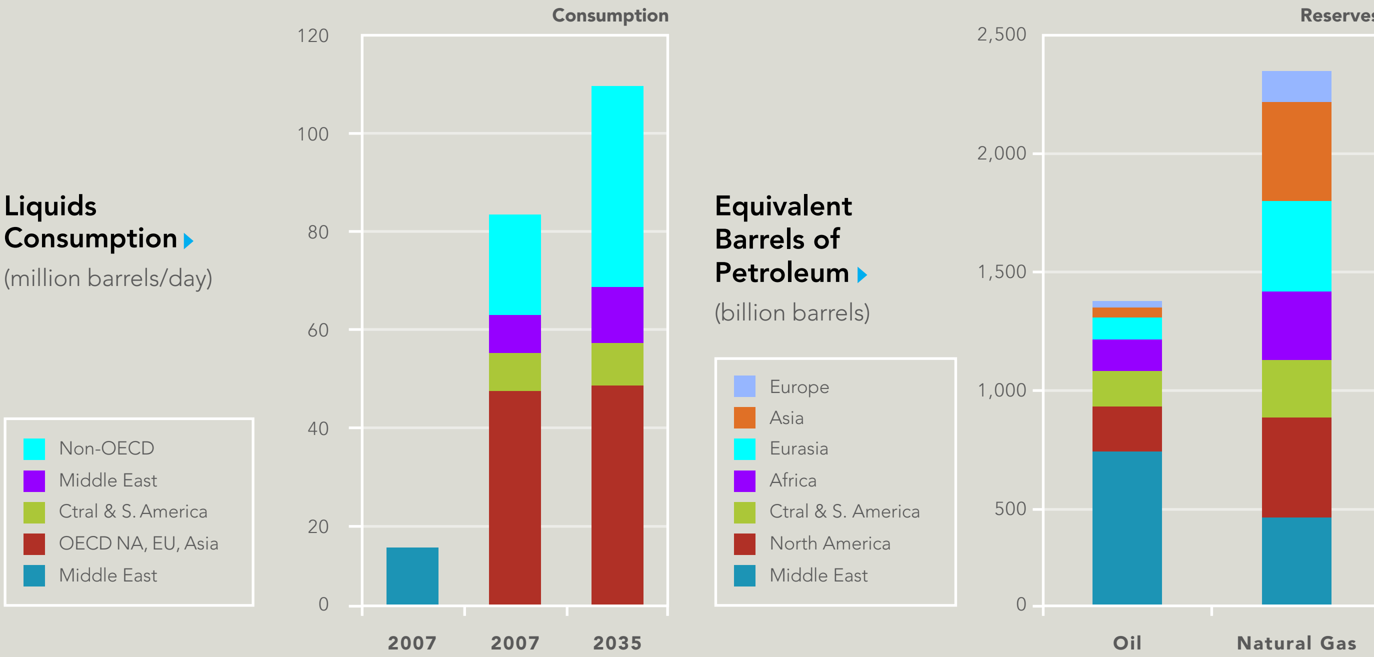
The North American natural gas supply is estimated (on an energy equivalent basis) at 500 billion barrels. The annual U.S. transportation consumption is 14 million barrels per day, compared to world consumption of over 80 million barrels per day. The total U.S. transportation demand is projected to increase to 16.2 million barrels per day in 2035. Little future growth in consumption is from the Organisation for Economic Co-operation and Development (OECD) countries, but significant growth is projected from developing (non-OECD) countries.

Natural gas can resolve a petroleum supply/demand imbalance

The worldwide supply of natural gas far outweighs the worldwide supply of petroleum. World petroleum resources are estimated at 1,350 billion barrels, and world natural gas resources are estimated (on an energy equivalent basis) at 2,260 billion barrels. At current consumption rates, these resources would last 46 and 121 years, respectively, and fewer years at projected future utilization rates. More importantly, from the perspective of domestically supplied and available fuels, natural gas resources in North America are 2.6 times greater than petroleum resources.

7 Data from Energy Information Administration, DOE/EIA-0484(2009), July 27, 2010; "Worldwide Look at Reserves and Production," Oil & Gas Journal 105(48), December 24, 2009.

Worldwide petroleum consumption and reserves[8]



As illustrated above, worldwide petroleum consumption is projected to remain relatively flat in North America, Europe, and Asia while increasing substantially in non-OECD countries and the Middle East (left). While petroleum reserves are concentrated in the Middle East, natural gas reserves are more widely distributed and are greater than petroleum (right). Even with fuel efficiency standards, increased demand from other parts of the world will increase pressure on petroleum prices for North American consumers and consumers around the world.

We have sufficient natural gas supply for both current & projected uses

Expanding natural gas applications can occur without limiting supply to current uses. Today, natural gas in North America is used primarily in sectors other than transportation, specifically, residential and commercial heating, industrial processes, and electric power generation. Combined, all U.S. sectors use 24.3 TCF of natural gas annually[9]. Of that amount, annual natural gas use in the transportation sector is 0.05 TCF. Given the extent of the North American natural gas resource, estimated at over 2,950 TCF[10], the supply of natural gas is sufficient to supply both the transportation and non-transportation sectors even as the NGV market expands.

8 Data from Energy Information Administration, DOE/EIA-0484(2009), July 27, 2010; "Worldwide Look at Reserves and Production," Oil & Gas Journal 105(48), December 24, 2009.
9 Energy Information Administration. "Natural Gas Consumption by End Use." http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm. Accessed September 11, 2012.
10 Massachusetts Institute of Technology. "The Future of Natural Gas." Interim Report, p. 7. 2010.

Current supplies of natural gas are sufficient for future natural gas demands[11]

Natural Gas Consumption
(TCF)

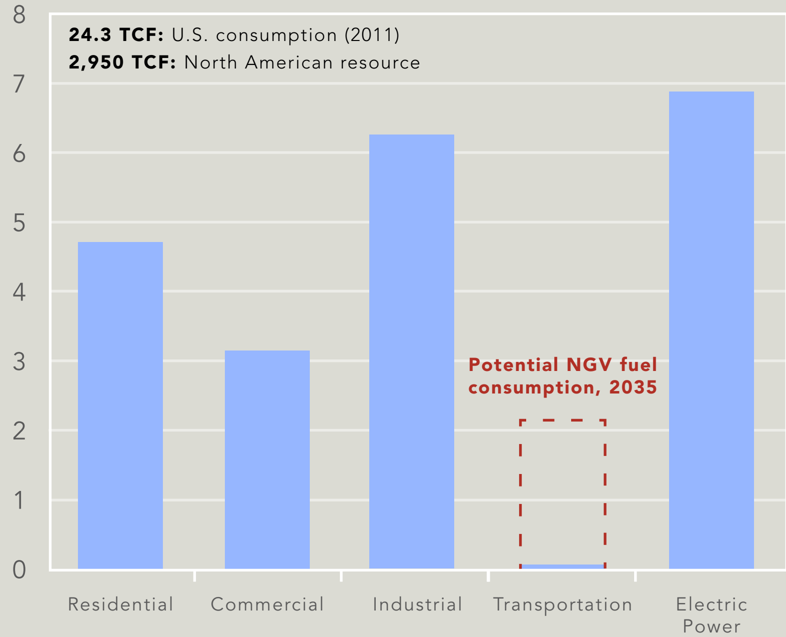
Estimated U.S. NGV population, current:
100,118-154,466 vehicles
(0.04-0.06% of 2012 on-highway vehicle population)

Estimated annual U.S. NGV fuel consumption, current:
361-366 million DGE
(0.05 TCF or 0.2% of 2012 on-highway consumption)

Potential U.S. NGV population, 2035:
16 million vehicles
(6% of 2012 on-highway vehicle population)

Potential annual U.S. NGV fuel consumption, 2035:
17 billion DGE
(2.2 TCF or 10% of 2012 on-highway consumption)

Source [28]



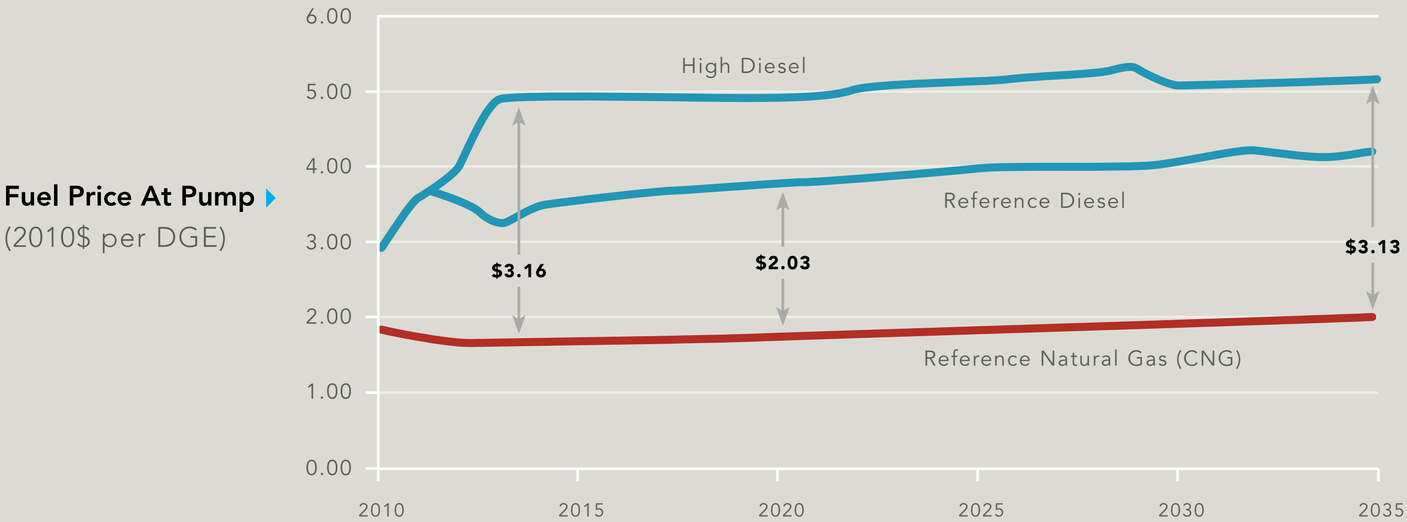
Natural gas is an economical fuel

Natural gas prices are gradually diverging from petroleum prices, making natural gas use in cars and trucks far more economical than gasoline or diesel fuels. NGVs cost more than conventional vehicles, but these higher costs are usually offset by lower fuel prices. The Energy Information Administration (EIA) projects natural gas pump price differentials of $1.00 to over $3.00 per diesel gallon equivalent (DGE) over the next 25 years. These savings are attributable to increasing petroleum prices, driven by increasing global demand and decreasing global supply, and stable natural gas prices, due to reliable domestic fuel resources.

As shown in the following graph, natural gas is less expensive (on an energy basis) than conventional fuels. Fuel price differentials at the pump of over $3.00 per gallon are possible in the near future.

11 See Market Segmentation and Scenario Analysis reports of overall TIAX assessment for NGV population and fuel consumption estimates and projections. Data from Energy Information Administration, "Natural Gas Navigator," http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm, accessed January 2011; Energy Information Administration, "Natural Gas Year-in-Review 2009," July 2010; Massachusetts Institute of Technology, "The Future of Natural Gas," Interim Report, p. 7. 2010

Future natural gas/diesel price differentials[12]

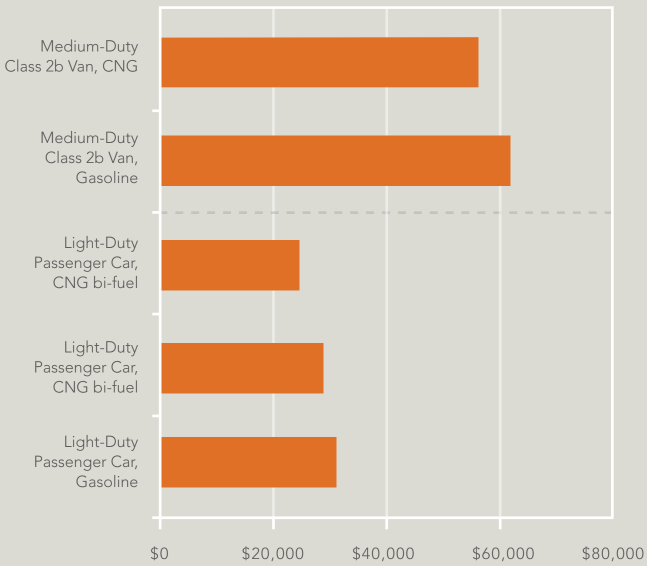


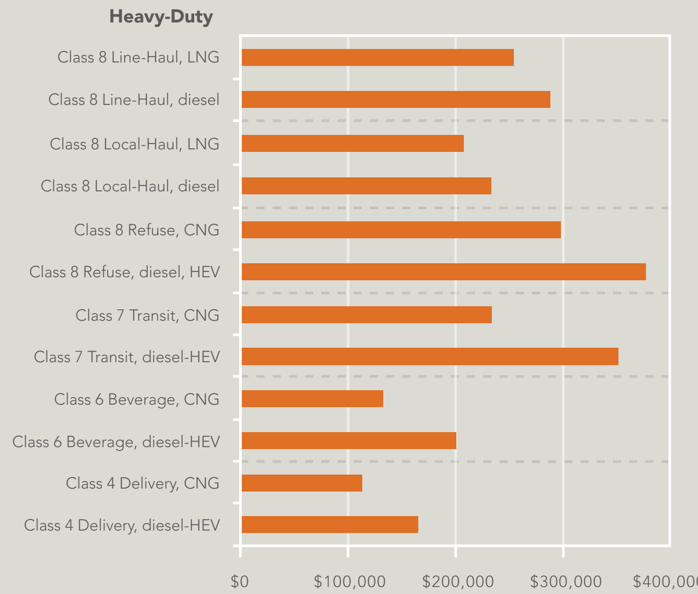
Direct costs for natural gas vehicles compare favorably to conventional vehicles

Estimates of vehicle ownership costs include vehicle costs, fuel and other operating and maintenance costs, residual value, insurance, and financing costs. The illustration below shows estimated ownership costs for various vehicle applications. These costs include only vehicle and fuel costs; all other costs are assumed to be the same for NGVs and conventional vehicles. These lifetime costs are referred to as direct costs. For each vehicle application, NGVs are compared to conventional baselines. The baseline configurations project possible improvements with advanced engine and driveline technology, such as hybridization. Thus, the comparison uses the next generation advanced conventional technologies. Even with this assumption and a conservative pump price differential of $1.50 per equivalent gallon, direct costs for NGVs are lower in nearly every vehicle application. With higher differentials, NGVs offer even greater savings.

12 Energy Information Administration. "Annual Energy Outlook 2012." June 2012.

Direct vehicle costs, by vehicle and fuel type[13]





Natural gas vehicles compare favorably to other alternative vehicles

Not all alternative vehicle ownership costs are equal. Ethanol and biodiesel blends can be used with existing technology without modification and do not require added vehicle costs. Natural gas and electric technologies have higher vehicle costs because they require more expensive storage systems—high-pressure or cryogenic tanks for natural gas and hydrogen and batteries for electric platforms. Fuel costs are lower for natural gas and electricity, projected to be the same for hydrogen, and the same or higher for biofuels. Infrastructure requirements also differ. Home refueling is primarily an option for electricity and natural gas, whereas blended fuels need few changes. Natural gas, hydrogen, electric, and E85 require the development of public fueling. Private fueling applies mostly to fleets using natural gas, biodiesel, or, in the future, hydrogen. Despite these differences, when contrasting NGV costs and fueling needs to those of other alternative vehicles, NGVs compare favorably.

13 See Comparative Analysis report of overall TIAX assessment for calculations of direct and societal costs of various vehicle technologies.

Comparison of alternative fuel vehicle and fuel costs to conventional

Alternative Fuels	Vehicle Costs	Fuel Costs
Ethanol blend (E10)	Same	Same
Ethanol (E85)	Same	Same
Plug-in hybrid electric vehicle (PHEV)	More	Less
Battery electric vehicle (BEV)	More	Less
Hydrogen fuel cell vehicle (FCV)	More	Same
Light-duty NGV	More	Less
Heavy-duty NGV	More	Less
Biodiesel (B20)	Same	More

The line-up of NGVs is limited today but consumer demand could expand offerings

The options for NGVs in the light-, medium-, and heavy-duty vehicle segments are currently limited. However, recognizing the growing potential of NGVs, vehicle and engine manufacturers have shown interest in producing NGVs. Original equipment manufacturer (OEM) products are small in number, though recent announcements by major automakers demonstrate renewed interest in expanding NGV offerings. The Honda Civic Natural Gas is the only OEM passenger car available at present. GMC, Chevrolet, VPG, and Ford currently offer NGV products, either as turn-key NGVs or conversion-ready NGVs. For light- and medium-duty segments, conversion companies currently offer a variety of options for converting existing engines. These vehicles typically offer the same or similar warranties and features that end users expect from OEMs.

For heavy-duty segments, in which vehicles are built according to customer specifications, the availability of NGVs depends on the availability of natural gas engines that meet the power and torque requirements of specific vehicle applications. For example, a refuse truck that requires a 10-liter engine for its particular duty cycle may not have a natural gas option in the near term, unless the purchaser is willing to accept a vehicle with a 9- or 11-liter engine. In the near term, it appears that natural gas engines will not be available for heavy-duty vehicles that require engines in the 10- and 14-liter ranges. However, heavy-duty engine OEMs have expanded their offerings to a wider range of engine sizes in recent years and are continuing to do so.

For light- and medium-duty vehicles, up to seven OEM and OEM conversion-ready NGVs are currently available. For heavy-duty vehicles, up to six engines may be available, but natural gas choices for specific vehicle segments may be limited. The currently available vehicles are listed on the next page:

Current NGV Lineup[14]

Light- and Medium-Duty:

OEM Turn-Key NGVs

GMC Savana

Chevrolet Express

Honda Civic GX

VPG MV-1

OEM Conversion-Ready NGVs

Ford Transit Connect

Ford E- Series

Ford F150- Series

Heavy-Duty

	7L Emission Solutions/ International Truck 7.6 L Phoenix	**8L** Landi Renzo USA/ Baytech 8.1 L	**9L** Cummins Westport 8.9 L ISL G	**10L**	**11L** Doosan Infracore America 11 L GK12	**12L** Cummins Westport 11.9 L ISX G	**13L** Navistar 13 L Maxx-Force	**14L**	**15L** Westport Innovations 15 L GX
Heavy-duty truck	green ●	green	green		green ●	orange	orange ●		green
Transit bus	green	green ●	green ●		green ●	orange	orange		green
School bus	green	green ●	green		green	orange	orange		green
Over-the-road coach	green	green	green		green	orange	orange ●		green
Refuse / utility truck	green	green	green	●	green ●	orange	orange		green
Drayage	green	green	green		green	orange ●	orange		green ●
Vocational	green	green ●	green		green	orange ●	orange		green

■ (green) HD NG Engine Currently Available ● Indicates New or Additional Engine Needed

■ (orange) HD NG Engine Expected Near Term

14 Illustrations courtesy of their respective manufacturers. See Light- and Medium-Duty Vehicle Ownership and Production and Heavy-Duty Vehicle Ownership and Production reports of overall TIAX assessment for details.

Short range vehicles can benefit from natural gas immediately

Transit buses, refuse haulers, and package delivery vehicles have had the strongest market drivers for adopting natural gas. These applications are also well suited to the use of natural gas based on their market enabling features of short range and return-to-base duty cycles. Additionally, depending on the fuel capacity and typical range, fuel type is important. Vehicles that carry more than 80 DGE are more suited to liquid natural gas (LNG), whereas vehicles with less than 80 DGE often use compressed natural gas (CNG). Thus, vehicles with ranges greater than 300 miles (e.g., line- or regional-haul tractors) are primarily suited for LNG, while with less range than 300 miles use CNG.

NGVs must keep pace with efficiency improvements in the conventional market

The current NGV market supports a limited number of vehicle offerings. Growth of the market could be influenced by lower vehicle ownership costs and by future regulations. Either of these factors would increase demand for natural gas engines and vehicles. Suppliers will need to be ready to provide products that include improvements to engine and vehicle efficiencies to this expanding market.

Natural gas is expected to compete well against diesel hybrid technologies in many sectors. Furthermore, with cost reductions, hybrid natural gas drivetrains could be competitive. With the focus on lower carbon dioxide emissions, diesel engine efficiency will also be improving. Similarly, gasoline technologies will be improving with technologies like direct injection, which may or may not be applicable to natural gas engines. Any increase in efficiency of conventionally fueled engines and vehicles without similar increases in natural gas technology will reduce the competitiveness of NGVs. This may result in lower fuel prices being required to compete. In addition to product improvements, engine and vehicle manufacturers should continue to educate dealers on the maintenance and servicing of NGVs as well as the benefits of NGVs.

One key question that remains for NGVs is whether they can keep pace with higher engine efficiency improvements for conventional fuel engines and therefore remain competitive as technologies evolve. Nevertheless, even with limited offerings of engines and vehicles, there are enough products available today to support expansion of the NGV market. As the market grows, more products will be demanded.

Chapter 3

Who will benefit from expansion of NGVs?

Natural gas vehicles can create millions of jobs

Natural gas creates domestic jobs. Increasing the use of natural gas in transportation has significant potential to impact national employment by displacing foreign petroleum jobs, establishing new manufacturing and construction opportunities, and stimulating economy-wide spending through fuel savings to the consumer. Jobs may be permanent, such as those established to support increased economy-wide spending, or temporary, such as those established for the duration of a particular construction project.

Expanding North America's fueling infrastructure would create a cumulative total of over 3.7 million jobs by 2035. While some of these jobs would be temporary, they provide opportunities that Americans need today:

Expanding the natural gas infrastructure is expected to create jobs[15]

	Light-Duty CNG	Medium and Heavy-duty CNG	Heavy-Duty LNG
Total number of new stations built by 2035[a]	12,800	12,100	700
Spending Changes and employment impacts in transportation fuel sectors			
Job impacts (FTEs) per station:	0.81	0.24	19.78
Overall job impacts (FTEs):[b]	10,400	2,900	13,800
Capital and infrastructure expansion			
Job impacts (FTEs) per station built:	112	179	166
Overall job impacts (FTEs):[c]	1,430,000	2,170,000	116,000

a - Based on potential market projections as detailed in the Scenario Analysis report of the overall TIAX assessment.
b - These jobs are permanent jobs across the economy.
c - These jobs are created for the duration of the manufacturing/construction project only; cumulative number in 2035 is presented.

15 Employment impacts based on IMPLAN Input-Output model and Jack Faucett Associates estimates; see Appendix

The societal benefits of NGVs compensate for higher direct costs

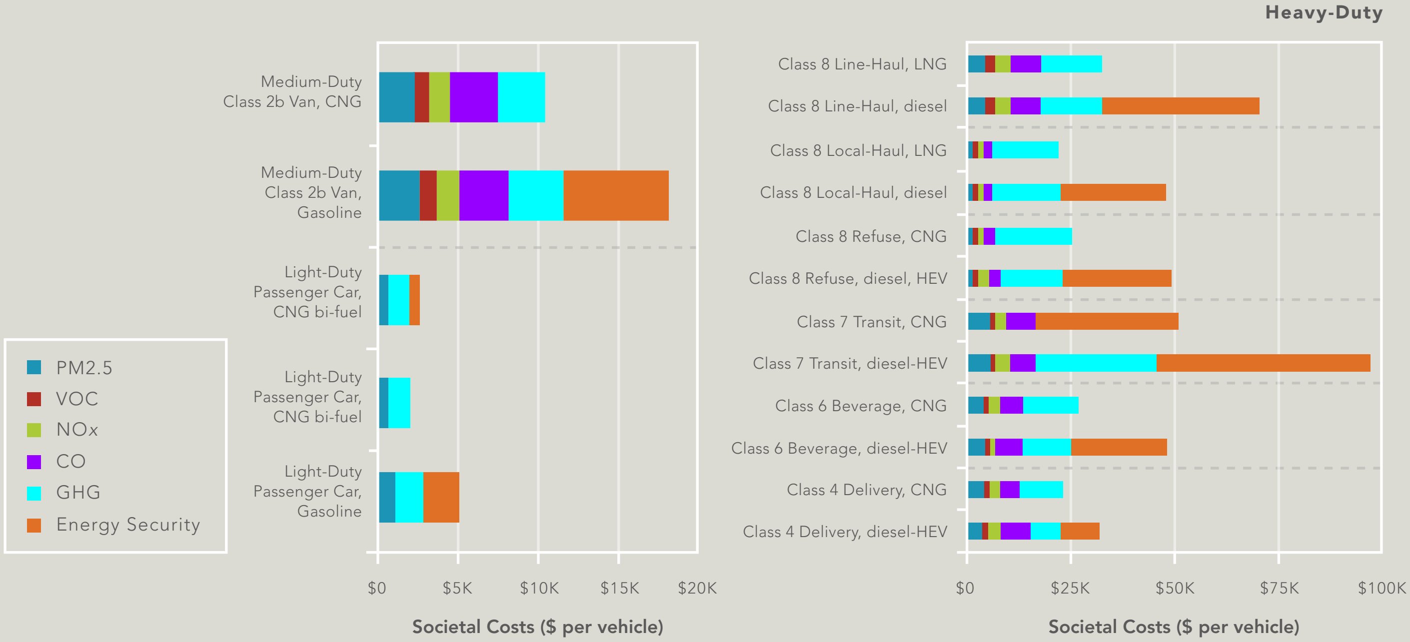
In addition to direct costs, the increased use of natural gas also results in fewer indirect costs to society as a whole. One of these reduced costs is the energy security premium, which has been estimated at approximately $0.462 per gallon.[16] Energy security can be defined as protecting the economy against significant increases and volatility in energy costs, which have contributed to U.S. recessions since the 1970s.

In addition, every transportation fuel carries a societal cost based on impacts to human health by criteria pollutant emissions. These costs are different for each fuel. The more use of natural gas as a transportation fuel, the more these societal costs can be reduced. The third societal cost of fuel use results from GHG emissions, which impact human health, property, agricultural productivity, and ecosystems.

Monetization of these societal costs provides a means to assess the societal benefits of the alternative fuels considered. The charts below demonstrate that, across multiple vehicle segments, the societal costs for NGVs are lower than those for conventional fuels. The net savings (of direct and societal costs) exceed $50,000 for some high fuel use applications and are comparable to saving 15 percent of lifetime costs. The savings for other applications may be less but are still significant. One way to capture these societal cost savings is by providing vehicle incentives to buy down the initial cost of the more expensive technology, noting that the total ownership costs of NGVs may be less than those of conventional vehicles due to lifetime fuel savings. This is currently done in several states and was recently part of federal programs as well.

16 See Comparative Analysis report of overall TIAX assessment for additional discussion of energy security and societal cost monetization.

Societal costs of various vehicles, by fuel type[17]



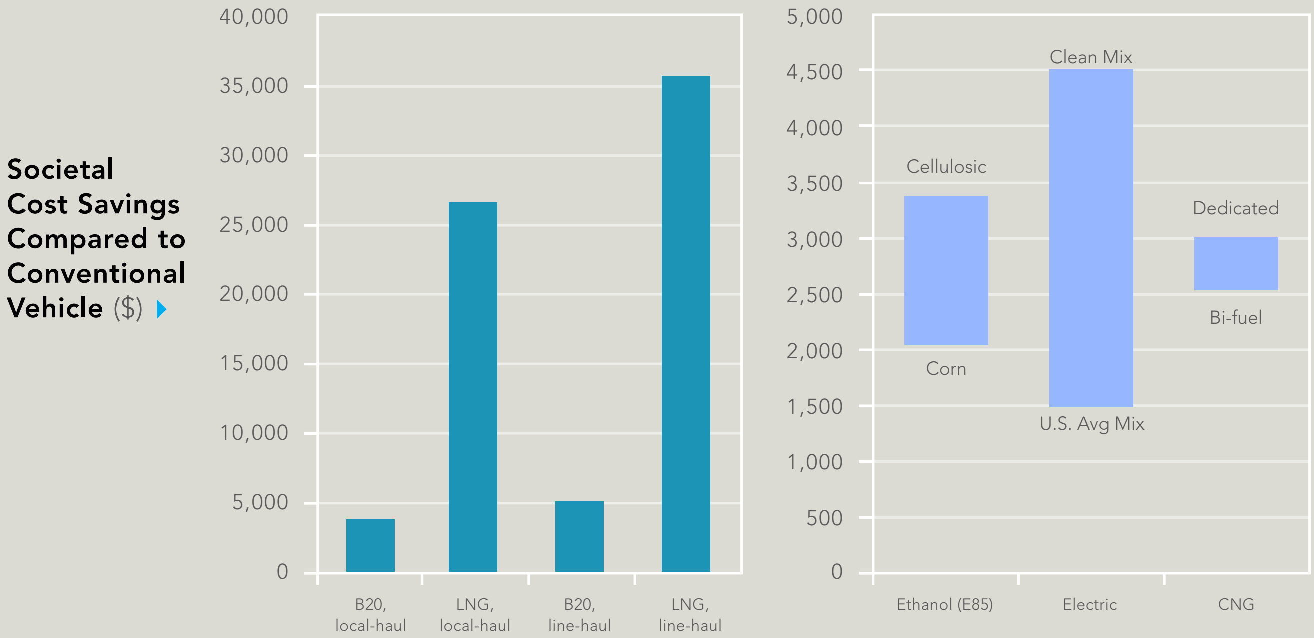
Note: Direct costs above include vehicle and lifetime fuel costs, assuming a $1.50 per equivalent gallon pump price differential. As indicated in Figure 2.3-1, the differential may be as high as $4.00 per equivalent gallon, which significantly lowers the relative direct costs of NGVs.

Heavy-duty NGVs deliver the greatest societal benefits

In understanding the societal costs of conventional and natural gas vehicles, this report monetizes the societal and indirect costs associated with various fuels and technologies. It focuses on those with the largest impact: local urban pollution, GHG emissions, and energy security. Emissions and energy use were determined using a full fuel cycle methodology, and the values of these externalities were calculated from accepted estimates used by federal agencies. The figure below shows two examples of the societal benefits of using alternative fuels compared with advanced gasoline and diesel technologies. For passenger cars, NGVs are essentially comparable to ethanol and electric options. In heavy-duty NGVs, high fuel use leads to greater societal benefits. The value of these benefits, applied as incentives, may help move the NGV market forward.

17 See Comparative Analysis report of overall TIAX assessment for calculations of direct and societal costs of various vehicle technologies.

Societal costs of various transportation fuels[18]



Energy policy to date has not decreased transportation fuel consumption

Americans experienced the first petroleum price shock in 1974 when the Organization of Petroleum Exporting Countries (OPEC) embargoed petroleum to the U.S. Its price more than doubled, and Americans experienced shortages at local fueling stations. The second "petroquake" occurred in 1979 with the Iranian War and petroleum again being embargoed. These two events resulted in the first of a series of Energy Policy Acts (EPActs) (Figure 6.1-1). The Corporate Average Fuel Economy (CAFE) standards of the first act approximately doubled fuel economy of new vehicles and were one of the reasons fuel prices fell in the early 1980s.

Although a number of other global events affected the price of petroleum over the next several decades, as world demand slowly increased, the price of petroleum reached a new high in 2008. Increasing petroleum prices have been associated with U.S. recessions; although each U.S. President responded to the energy crisis, there were no standards or regulations implemented to reduce fuel consumption in the transportation sector (other than CAFE and the more recent fuel economy and GHG standards).

The policy approach of the time was to let market forces regulate energy prices. This was a reasonably successful policy for providing consumers with relatively low and stable fuel prices from 1985 to the early 2000s. This policy also resulted in the U.S. importing more and more petroleum to meet the growing demand associated with population and economic expansion. The chart below details significant energy milestones and government energy policy introductions:

18 See Comparative Analysis report of overall TIAX assessment for societal cost calculation details and assumptions.

Date	Energy Milestones
1973	Yom Kippur War, OPEC petroleum embargo, Project Independence (self sufficient by 1980)
1975	Energy Policy and Conservation Act
1977	Carter signs DOE Organization Act
1978	National Energy Act-Energy Tax Act
1979	Iran War, 2nd oil crisis, decontrol of oil prices
1980	Energy Security Act
1981	Decontrol of crude and refined product prices
1988	Alternative Motor Fuel Act
1990	Gulf War
1992	EP Act 1992
2001	"9-11" Terrorist Attack
2003	Iraq War
2005	Gulf hurricanes—Katrina, Rita
2005	EP Act
2007	EISA
2008	Great Recession

Environmental standards are decreasing emissions and need to keep pace with fuel consumption

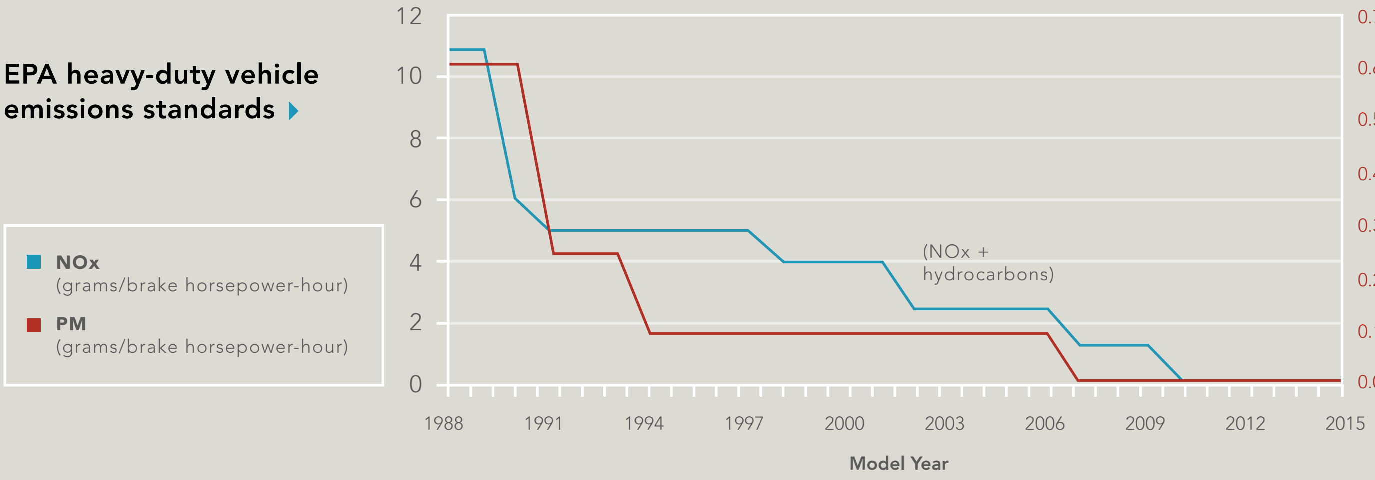
In response to health effects of local pollution (ozone, carbon monoxide, oxides of nitrogen (NOx), particulate matter (PM), and lead)[19], the U.S. federal government established the EPA and empowered it through the Clean Air Act (CAA) and its Amendments (CAAA) to set ever tighter fuel and vehicle standards to help regions comply with health-based ambient air quality standards. A number of programs that resulted from this overall policy are also shown in the table.

19 Health effects of these pollutants include respiratory and cardiovascular diseases.

Date	Environmental Milestones
1970	EPA opens, Clean Air Act passes
1971	EPA sets National Ambient Air Quality Standards
1973	EPA starts lead phase-out
1975	EPA requires catalysts on vehicles
1977	CAAA passed
1985	EPA sets new limit on lead in gasoline; expands air toxins program
1988	EPA sets standards for underground tanks
1989	Exxon Valdez oil spill
1990	CAAA of 1990
1993	Wintertime Oxygenated Fuel Program
1994	Phase in cleaner car standards
1995	Reformulated Gasoline Standard
2002	Diesel NO_x and PM standards
2005	RFS
2006	Ultra low sulfur diesel fuel
2007	Tighter diesel NO_x and 90% PM standards
2007	RFS II
2010	90% control of NO_x PM diesel

The environmental policy of the 1970s (the Clean Air Act) was much different than the energy policy in that affected industries were mandated to reduce emissions. In general, the philosophy was to set performance standards and let industry determine the most cost-effective ways to comply. The result has been a dramatic decrease in fuel and vehicle emissions and substantial improvement in air quality, as evidenced in the graphic below. However, economic expansion continues to put pressure on achieving and maintaining air quality in many regions of the U.S. In addition, the finding that climate change is a serious threat to human health requires additional reductions in GHG emissions—promoting improved fuel economy and lower carbon fuels.

EPA heavy-duty vehicle emissions standards



Economists agree that policy intervention is needed when market forces do not account for the full costs of using a technology, such as the societal damages caused by vehicle emissions. In the past, this has justified the use of incentives to correct for this market imperfection. However, except for incentives in the various EPA acts and the mandates in the Renewable Fuel Standard (RFS), there has not been a clear objective to reduce the U.S. dependence on foreign sources of energy from geopolitically unstable regions of the world, despite growing evidence that the costs of this dependence are not fully accounted for in the fuel price.

Where energy and environmental policies have been unsuccessful, NGVs can succeed in increasing our energy security

Despite the volatility of our energy prices and warnings about the dangers of climate change, energy and environmental policy has not significantly affected transportation fuel consumption. As global demand for petroleum grows, North American dependence on foreign petroleum from geopolitically unstable regions of the world becomes an increasing vulnerability. Recent discoveries of abundant and domestic natural gas supplies coupled with the maturity of NGV technologies makes natural gas a viable and sustainable option for widespread use in transportation. NGVs can provide lower overall operating costs, reduced air pollutant and GHG emissions, and reduced petroleum consumption, as well as offer significant job creation opportunities. Given these factors, North America is currently in a position to make radical changes in its approach to fuel sources for transportation.

NGVs offer proven benefits and are the new frontier of North American prosperity

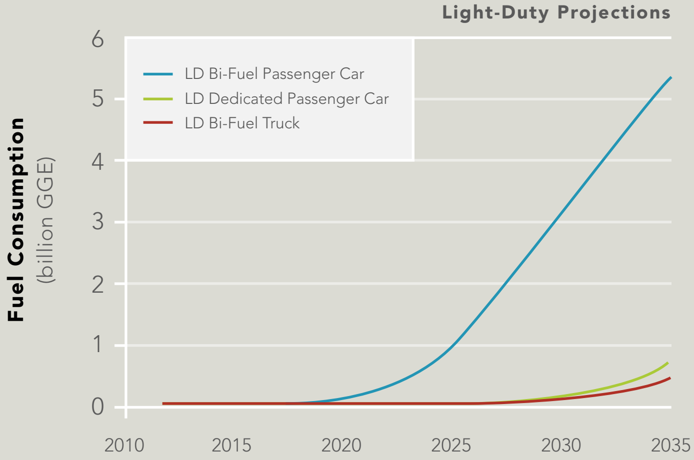
Proliferation of NGVs establishes a new market for natural gas

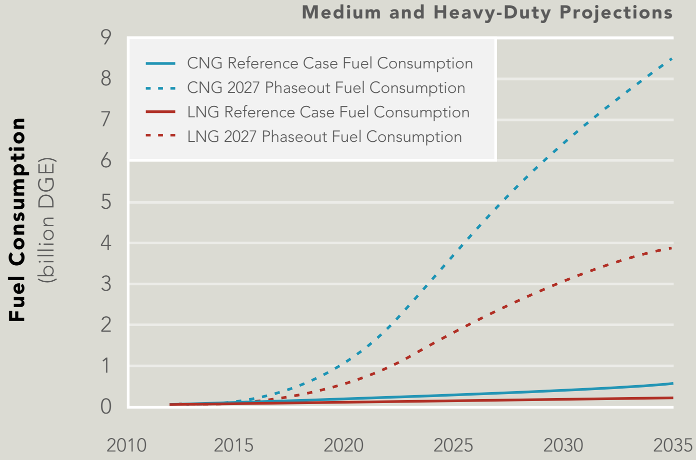
The NGV market can be considered to have three main components: the light-duty CNG market, the medium- and heavy-duty CNG market, and the heavy-duty LNG market. Medium- and heavy-duty vehicles are grouped in the same market because they are employed in commercial applications, whereas the light-duty vehicles are also employed for personal use.

Under an aggressive expansion scenario, by 2035, the NGV market may potentially enable the consumption of 5.5 billion GGE of CNG in the light-duty market and 8.5 billion DGE of CNG and 3.9 billion DGE of LNG in the medium- and heavy-duty markets. Together, this consumption equals 2.2 TCF of natural gas annually and is approximately 30 percent of the current natural gas consumption in the power generation sector. This level of use in the transportation sector represents a significant new market for natural gas. The increase in fuel required to power a growing NGV market is shown below:

20 Data from DieselNet, "Emission Standards: USA: Heavy-Duty Truck and Bus Engines," http://www.dieselnet.com/standards/us/hd.php, accessed October 2010;

Prospective fuel consumption in light, medium, and heavy duty vehicles[21]





Natural gas also offers profitable opportunities for players in the natural gas supply chain

The transportation sector offers significant market potential for natural gas supply chain companies. The business case for gas producers, pipeline companies, gas utility companies, and fueling station operators depends on reliable natural gas throughput and reasonable profit margins over costs. Because all of these individual companies are part of the same supply chain, they must work together to provide compelling natural gas prices at the pump. As such, it is critical to the long-term sustainability of the natural gas transportation market that these entities cooperate with one another to efficiently deliver natural gas to transportation customers. In order for each of these entities to remain in the NGV market, each must see a reasonable business case.

Making vehicles ready for natural gas creates new business opportunities for manufacturers and suppliers

End user vehicle requirements vary widely depending on the application in which vehicles are used. Different end use applications need different vehicle attributes and place varying levels of importance on these attributes. Aligning NGV characteristics with required attributes determines whether NGVs are a viable option for end users. Some characteristics of various vehicle segments are conducive to the use of natural gas while others require tradeoffs in order to gain the benefits of natural gas. Transit, refuse, school buses, and heavy-duty package delivery vehicles have the most favorable characteristics, and not surprisingly, these applications currently dominate NGV use, along with light-duty fleet applications. Other applications are considering or currently trying NGVs, including local- and regional-haul tractors.

The table below summarizes current suitability of different vehicles for natural gas. It also provides insight into the work that will be required to bring products to market.[22]

21 See Scenario Analysis report of overall TIAX assessment for details and assumptions.
22 See Market Segmentation report of overall TIAX assessment for additional discussion of vehicle segment characteristics.

Vehicle Segment	Range	Base	Fueling Infrastructure	Vehicle Availability	Fuel Cost Sensitivity	Environmental Policies
Passenger Car/Light Truck (Retail)	Good	Good	Fair	Fair	Weak	Fair
Passenger Car/Light Truck (Commercial)	Fair	Good	Good	Fair	Weak	Fair
Medium-Duty Private and Commercial Van/Truck	Good	Good	Good	Fair	Fair	Fair
Heavy-Duty: Package Delivery	Good	Good	Good	Weak	Good	Good
Heavy-Duty: Utility Trucks	Good	Good	Good	Fair	Fair	Fair
Heavy-Duty: Beverage Truck	Good	Good	Fair	Fair	Fair	Fair
Heavy-Duty: School Bus	Good	Good	Good	Fair	Weak	Good
Heavy-Duty: Transit Bus	Good	Good	Good	Good	Good	Good
Heavy-Duty: Refuse Trucks	Good	Good	Good	Good	Good	Good
Heavy-Duty: Local-Haul Tractor	Good	Fair	Fair	Fair	Good	Fair
Heavy-Duty: Line Haul-Truck Tractor	Weak	Weak	Weak	Weak	Good	Fair
Off-road Service/Utility Vehicles	Fair	Good	Good	Fair	Fair	Fair
Construction Equiptment	Weak	Weak	Weak	Weak	Weak	Weak
Mining Equiptment	Weak	Good	Good	Weak	Good	Weak

● Good ○ Fair ◦ Weak

Definitions*

Good:
1- Strongly enables the use of NGVs with the current state of the NGV market, or
2- Provides significant benefits from the use of NGVs

Fair:
1- Provides limited options to enable the use of NGVs or needs additional development, or (2) Provides modest benefits from the use of NGVs

Weak:
1-Requires significant additional development to enable the use of NGVs, or
2-Provides no benefits from the use of NGVs or increases overall costs

*Note that the assessment of any criterion for any application as good, fair, or weak is subject to change as the markets and various external pressures change

Legend:
For each vehicle segment, six criteria are identified that align with characteristics that are suitable for natural gas. These are described below. Ratings of good, fair and weak are assigned to identify the best markets for NGVs.

"Range" describes the typical daily operating range of vehicles in a particular application. In most applications, whether on-road or off-road, it is preferred by vehicle users that the vehicle carry enough fuel to operate for several days or be able to miss a typical refueling event without running out of fuel. This provides the user with some margin of safety if daily operations deviate from the norm. At a minimum, it is assumed that a vehicle must carry enough fuel to work through an entire shift or typical day of operation.

"Base" refers to the location where the vehicle is parked or stored when not in operation. Return-to-base applications, where the vehicle is returned to the same location each day, are the most conducive to NGV use because they allow for daily refueling, thereby minimizing onboard fuel storage requirements. These return-to-base applications often include centralized maintenance facilities and staff, allowing a few trained technicians to support numerous NGVs.

"Fueling Infrastructure" describes the typical method of refueling employed for a particular vehicle application as well as the potential for adding natural gas capability. Fleets that fuel their vehicles at fleet yards or operations centers (e.g., warehouses and ports) are best positioned to use nearby public fueling stations or install fleet-controlled natural gas fueling equipment.

"Vehicle Availability" describes the number and types of vehicles currently available for a particular application. In general, more vehicle and engine options ensure that NGVs will be suitable for users within an application. Original equipment manufacturer (OEM) options provide a single responsible party for warranty and service, making these offerings more appealing.

"Fuel Cost Sensitivity" considers the relative importance of fuel costs to vehicle purchase and operating costs. In general, high fuel consumption applications are highly sensitive to fuel costs. Low fuel consumption applications tend to be more sensitive to purchase and maintenance costs.

"Environmental Policies" as a criterion attempts to describe whether vehicle users within a particular application are sufficiently motivated by internal policies or external regulations to make vehicle purchase decisions based on the relative environmental impacts of the vehicles.

Chapter 4

How can we make NGVs more available and affordable?

Making NGVs more available and affordable will involve all of the four major stakeholders in the NGV industry—end users, natural gas supply chain companies, vehicle and engine manufacturers and government—working together. Each has a specific role, as well as significant opportunities for gain, in the NGV market:

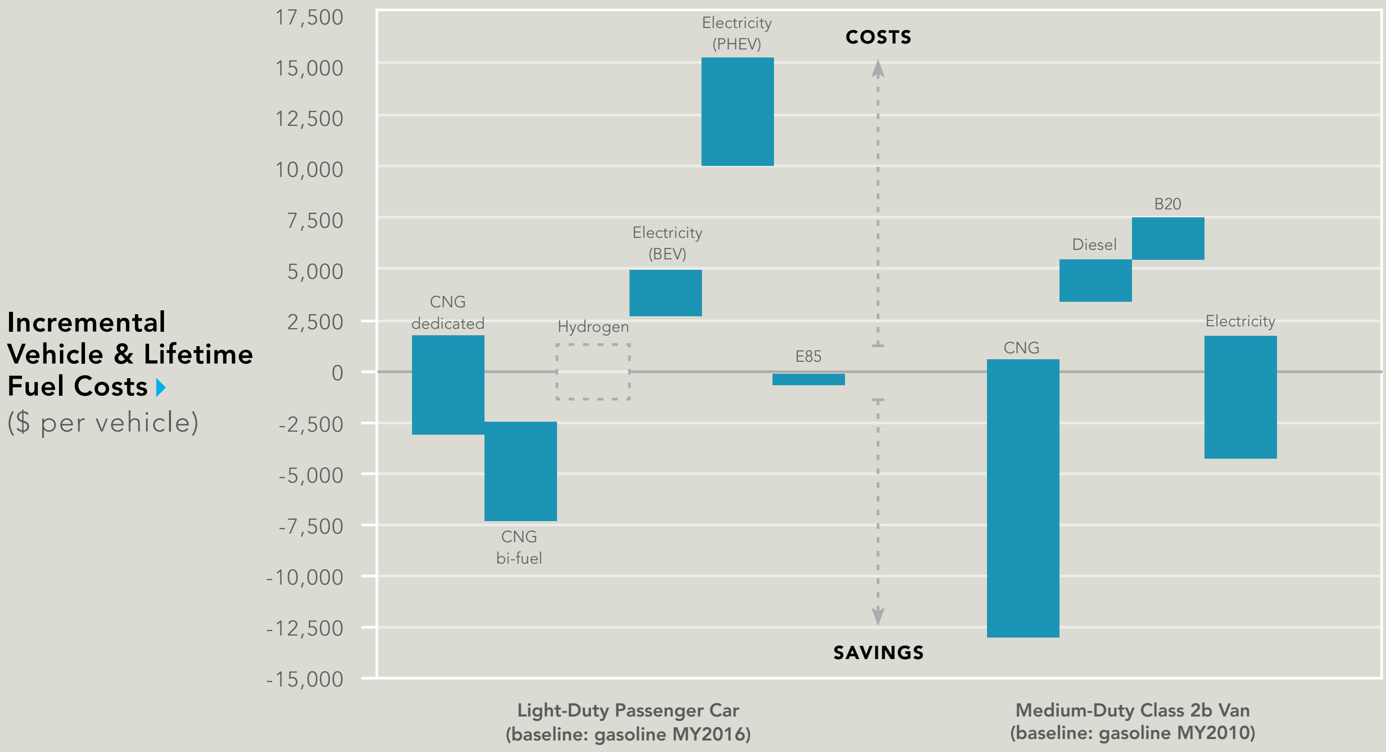
Major NGV Stakeholder	Role in NGV Market
End users	Provide demand for NGVs and natural gas fuel
Natural gas supply companies	Supply natural gas to transportation market; establish and operate fueling infrastructure; help in the education and training of and outreach to the other industry stakeholders to dispute market risk
Vehicle & engine manufacturers	Provide NGV offerings meeting the requirements of end users
Government	Level the playing field relative to other alternative fuels and vehicles and avoid picking alternative fuel winners and losers

Building a foundation for NGVs: End users need affordable options

End-user vehicle purchase decisions focus primarily on three criteria: potential savings, fueling infrastructure availability, and vehicle choices. Whether end users rely on public fueling infrastructure or are capable of accessing a home fueling appliance[23], the availability of infrastructure drives the vehicle purchase decision. End users' purchase decisions will be influenced by the relative lifetime costs or savings offered by various technology options compared to gasoline and diesel vehicles. The table below presents information on the existing fueling infrastructure by fuel type. Adoption of NGVs is also highly dependent on engine and vehicle availability.

23 An in-home fueling device is a home-based gas utility or personal fueling device. It would be approximately the size of a small chair and could sit outdoors or indoors.

Lifetime fuel costs by vehicle and fuel type[24]



24 Lifetime costs include the cost of fuel over the vehicle's first-owner operating lifetime and reflect the vehicle application's operating characteristics. See Comparative Analysis report of overall TIAX assessment for calculation details and assumptions.

Rising fuel costs and environmental concerns attract consumers to NGVs

There are six criteria that drive end-user purchase decisions: range, base, refueling infrastructure, vehicular availability, fuel cost sensitivity, and environmental policies. In general, economic, environmental, and social pressures influence vehicle purchase decisions. These pressures will ultimately dictate which market segments seek alternatives to traditional petroleum fuels and what alternative fuels they select. Of the six criteria used to evaluate the various market segments as previously discussed, two of these criteria represent market drivers that incentivize or discourage the acceptance of alternative fuels. These criteria are sensitivity to fuel cost and environmental policies and represent economic and environmental/social pressures respectively. While not complete or exhaustive, these two criteria are important and reflect those markets that have seen the greatest penetration of NGVs.

Consumer demand for NGVs depends on their value proposition, which depends on initial vehicle costs, expected fuel savings, vehicle incentives, vehicle and fueling infrastructure availability, and other non-financial motivators, such as carpool lane access or a "green" image. They want sufficiently large and constant fuel cost differentials and reasonable initial vehicle costs relative to their discounting of future fuel savings.

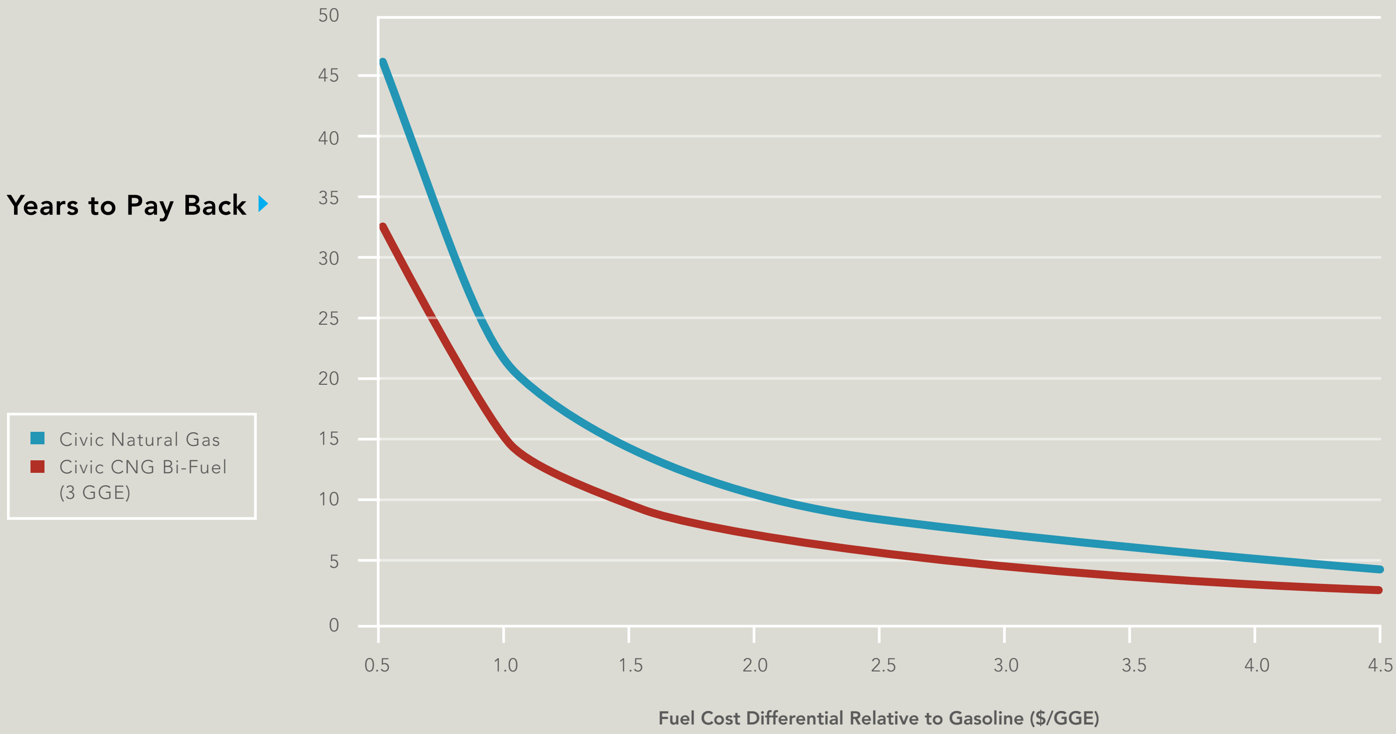
Consumers consider payback timeframe when making a purchase decision

Years-to-payback is the main economic indicator end-users focus on when determining the attractiveness of an NGV. This is defined as the number of years required to achieve payback on higher initial vehicle costs through fuel savings. It is a function of the pump price differential between natural gas and petroleum fuels, as well as incentives for vehicle purchase, including tax credits and rebates. Because there are several competing vehicle technology options to choose from, end users should weigh the relative merits of conventional and other alternative fuel vehicles against those of NGVs in their purchase decisions.

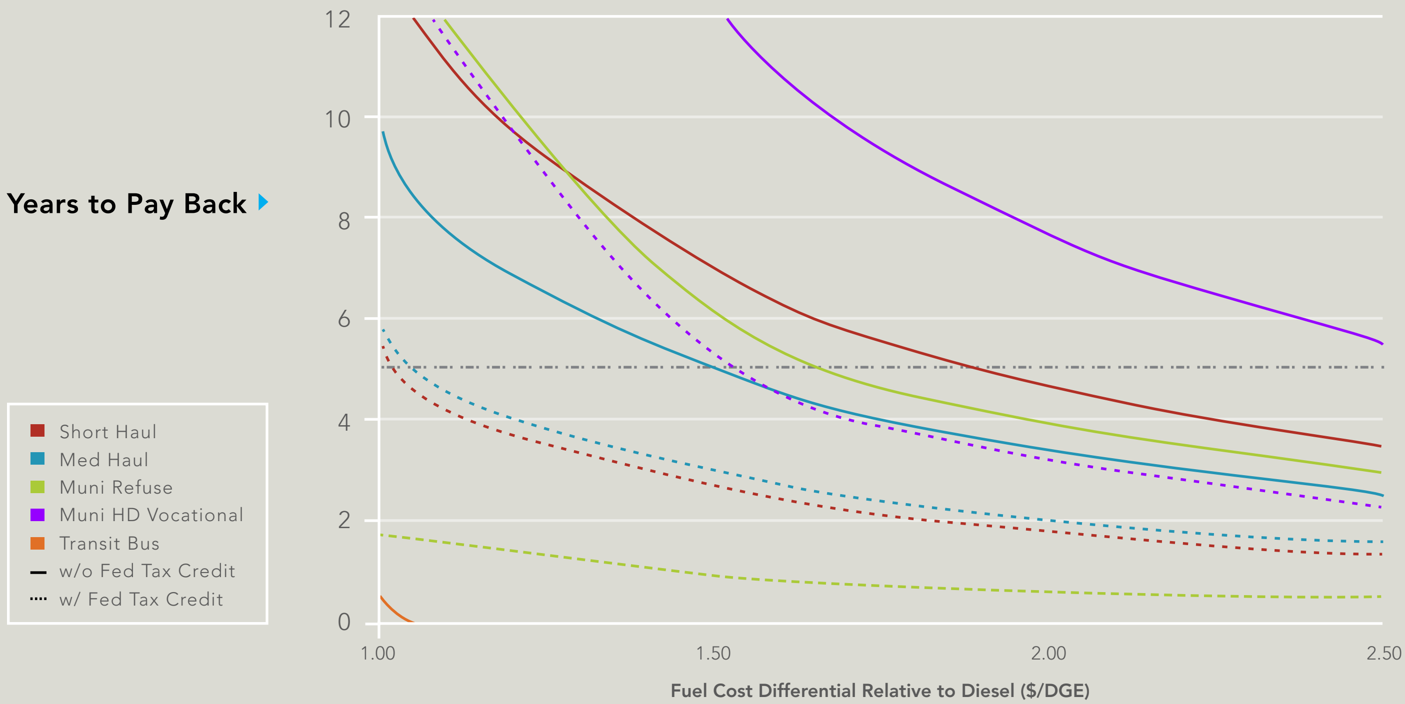
Though the duration of vehicle ownership may be much longer, the payback period required by consumers may be three to five years, so the value proposition hinges on whether the combination of fuel price differentials and incentives allows such a payback period, if any. In the light-duty personal use vehicle market, typical driving cycles may allow the option of using small natural gas capacity bi-fuel NGVs[25] (operating on both natural gas and gasoline), which attains payback more quickly than dedicated NGVs. If consumers see a value proposition for NGVs, whether in the personal use market or the commercial fleet market, manufacturers have indicated that they will be "fast followers" into this market.

25 On the order of 3 GGE of natural gas capacity; see Light- and Medium-Duty Vehicle Ownership and Production report of overall TIAX assessment for details.

Years-to-payback for a Honda Civic Natural Gas and a bi-fuel model[26]



Years-to-payback for heavy-duty NGVs[27]



26 See Light- and Medium-Duty Vehicle Ownership and Production report of overall TIAX assessment for details and assumptions of payback analyses.
27 See Heavy-Duty Vehicle Ownership and Production report of overall TIAX assessment for details and assumptions of payback analyses.

Building a foundation for NGVs: Manufacturers need a viable marketplace

Consumer demand, profitability and supporting regulations will drive vehicle and engine manufacturers' activity

Vehicle and engine manufacturers across the light, medium, and heavy-duty segments are driven by three key factors: consumer demand, profitability, and regulations. As detailed above, to capture consumer demand, manufacturers must play a role in garnering rebates. The attractiveness of natural gas to vehicle and engine manufacturers will depend on how well it can meet the standards and the cost of producing natural gas vehicles and engines compared to other options that meet the same standards.

Manufacturers' profitability depends on the costs of developing a natural gas version of their products and the volume of vehicles or engines over which these development costs can be amortized. Light-duty vehicle OEMs are estimated to require volumes of 50,000 to 60,000 units for NGVs to be considered "at scale,". For OEMs with existing CNG experience, the cost of developing a new, ground up natural gas powertrain is estimated to require $50 million in incremental costs. Heavy-duty vehicle OEMs reported the need for annual sales of approximately 1,000 to 10,000 units to justify expanded investments in the North American NGV market, estimating costs to develop and commercialize natural gas versions of their vehicles at $100,000 to $3.5 million, depending on the vehicle type and previous natural gas vehicle design. Heavy-duty engine OEMs reported the need for annual sales of approximately 10,000 units worldwide and estimated costs to develop and commercialize natural gas versions of their engines at $2 to $10 million also depending on the extent of base engine modifications.

Finally, regulations influence manufacturers to produce certain vehicles and engines. As air pollutant and GHG emissions standards are expected to grow more stringent, vehicle offerings will need to meet these standards. In the near term, air pollutant emissions standards and fuel economy standards will drive light-, medium-, and heavy-duty vehicle production.

Natural gas requires an efficient fueling infrastructure

Consumers see natural gas as a viable transportation option but fueling infrastructure is lacking

Natural gas is a mature and proven technology that can hold its own with other fuels across a range of vehicle segments but will require significant expansion of infrastructure to be widely accepted. The figure below presents a comparison of vehicle ownership costs in seven market segments for both baseline and alternative fuel types.

Comparison of consumer considerations for alternative fuel vehicles[28]

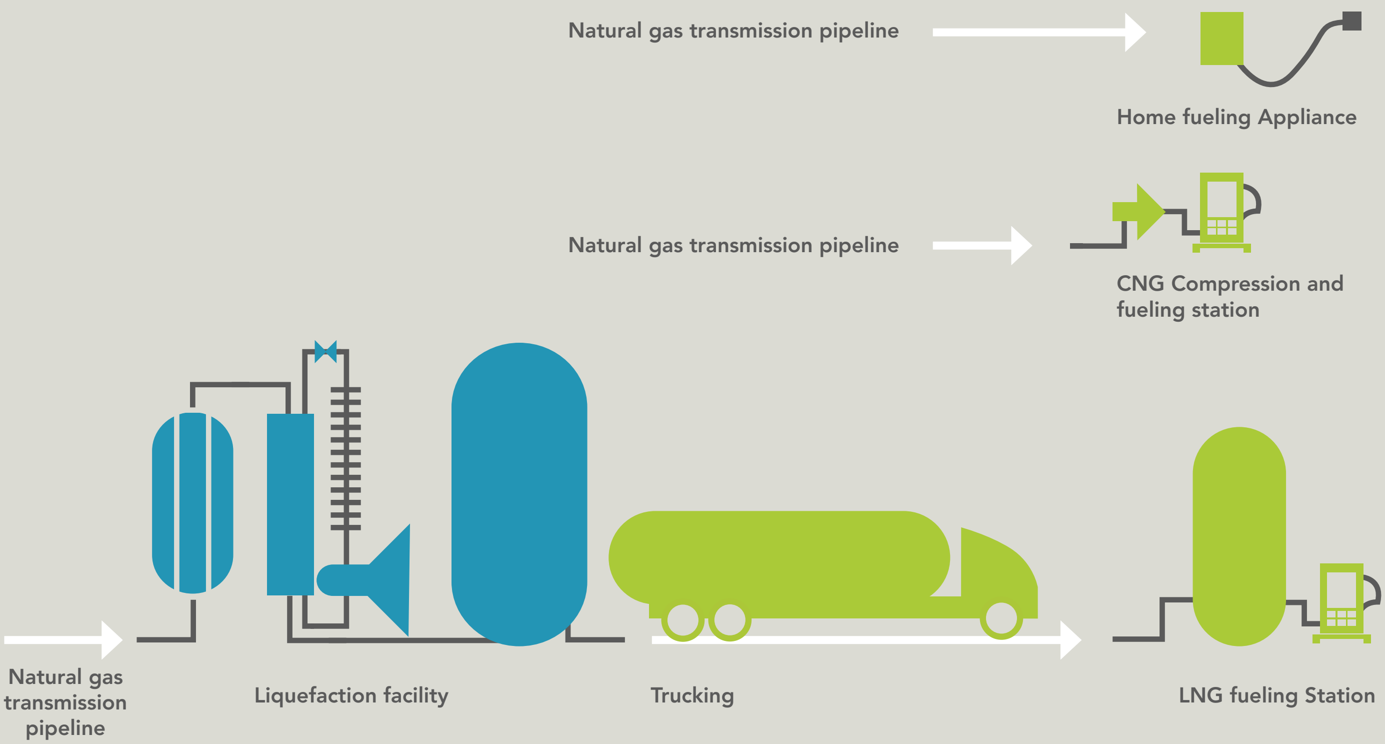
Vehicle Technology	Number of U.S. Stations	Primarily Used In:			Consumer Perception
		Light-Duty	Med-Duty	Heavy-Duty	
Gasoline	118,756	O	O		Familiar technology; for medium-duty vehicles, may be more economically attractive than the 2010 compliant diesel technologies emissions
Diesel	32,000		O	O	Familiar and efficient; new diesel technology may be costly
E85	2,544	O			Generally, unaware that vehicles may already be an FFV; E85 price may not be enough to motivate acceptance of lower energy content and station availability
CNG	1,091	O	O	O	Mature and proven technology that may be more economically attractive than advanced gasoline or diesel technologies
Biodiesel	679		O	O	Quality-controlled B20 accepted by many manufacturers; potential issues at cold temperatures and fuel price
Electricity	12,542	O	O	O	Can help enhance green image; economics may be favorable if battery costs meet expectations
Hydrogen	54	O			Significant interest, but not yet commercially available
LNG	58			O	Can help enhance green image; economics may be favorable for high fuel use applications

The discoveries of significant natural gas resources expand natural gas use from heating and power generation to include transportation. However, significant investments aimed at establishing a cohesive network of fueling stations are required. In order for the transportation market to access this supply of natural gas, the appropriate infrastructure must be in place to fuel vehicles.

The required infrastructure for CNG and LNG differs from that of gasoline and diesel. For CNG, natural gas is supplied to the fueling station or home garage via pipeline and compressed before it is dispensed as vehicle fuel. For LNG, natural gas is supplied to a liquefaction facility via pipeline, where it is cooled and liquefied into LNG and transported by truck to fueling stations, as the following diagram shows:

28 U.S. Census Bureau, "Economic Census," 2007; Alternative Fuels and Advanced Vehicles Data Center, "Alternative Fueling Station Counts by State," http://www.afdc.energy.gov/fuels/stations_counts.html, July 31, 2012; TIAX LLC, "SCR-Urea Implementation Strategies Update," prepared for Engine Manufacturers Association, 2006

Natural gas fueling options[29]



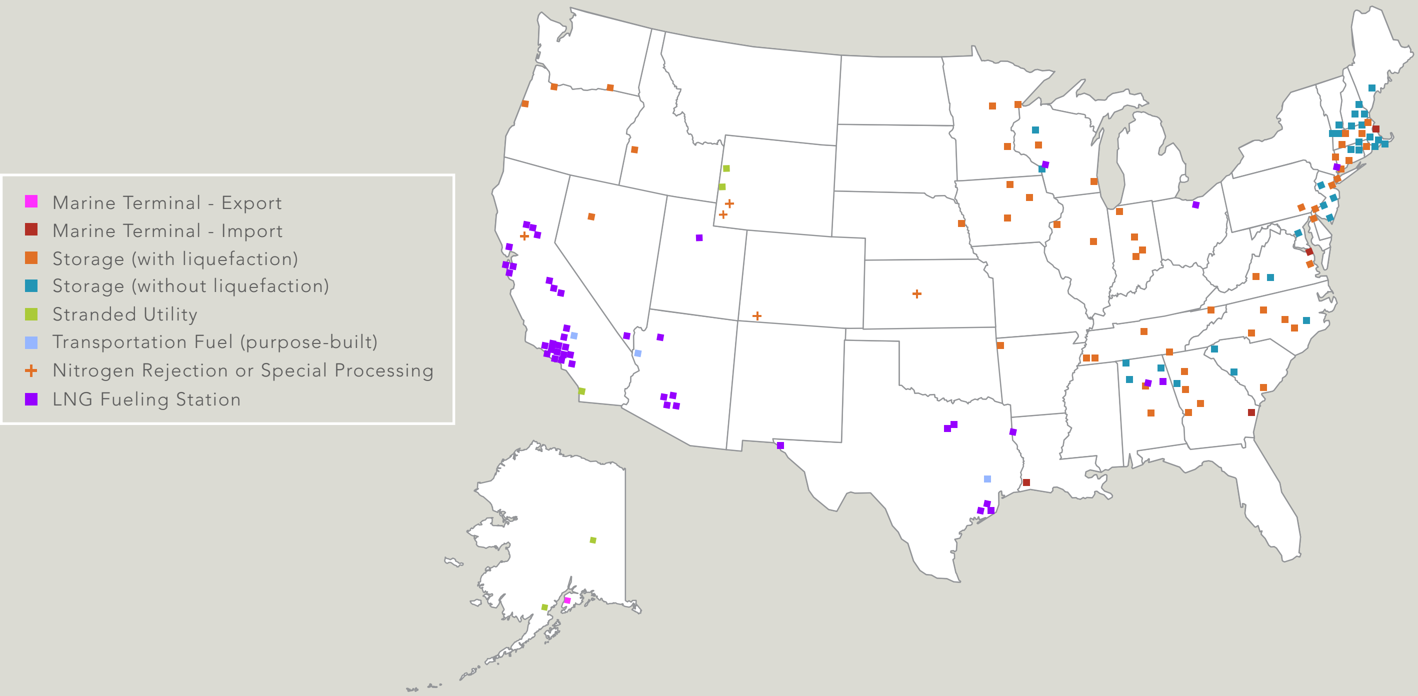
Initially, the current infrastructure can be leveraged in the natural gas supply chain

Several approaches have been used to establish natural gas fueling infrastructure. For example, a gas utility company may decide to build a station to serve its own NGV fleet as well as provide natural gas for public access. A transit agency or large commercial fleet may decide to build a station to fuel its NGV fleet and may or may not offer natural gas for public access. Alternatively, an independent fuel retailer may decide to build a station to serve the public at large. Combined, the various approaches to building infrastructure have resulted in 1,091 CNG and 58 LNG stations to date in the U.S.[30] It is important to note that a regional hub-and-spoke approach to building up natural gas infrastructure can be effective in establishing a fueling network, but purely private fleet stations may not help in this regard.

To achieve the reliable throughput needed by natural gas supply chain companies, the expansion strategy for natural gas infrastructure should be focused and incorporate growth potential. The transition between low demand in the near term and higher demand in the long term may be bridged by leveraging current stations and liquefaction facilities. Most, if not all, stations at present are operating below maximum capacity and thus are able to support significant growth of the NGV market in the near term. (Location, however, may be limiting.) As shown in the map below, liquefaction facilities exist across the U.S., even in areas where LNG stations do not yet exist

29 See Compressed Natural Gas Infrastructure and Liquefied Natural Gas Infrastructure reports of overall TIAX assessment for additional discussion of natural gas supply chains for transportation.
30 Alternative Fuels and Advanced Vehicles Data Center. "Alternative Fueling Station Counts by State." http://www.afdc.energy.gov/fuels/stations_counts.html. July 31, 2012.

Current U.S. LNG fueling infrastructure[31]



Only three liquefaction facilities currently serve the transportation market, though LNG is produced for other purposes in various areas. Leveraging this remaining liquefaction capacity can support a regional expansion model of natural gas infrastructure development. Though these facilities do not specifically serve the transportation market, they can help meet demand for LNG as new LNG infrastructure is being developed. Furthermore, building stations with modularized natural gas capacity, such that additional compressors, tanks, and/or dispensers can be easily added as needed at a later date, can help match capacity to throughput and offer more favorable return on investment.

Future fueling infrastructure requirements differ depending on NGVs types

At the systems level, the expansion strategy for CNG and LNG may differ slightly, depending on the vehicle segments being targeted. Growth of the fueling infrastructure network for both CNG and LNG may be based on first establishing regional centers then connecting regional centers to allow expansion. For LNG, regional/line-haul tractors will require a complete corridor before they can be placed into long-distance service, and thus pre-planning of the location of these corridors will be important to infrastructure development. Finally, because the pipeline infrastructure is currently designed to serve heating and power generation needs, pipeline companies must ensure that the distribution infrastructure will be capable of handling increased volumes for transportation.

31 See Liquefied Natural Gas Infrastructure report of overall TIAX assessment for additional discussion of the various types of LNG facilities.

A North American natural gas fueling infrastructure requires significant investments

While some of the existing fueling infrastructure can be used for an expanding NGV market, large investments are needed to expand the fueling infrastructure to support its growth. The cost of establishing a CNG station may range from $675,000 for a time-fill station dispensing 1,320 DGE in a ten-hour period to $1,000,000 for a fast-fill station dispensing 200 DGE in a one-hour period. The cost of establishing an LNG station may range from $2.25 to $7.5 million for dispensing capacities of 4 to 20 million DGE per year. The LNG pathway also requires constructing liquefaction facilities, which may cost on the order of $30 million per facility with capacity of approximately 100,000 LNG gallons per day[32]. In order for these investments to be reasonable, the throughput of natural gas must grow quickly enough to offer favorable return on investment and justify costs.

Vehicle suppliers and natural gas supply chain companies must collaborate

The natural gas supply chain includes production companies, pipeline companies, LDCs, and private companies. To grow the NGV market, these companies will have to provide a cost-effective fuel that meets fuel quality and supply expectations similar to those provided by the petroleum supply chain. By 2035, aggressive expansion of the NGV market may potentially enable the equivalent of 2.2 TCF of natural gas to be consumed annually in transportation. Work has started on building an infrastructure to compete with petroleum, but much more work will be required to scale up this initial effort to effectively cover a much broader range of vehicle applications—from light-duty passenger cars to over-the-road trucks. This much broader adoption of NGVs can be a major growth market for the industry.

To support this emerging market, the supply chain companies will have to work closely with other stakeholders to develop the business cases for using natural gas. This will include working with government and other stakeholders to develop a comprehensive energy and environmental policy, working with engine and vehicle manufactures to improve their NGV offerings, and working with users to make sure their fueling requirements are met. A major focus of the supply chain companies should be on developing a robust, cost-competitive fueling infrastructure throughout the U.S. and Canada. This will require private firms working with regulated entities and equipment and construction companies to execute a plan to bring natural gas to the transportation market. The table below spells out the specific actions that vehicle suppliers and natural gas supply chain companies must take in order to grow the NGV market:

32 See Compressed Natural Gas Infrastructure and Liquefied Natural Gas Infrastructures reports of overall TIAX assessment for additional details of vehicle throughput and fuel volume.

Vehicle suppliers' steps going forward to provide NGVs to the commercial and retail vehicle markets:

Engine Manufacturers:

Provide most efficient technology for natural gas

2. Continue to evaluate cost-effective applications of advanced diesel engine technologies to natural gas engines

3. Develop and commercialize wider selection of natural gas engines and ratings to meet the increasing demand

Vehicle Manufacturers:

1. Continue to provide a quality natural gas vehicle to customers meeting the same reliability, durability as gasoline and diesel products

2. Continue to train and educate dealers on the service and maintenance of natural gas vehicles as well as the benefits of NGVs

3. Work with equipment suppliers to drive down the costs of natural gas vehicle components

Natural gas supply chain companies' steps going forward to provide natural gas to commercial and retail customers:

Fuel Supply Chain:

1. Work to match fueling station throughput to vehicle demand

- a. Pipeline infrastructure
- b. Liquefaction facilities
- c. Local fueling stations

2. Develop successful business cases for infrastructure development

3. Use government fuel infrastructure incentives to connect regions

4. Promote competition to reduce costs of CNG and LNG supply to end-users

5. Work with equipment suppliers to develop cost effective, modular station designs to drive down cost of designing, building, and operating natural gas fueling stations

Government can level the playing field to make NGVs more affordable

For the NGV market to grow, each major market player will need to take steps to promote the use of natural gas. The higher incremental cost of NGVs is one reason that natural gas tends to rely on regulations and incentives rather than fuel cost differential. In particular, the infrastructure costs associated with installing private natural gas fueling stations can be prohibitive for many small fleets without funding assistance to offset costs. In addition, the incremental cost of NGVs can prevent adoption in low fuel consumption applications where the return on investment is low.

A level playing field among alternatives can make NGVs more affordable.

Government intervention is critical to support new fuel alternatives that are more expensive for consumers. For example, no vehicle incentives are needed for fuels that do not have increased costs, whereas vehicle incentives may be recommended for those that do. Similarly, no incentives are needed for fuels that are less expensive on an energy basis or that are currently mandated through existing standards. The table below shows how policy might be structured to reflect the differences between alternative fuels:

Alternative Fuel	Vehicle Costs	Fuel Costs	infrastructure Needs			Incentive Needs		
			Home	Public	Private	Vehicle	Fuel	Infra-structure
Ethanol blend (E10)	Same	Same	No	No	No	No	No	No
Ethanol (E85)	Same	Same	No	Yes	No	No	Yes	Yes
Plug-in hybrid electric vehicle (PHEV)	More	Less	Yes	Some	No	Yes	No	Yes
Battery electric vehicle (BEV)	More	Less	Yes	Some	No	Yes	No	Yes
Hydrogen fuel cell vehicle (FCV)	More	Same	No	Yes	Yes	Yes	Yes	Yes
Light-duty NGV	More	Less	Yes	Yes	No	Yes	No	Yes
Heavy-duty NGV	More	Less	No	Yes	Yes	Yes	No	Yes
Biodiesel (B20)	Same	More	No	Yes	Yes	No	No?	No

The growth of NGVs over the past twenty years has been driven by environmental objectives of lowering fuel and vehicle emissions—particularly those produced by heavy-duty diesel vehicles.

EPAct helped drive the purchase of NGVs and the establishment of natural gas fueling stations. Regions having the most success at increasing the use of NGVs were those that required alternative fuels but at the same time provided incentives for users to purchase the higher cost technologies. The South Coast Air Quality Management District (SCAQMD) "1190" fleet rules are a good example of requiring the use of alternative fuels in fleets such as transit and refuse as a way to reduce NOx and PM emissions from diesel engines. Using local and state funding, SCAQMD was able to provide incentives to those complying with the regulations.

Federal and state agencies are developing regulations to control GHG emissions. At the federal level, EPA is working with the U.S. Department of Transportation to regulate GHG emissions for light- and heavy-duty vehicles. To date, these regulations have primarily focused on increasing fuel economy and not on the use of low carbon fuels. An exception to this is California and other states that are developing a low carbon fuel standard to encourage the use of alternative fuels that will decrease carbon emissions and increase energy security. Increased CAFE standards will also help to increase the use of alternatives. Going forward, there needs to be a consensus on reducing transportation energy consumption above and beyond that is achievable through increased efficiency alone. Furthermore, government policy, supported by stakeholders, should reflect parity for the various alternative fuels, each of which has different requirements as indicated earlier in this report. The current renewable fuels standard is a step in the right direction but is specific to biofuels. A broader stakeholder-supported regulation is needed to include not only efficiency and biofuels but also other low carbon fuel sources like natural gas. The specific actions that the government and end users must take in order to grow the NGV market are outlined below:

Government steps going forward to encourage the use of natural gas in the transportation sector:

1. Develop consensus on objectives and policies to increase energy security

2. Integrate energy objectives and policies with environmental objectives and polices

3. Evaluate and select policy instruments to achieve environmental and energy objectives

4. Do not wait for "silver bullet" technologies.

5. Level the playing field by evaluating alternative fuels based on needs and benefits

6. Set performance standards for increasing use of alternative, domestic fuels in government fleets to avoid "picking winners" and to allow for industry to comply cost-effectively

7. Continue to educate consumers through Clean Cities program

Commercial and retail car, truck, and bus purchasers' steps going forward on the use of natural gas as a transportation fuel:

1. Make use of information, funding, and incentives available from natural gas suppliers, vehicle suppliers, and government to evaluate the benefit of NGVs to company's operation.

2. Work with similar industries in region to evaluate and aggregate demand to justify public natural gas stations.

3. Work with vehicle suppliers to expand availability of NGV products—vehicle and performance characteristics

Any regulation developed should be structured to allow the affected industries the flexibility to meet the regulations as cost-effectively as possible. Lastly, government organizations are very effective at disseminating unbiased information on alternatives. The U.S. Clean Cities program has been particularly effective in this regard and should be leveraged to continue providing information on NGVs as well as other alternatives.

End users should make use of the information provided by the government and vendors to make business decisions on the savings possible with NGVs. Users should also work with similar industries to help natural gas fuel providers to aggregate demand in various locations and regions. Finally, users should provide feedback to engine and vehicle manufacturers as well as suppliers regarding needed product improvements and expansion of product offerings

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This analysis covers three scenarios (light-duty CNG, medium- and heavy-duty CNG, and heavy-duty LNG) involving expansion of the supply of natural gas as a transportation fuel, as well as the construction of the necessary infrastructure (including stations, processing plants and heavy-duty trucks) to support that expansion. Employment impacts vary with the scale of additional spending that occurs within sectors. For this analysis, the results are reported as the impact associated with each additional station. These numbers should be understood as averages, however, and they take into account the assumption that a significant expansion is modeled. These numbers would be less reliable in the case of an expansion on a very small scale (involving only a few new stations and a few thousand new vehicles).

Employment impacts are expressed in full-time equivalent units (FTEs) of employment. An FTE represents the level of employment equal to a single full-time employee working forty hours per week. The use of FTEs as a measure does not imply that the employees under consideration are full-time employees, however. Two or more employees may be employed on a part-time basis, and their total employment may comprise a single FTE.

Employment impacts from infrastructure expansion

Infrastructure expansion for the provision of expanded supplies of natural gas requires significant spending on fueling stations, processing facilities and additional heavy-duty tanker vehicles to carry supply not deliverable through the existing natural gas pipeline network. In addition, incremental capital costs are anticipated for the construction of vehicles capable of using natural gas as a transportation fuel.

In the three scenarios under consideration, the assumptions regarding the capital costs of infrastructure and vehicles are expressed as the costs associated with each additional natural gas fueling station. As such, the vehicle costs represent the additional fleet that can be supported by a single additional fueling station. The processing plant costs represent that share of a single plant's output sold by a single additional fueling station. The truck and pipeline costs are the cost to supply a single station.

The full infrastructure expansion costs are shown in Table A-1.

Table A-1. Assumptions and Costs of Capital and Infrastructure

	Light-Duty CNG	Medium and Heavy-duty CNG	Heavy-Duty LNG
Fueling Station Construction			
Units	1	1	1
Cost/unit ($millions)	$1.00	$1.00	$0.77
Total Cost ($millions)	$1.00	$1.00	$0.77
Processing / Liquefaction Facility Construction			
Units	0	0	0.1
Cost/unit ($millions)	$31.8	$31.8	$31.8
Total Cost ($millions)	$0	$0	$3.18
LNG Distribution Trucks			
Units	0	0	1
Cost/unit ($millions)	$0.345	$0.345	$0.345
Total Cost ($millions)	$0	$0	$0.345
Supported Vehicle Fleet			
Units	2,300 (LDVs)	34 (Class 3) 200 (Class 4-6) 47 (Class 7-8)	114 (Class 7-8)
Incremental Vehicle Cost/unit ($millions)	$0.002916	$0.017 (Class 3) $0.040 (Class 4-6) $0.060 (Class 7-8)	$0.060 (class 7-8)
Total Cost ($millions)	**$6.71**	**$11.40**	**$6.84**

To produce employment impacts, these final demand values were converted to associated employment levels per station through the use of input-output multipliers. These employment multipliers are developed as part of macroeconomic modeling tools and utilized to determine the specific employment impacts of changes in spending in particular sectors.

Employment multipliers for the construction and heavy manufacturing sectors were taken from the IMPLAN Input-Output Model, a macroeconomic modeling tool. Employment multipliers are expressed as the number of FTEs created for each $1 million in final demand directed to a given sector. The IMPLAN employment multiplier for the construction sector is 15.95, indicating that the model assumes that 15.95 FTEs are created for every $1 million of spending in the construction sector. The employment multiplier for manufacturing is 14.28. This slightly lower number indicates that manufacturing is slightly less labor-intensive per dollar of spending in the sector than construction.

Employment impacts in specific sectors are derived from the product of the spending in a given sector and its corresponding employment multiplier. Table A-2 shows the estimates of employment impacts from natural-gas infrastructure expansion (again, measured per fueling station).

Table A-2. Employment Impacts from Capital and Infrastructure

	Light-Duty CNG	Medium and Heavy-duty CNG	Heavy-Duty LNG
Fueling Station Construction			
Employment Impacts	15.95	15.95	12.28
Processing/Liquefaction Facility Construction			
Employment Impacts	0	0	50.72
LNG Distribution Trucks			
Employment Impacts	0	0	4.93
Supported Vehicle Fleet			
Employment Impacts	95.77	162.76	97.68
Overall Job Impacts (FTEs) per Station:	**111.72**	**178.71**	**165.60**

These numbers refer to the years in which the spending occurs. The additional employment created by this expenditure would disappear when the construction and manufacturing was completed.

Employment impacts from transportation fuel sales

Employment impacts from the increased use of natural gas fuels are affected by both the growth in employment created from expanded spending on natural gas as well as losses in employment caused by spending shifting away from the petroleum sector. Importantly, because the scope of the job impacts is domestic, petroleum jobs lost outside of the country are not counted as losses to the domestic economy; in essence, the effect is a shift of foreign petroleum jobs to domestic natural gas jobs. The overall net impact is positive – the increased use of natural gas under these scenarios creates more employment than it displaces.

An important component of these job impacts is driven by the fact that natural gas has historically been, and is projected to be, approximately 45 percent cheaper than gasoline or diesel when measured per unit of energy. For this analysis, which is prospective, price projections for the near future were selected. The averages of the projected prices for all three fuels for the next five years were taken from the Department of Energy's "Annual Energy Outlook," published in March 2010. The prices assumed are in the table below, and are expressed in both GGE and DGE (Table A-3).

Table A-3. Fuel Prices[33]

	CNG/LNG	Gasoline	Diesel
GGE	$1.37	$2.81	$2.34
DGE	$1.56	$2.91	$2.86

Because the additional energy used from natural gas was similar in quantity to the energy left unused from petroleum fuels, the shift from consumption of gasoline and diesel to the consumption of natural gas presents a net savings to the consumer. This has two conflicting impacts on employment. First, employment from the direct provision of fuel goes down, because natural gas is less labor-intensive to provide and because less money enters that sector than leaves the petroleum sector. Second, economy-wide employment rises as a result of increased spending triggered by the additional money available as a result of fuel savings.

Employment Multipliers

Accurate assessment of the impacts of spending on CNG and LNG as transportation fuels required the development of customized employment multipliers. The IMPLAN and REMI macroeconomic models use historical data, and have not developed sector-specific multipliers for the large-scale provision of natural gas as a transportation fuel. Multipliers exist for provision of natural gas for heat and power generation, but these multipliers do not take into account the additional labor involved in distributing transportation fuels (especially liquid fuels) to fueling stations, or the additional labor involved in maintaining and operating retail fueling facilities.

For CNG, analysts began with the employment multiplier established in IMPLAN for the natural gas utility sector, which is 5.57 jobs/$million in final demand. Analysts treated this level as a lower bound, and then made assumptions regarding additional labor requirements regarding the distribution and retail components of CNG as a transportation fuel. This produced a custom employment multiplier of 9.18 jobs/$million in final demand.

For LNG, which must be distributed in the same manner as conventional gasoline and diesel fuel, analysts used the employment multiplier of petroleum fuels (12.8 FTE/$million in final demand) as a benchmark from which to start. Analysts then adjusted the distribution to take into account that LNG contains only 58 percent of the energy per unit volume that diesel fuel contains. This lower energy content requires significant additional transportation resources to transport the same amount of energy to the fueling station. Analysts developed an estimate of the share of the employment multipliers dedicated to distribution, and adjusted for the scenario stipulations regarding total amounts of energy produced and displaced, to arrive at a custom employment multiplier for LNG of 15.6 FTE/$million in final demand.

Table A-4 displays the scenario assumptions, corresponding spending changes, and employment multipliers for transportation fuel sales.

33 Source: U.S. Energy Information Administration "Annual Energy Outlook," 2010, averages of projected prices for 2011 to 2015

Table A-4. Spending Changes and Employment Impacts, Transportation Fuel Sectors

	Light-Duty CNG	Medium and Heavy-duty CNG	Heavy-Duty LNG
Natural Gas Fuel Sales Growth			
Final Demand Change	$0.88	$1.59	$2.99
Employment Multiplier	9.185	9.185	15.60
FTEs Created	8.12	14.61	46.70
Petroleum Fuel Sales Displacement			
Final Demand Change	-$1.77	-$2.92	-$5.53
Employment Multiplier	12.8	12.8	12.8
FTEs created	-22.70	-37.40	-70.76
Increased Non-Fuel Spending			
Final Demand Change	$0.89	$1.33	$2.53
Employment Multiplier	17.3	17.3	17.3
FTEs created	15.39	23.03	43.85
Overall Job impacts (FTEs) Per Station per Year:	**0.81**	**0.24**	**19.78**

These results indicate that the scenario seeking to expand the use of LNG in the heavy-duty sector produces the largest ongoing positive job impact. Because LNG provision is more labor-intensive, expansion of LNG has a larger positive impact on employment. All three scenarios demonstrate the benefits to the overall economy of savings from using natural gas in place of petroleum. In all three cases, the scenario produces greater positive employment impacts outside the natural gas sector than within it – entirely through creating significant energy savings to the transportation sector.

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For questions, please contact:

TIAX LLC
20813 Stevens Creek Blvd, Suite 250
Cupertino, CA 95014

http://www.tiaxllc.com/services/

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

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