AMERICAN CLEAN SKIES FOUNDATION

DRIVING ON NATURAL GAS:

FUEL PRICE AND DEMAND SCENARIOS FOR NATURAL GAS VEHICLES TO 2025

APRIL 2013

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Acknowledgements

This report was supported, in part, by a grant from the Drive Natural Gas Initiative (a collaboration between the American Gas Association and America's Natural Gas Alliance). The authors also gratefully acknowledge the analytical work of the Navigant Consulting team including Gordon Pickering, Rebecca Honeyfield, and Liqing Wang. ACSF Senior Regulatory Counsel Warren G. Lavey and Drive Nat Gas Executive Director Kathryn Clay provided helpful comments as well.

About American Clean Skies Foundation

Established in 2007, ACSF seeks to advance America's energy independence and a cleaner, low-carbon environment through expanded use of natural gas, renewables, and efficiency. The Foundation is a 501(c)(3) not-for-profit organization.

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Executive Summary

Petroleum-based fuels have dominated the U.S. transportation market for many decades. However, the lack of fuel diversity makes the economy and consumers susceptible to price shocks. This risk has spurred a growing commercial and public policy interest in alternative transportation fuels such as biofuels, natural gas and electricity.

Natural gas provides one of the most promising long-term opportunities to diversify transportation fuel usage because it can readily power medium and heavy duty trucks—which now account for approximately 22 percent of the U.S. transportation sector's oil use—and also can provide fuel cost savings to fleet managers.

Economy-wide competition for natural gas, however, raises an important question: Is it prudent for the U.S. to substitute natural gas for other transportation fuels or will this lead to significant additional pricing pressure for the fuel?

This report aims to answer this and related questions by constructing different natural gas vehicle (NGV) growth scenarios and the natural gas demand and price impacts these scenarios may generate. The three scenarios reviewed here for NGVs range from trend line projections to an aggressive—but business-based—growth path for natural gas light duty vehicles and the heavy duty truck segment. The scenarios were compared to a reference case to determine natural gas demand and price changes.

In our highest growth case, with combined high adoption rates of light duty and heavy duty vehicles, the transportation sector's share of total natural gas demand remains modest—ranging from 0.2 percent in 2013 to 2.3 percent in 2025. By 2025, we estimate roughly 2.4 million NGVs will be on the road, of which 480,000 are heavy duty trucks. These vehicles will consume about 711 Bcf of gas annually by 2025 and displace over 180 million barrels of oil.

We conclude that this estimated level of gas demand for NGVs—roughly 2 percent of overall gas demand in 2025—and the estimated price rises attributable to incremental NGV demand by 2025—at most, $0.25/Mcf—are both very modest. These findings differ from some previously reported studies in two major respects.

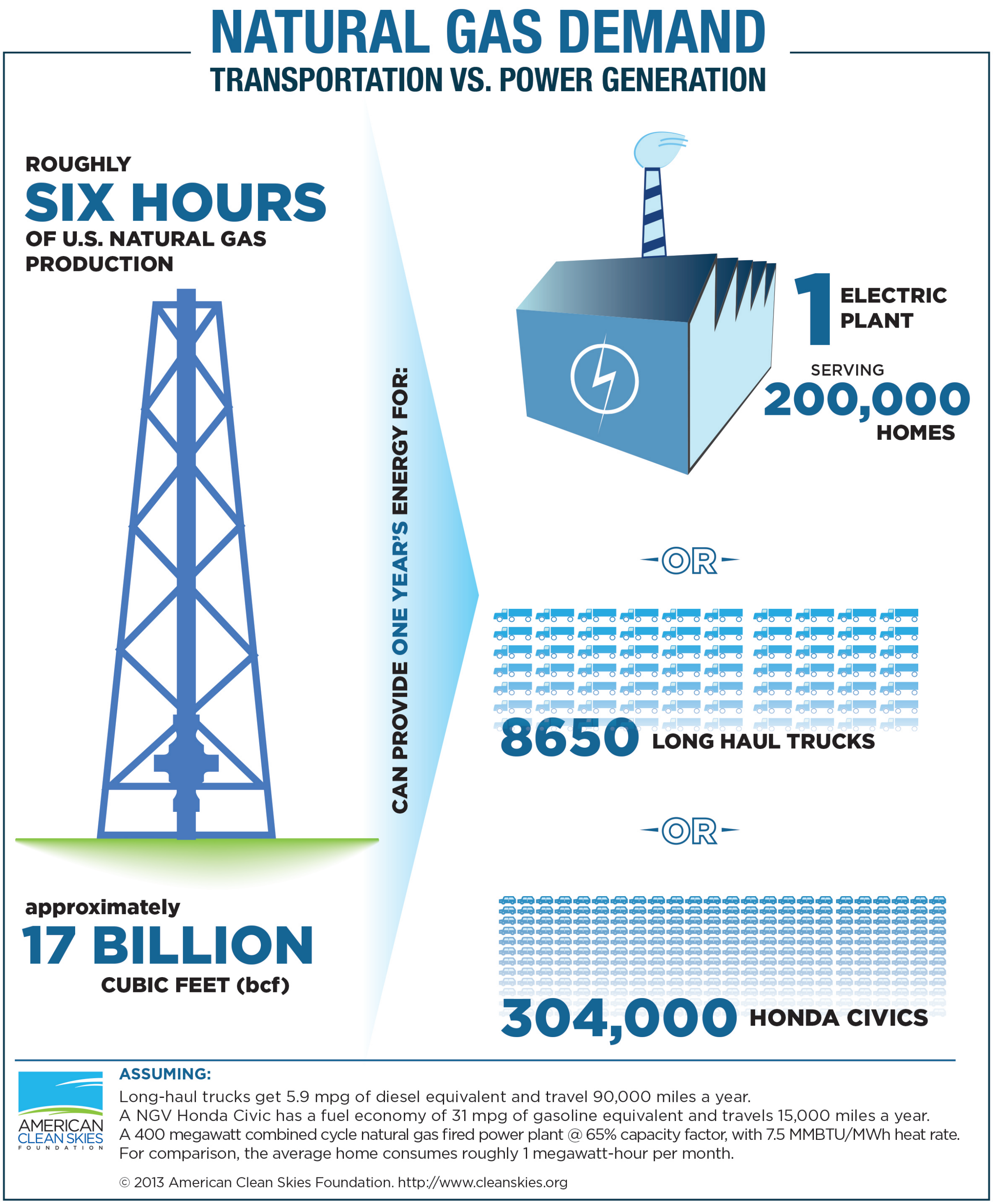
First, our report relies on a market-tested general equilibrium model of the overall natural gas market to estimate the impact of any given incremental demand for gas on the overall price of the commodity. It is a dynamic model and assumes that price changes elicit producer and consumer responses in supply and demand—subject to certain constraints, such as technically recoverable gas reserves. By comparison, some prior studies appear to have estimated potential price impacts using a static model which likely over-estimates the actual market impact of any given increment of demand.

Second, the projected growth of NGVs—especially heavy duty trucks—used in some other studies is much larger. As a result, such studies are likely to over-estimate the medium term natural gas demand and any inflationary impact attributable to NGVs from the transportation sector. Our analysis assumes that NGV adoption will increase in scale steadily in the near and medium term, and that the number of medium and heavy duty trucks will top 800,000 by 2025. Steady, modest growth over the next decade or so is likely to provide adequate time for supply and infrastructure developments to keep pace with demand, and thus should moderate any incremental fuel price impact attributable to the transportation sector.

While the analysis presented in this report considers price impacts only to the year 2025, we believe that growth in the NGV market segment is likely to continue in the longer-term. This is due to the long timeframes required for new technologies to displace older technologies in the transportation sector. For example, in the 1950s about 90 percent of vehicles in the Class 8 heavy duty segment were fueled by gasoline. It took roughly forty years for diesel to completely displace gasoline as the preeminent fuel for heavy duty Class 8 trucking.

The findings in this analysis should give businesses, consumers, regulators and political leaders confidence that fueling future vehicles with natural gas will likely have a minimal impact on prices and competition for the fuel. Additionally, realization of the most aggressive NGV scenarios in this report would provide significant environmental, economic and energy security benefits to the United States.

Figure 1.


NATURAL GAS DEMAND
TRANSPORTATION VS. POWER GENERATION
ROUGHLY
SIX HOURS
OF U.S. NATURAL GAS PRODUCTION
approximately
17 BILLION
CUBIC FEET (bcf)
CAN PROVIDE ONE YEAR'S ENERGY FOR:
1 ELECTRIC PLANT
SERVING
200,000
HOMES
OR
8650 LONG HAUL TRUCKS
OR
304,000 HONDA CIVICS
ASSUMING:
Long-haul trucks get 5.9 mpg of diesel equivalent and travel 90,000 miles a year.
A NGV Honda Civic has a fuel economy of 31 mpg of gasoline equivalent and travels 15,000 miles a year.
A 400 megawatt combined cycle natural gas fired power plant @ 65% capacity factor, with 7.5 MMBTU/MWh heat rate.
For comparison, the average home consumes roughly 1 megawatt-hour per month.
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Introduction 1

The swift and stunning rise in domestic natural gas production, principally from shale formations, is causing a dramatic shift in energy consumption patterns and has spurred growing interest in using natural gas to power America's cars and trucks.

Multiple factors are driving the interest in natural gas vehicles (NGV). The first is the significant price spread—now $1.50 or more per gallon-equivalent fuel at the retail level—between petroleum-based fuels, such as diesel and gasoline, and compressed and liquefied natural gas (CNG and LNG). Trucking companies, fleet vehicle managers and individual consumers can reduce their annual fuel costs by switching to natural gas; these cost savings typically defray the higher incremental costs of buying new NGVs within 2-5 years.[1] NGV rental options for fleet vehicles and medium duty trucks are also available.[2]

A second factor spurring interest in NGVs is the public policy goal of maintaining energy and national security. The U.S. economy is exposed to global oil price risks because oil accounts for about 93 percent of the transportation fuel consumed domestically.[3] Oil-price spikes can hurt the livelihood of millions of consumers; they also increase the costs of many goods and services due to higher transportation costs. By diversifying the transportation sector to more domestic alternative fuels, such as natural gas, the economy can become more resilient to oil-price fluctuations.

A third factor driving the interest in NGVs is the environmental benefit attributable to fuel switching. Natural gas is a cleaner burning fuel than diesel or gasoline. Vehicles using natural gas produce less particulate matter, nitrogen oxide, and carbon dioxide emissions per mile traveled.[4] The environmental benefits of NGVs are both local and global in nature by reducing ground-level localized pollution, and greenhouse gases. The net social benefits (including reduced economic dislocation "shocks") of converting a conventional light duty gasoline vehicle to a CNG replacement have been estimated at $2,000-$4,500.[5]

The opportunity to use natural gas as a transportation fuel is significant, but substantial commitments to infrastructure and vehicle investments will be necessary to markedly reduce the role of petroleum fuels. Currently a very small amount of natural gas is used for transportation fuels—well under one percent of daily U.S. consumption. What will the widespread substitution of natural gas for oil in both the trucking and light duty vehicle markets look like?

1. *See e.g.*, Vijay Gill and Len Coad, "Cheap Enough? Making the Switch From Diesel Fuel to Natural Gas, The Conference Board of Canada (April 2012); Alan J. Krupnik, "Will Natural Gas Vehicles Be In Our Future?" Issue Brief 11-06, Resources For the Future (May 2011) available at http://www.rff.org/rff/documents/rff-ib-11-06.pdf
2. *See e.g.*, Lynn Kelly, The SANBAG/Ryder Natural Gas Vehicle Project Merit Review and Peer Evaluation Meeting, Publication No. ARRAVT044, San Bernardino, SANBAG/Ryder (2012)).
3. EIA. (2012). *Annual Energy Review 2012.* Table 2.1e, 2011 data. Available at http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0201e
4. DOE. (2013). *Natural Gas Vehicles Emissions.* U.S. Department of Energy, Alternative Fuels Data Center. Available at: http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html
5. *See* Christopher R. Knittel, "Leveling the Playing Field For Natural Gas in Transportation," Discussion Paper, The Hamilton Project, Brookings, (2012), p. 14. *See also*, Brent D. Yacobucci, "Natural Gas Passenger Vehicles: Availability, Cost, and Performance," Report 7-5700, Congressional Research Service (May 25, 2011).

Some studies suggest that a transition to NGVs has the potential to increase natural gas demand significantly, which could trigger price increases given concurrent increases in natural gas demand from the power sector, manufacturers and prospective exporters.[6] Others contend that U.S. gas producers have sufficient reserves to accommodate the foreseeable demand from various sectors of the economy (including exports) and that, in any case, increased demand from NGVs—both in the trucking and automobile sectors—is likely to be quite modest for at least the next decade or so.[7] As a result, any price increases for NGV fuels are likely to be limited and will not change the basic economic case for fuel switching or building out an NGV infrastructure.

Nonetheless, the required investment, along with growing competition for natural gas from other sectors, has given some transportation managers, investors and policymakers reason to pause. How can we be assured the favorable economics of natural gas will continue?

This report addresses the economic question with a rigorous new analysis of the supply and demand factors implicating the future price of NGV fuels. It is based on a bottom-up set of potential NGV growth and fuel demand scenarios. These scenarios were then inserted into a dynamic macro-economic forecasting model by Navigant Consulting Inc. (Navigant) to estimate future fuel prices taking into account changing natural gas supplies.

In the remaining sections, we summarize fuel usage in the transportation sector, describe the merits of NGVs, and review the modeling assumptions and results.

6. For example, a representative of ConocoPhillips is reported to have suggested that half of the heavy duty trucking industry's demand for diesel fuel (some 2 million barrels annually) could be replaced by LNG or CNG, leading to 5 Bcf/day of new demand, although the time frame for such a switch was not specified. Similarly, Citigroup is reported to have forecast a 10 percent - 30 percent switch to natural gas for heavy duty trucking by 2020, resulting in to up to 3 Bcf/day of new demand. See, Bryan Schutt, "Fuel Economics Could Push NGVs Past Chicken-Egg Dilemma," SNL Gas Report, December 26, 2012. The PIRA Energy Group, a NYC-based energy consulting firm, also released a special report in September 2012 forecasting at least 15 Bcf/day of demand for NGV fuels by 2030. See "PIRA Energy Group Sees Natural Gas Vehicles Gaining Traction," PR WEB, September 4, 2012 available at http://www.prweb.com/releases/2012/9/prweb9866603.htm. As detailed elsewhere, based on current information, we think the foregoing demand projections are much too high and that the incremental demand for NGV fuels is unlikely to exceed 2-3 Bcf/day by 2025, or approximately 2.5 percent of forecast U.S production.

7. *See* EIA. (2012). *Annual Energy Outlook 2012.* Available at http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf

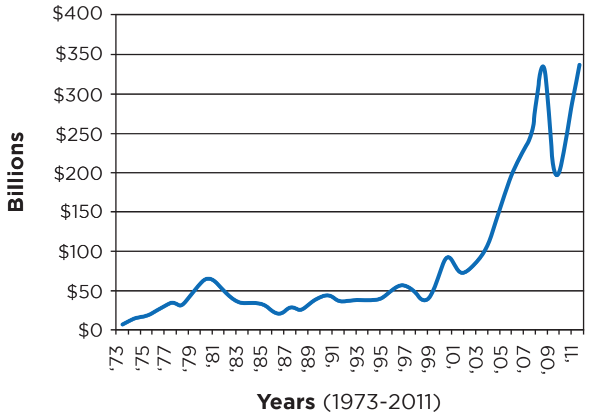
Opportunity for Natural Gas Vehicles 2

Today, natural gas fuels a fraction of one percent of the country's transportation sector, while oil-based fuels account for 93 percent of the sector's fuel consumption.[8] (Biofuels, such as ethanol, account for most of the remaining consumption.) Oil's dominance is due to an extensive infrastructure - including refineries and 180,000 fueling stations nationwide[9]—as well as the installed base of hundreds of millions of gasoline and diesel fueled vehicles.

This extensive oil-based network has proved to offer mixed benefits, especially as the U.S. became more dependent on imported oil in the 1990s and the early part of this century. Moreover, as oil prices increased, American consumers and the economy became more captive to oil prices and the attendant security risks.[10]

In total, the United States consumes about 19 million barrels of oil products per day, and the majority of the fuel goes to power our vehicles.[11] Although annual petroleum imports are currently on a downward trend, the value of the imports is still very high because of price increases. In 2011 the value of U.S. petroleum imports was about $335 billion or nearly $1 billion a day (Figure 2).[12]

Figure 2.
Value of the United States' crude oil imports



Data source: EIA

The rising prices of petroleum and dependence on imports are driving the desire for fuel diversity in the transportation sector. Interest in using natural gas as a transportation fuel has grown in recent years because of the discovery of new reserves and the favorable prices compared to gasoline and diesel. Since 2009, CNG has become cheaper than gasoline and diesel by nearly $2.00 a gallon of gasoline equivalent (Figure 3).[13] The outlook for attractive CNG and LNG prices compared to oil-based fuels is equally appealing (Figure 4).

8. Natural gas's share equates to about 2 percent according to EIA's *Annual Energy Review 2012* table 2.1e, but that includes natural gas used by the pipeline network. A trivial amount of natural gas is actually used as a vehicle fuel.

9. FC Business Intelligence. (2012). *NGV Infrastructure Fact Pack 2012.* http://www.ngvevent.com/pdf/Natural-Gas-Vehicle-Infrastructure-Market-Fact-Pack.pdf

10. In 2012, for example, the U.S imported about 4 billion barrels of petroleum products EIA (2013). *U.S. Imports of Crude Oil and Petroleum Products.* Available at: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mttimus1&f=m

11. EIA. (2013). *Petroleum and Other Liquids: Product Supplied.* Available at: http://www.eia.gov/dnav/pet/pet_cons_psup_dc_nus_mbblpd_a.htm

12. EIA. (2013). *Annual Energy Review 2012.* Table 5.20. Available at http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0520

13. DOE. (2013). *Alternative Fuels Data Center.* Data available at: http://www.afdc.energy.gov/data/

Figure 3.
U.S. average retail transportation fuel prices

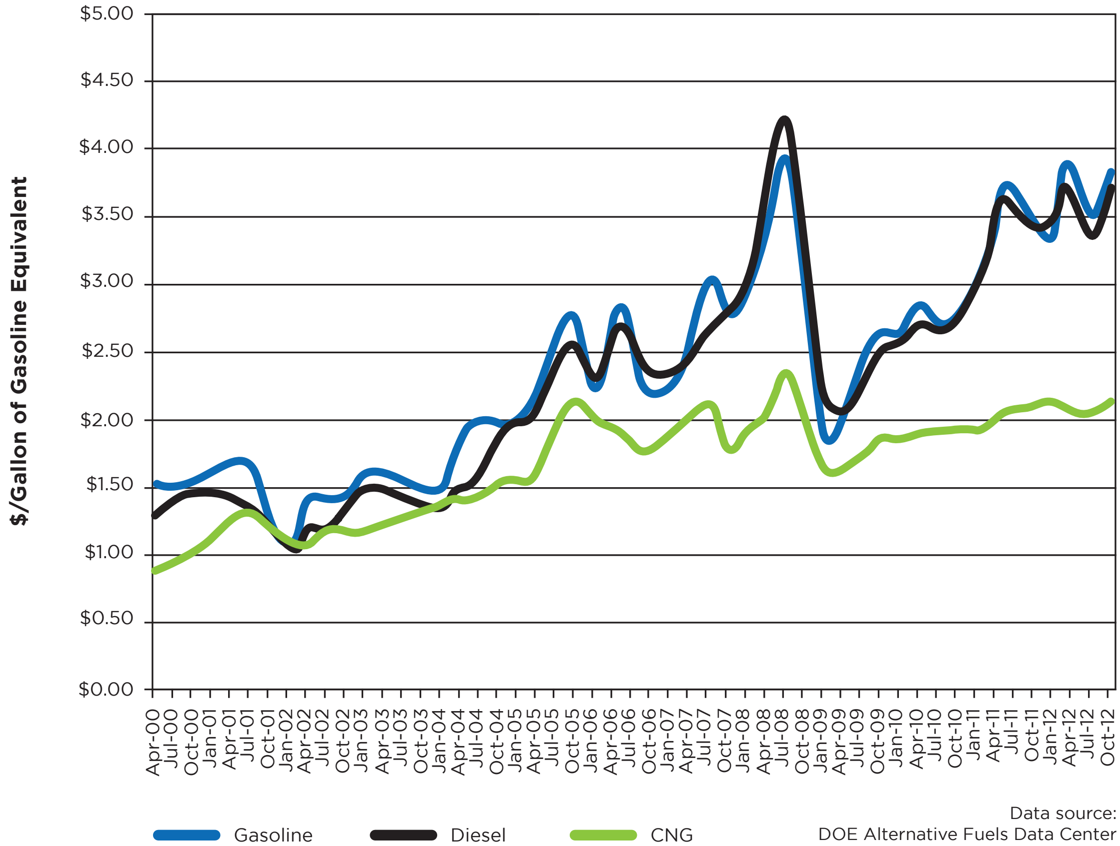
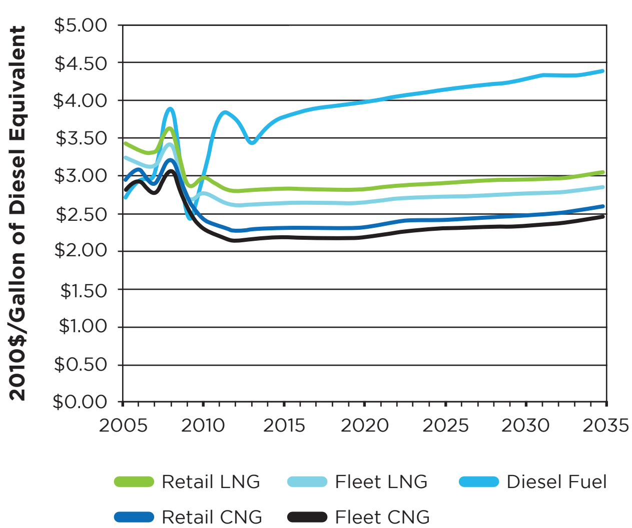


Figure 4.
EIA Annual Energy Outlook 2012 Heavy Duty Vehicle Reference Case: transportation fuel prices



Moreover, any increase in the price of natural gas does not lead to a similar percentage increase in the price to retail buyers of CNG or LNG. The natural gas price component of CNG currently makes up about 20 percent—or roughly $0.30/gallon of gasoline equivalent—of the retail CNG price given the current natural gas price of about $4/MMBtu. Even if natural gas prices were to double to $8/MMBtu, the commodity component of CNG would be about 40 percent or less of the total retail CNG price.[14] Therefore, CNG prices are insulated from commodity price swings (See Box 1). Retail diesel and gasoline prices, on the other hand, are more susceptible to commodity price swings. In 2012, crude oil accounted for 61 percent of retail diesel costs[15] and 66 percent of retail gasoline costs.[16]

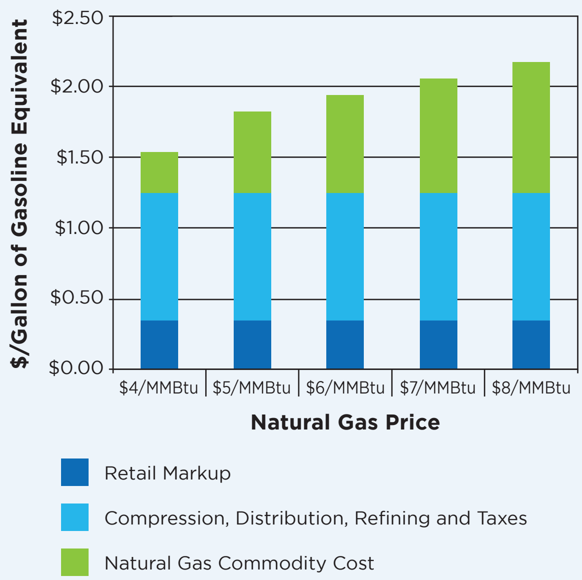
Although fuel savings opportunities exist, the upfront purchase prices of new NGVs are higher than their petroleum-fueled counterparts. The fuel cost savings, however, can overcome the larger investment required, especially for vehicles that have high annual vehicle miles traveled (VMTs).[17] Additionally, the upfront purchase prices of NGVs are likely to decline with the economies of scale in larger-scale manufacturing[18] while the fuel price spread between natural gas and oil-based fuels remains robust.

Box 1: Price components of CNG

The price paid at the pump by commuters and truckers includes more than just the commodity cost of the fuel. Prices posted by retailers include the commodity fuel costs as well as fuel taxes, costs for refining or compressing the fuel, and a retail mark up to cover costs of the fuel dispensing operation. Retail prices for CNG and LNG are cheaper than an equivalent diesel or gasoline gallon, and that is likely to remain true even if natural gas commodity costs increase significantly.

The commodity price component of CNG can range from about 20 percent of the retail CNG price if natural gas is $4/MMBtu, or about 40 percent if natural gas reaches $8/MMBtu—while assuming a $0.35/gallon of gasoline equivalent (GGE) retail mark-up, and $0.90/GGE for taxes, distribution and compression. Figure 5 shows retail CNG's sensitivity to natural gas commodity price swings, and that even at $8/MMBtu, CNG is significantly cheaper than gasoline prices from the past few years.

Figure 5.
Price components of retail CNG



14. Calculations for Figure 5 are based on assumed retail mark-up costs of $0.35/gallon of gasoline equivalent (GGE), and $0.9/GGE for compression, distribution, taxes and refining costs. The energy content of a gallon of gasoline is assumed to be 115,540 Btu.

15. EIA. (2013). *Diesel Fuel Pump Components History.* Available at: http://www.eia.gov/petroleum/gasdiesel/dieselpump_hist.cfm

16. EIA. (2013). *Gasoline Pump Components History.* Available at: http://www.eia.gov/petroleum/gasdiesel/gaspump_hist.cfm

17. *See* Krupnick, A.J. (May 2011). *Will Natural Gas Vehicles Be in Our Future?* Resources for the Future, Issue Brief 11-06. Available at http://www.rff.org/rff/documents/rff-ib-11-06.pdf

18. The Department of Energy's Advanced Research Projects Agency—Energy (ARPA-E) is funding research to radically reduce the cost of natural gas fuel tanks. Information available at: http://arpa-e.energy.gov/?q=project-tech-areas/natural-gas-storage

Yet, to date the transportation sector accounts for only a small fraction of natural gas consumption. The electric power sector is the largest consumer of natural gas, constituting about 39 percent of demand, while industrial customers make up 30 percent of demand. Natural gas for vehicle use is only 0.14 percent of total demand for natural gas.[19] The annual natural gas demand from the transportation sector is roughly equivalent to the gas required to fuel two medium size (400-megawatt) combined cycle power plants for a year;[20] there are about 240,000-megawatts of combined cycle power plants nationwide.[21]

To put this report in context, it is important to bear in mind the timeframe considered in this report is only the initial chapter in the overall story. Transitions to new technologies and fuels in the transportation sector are typically measured in decades rather than years.

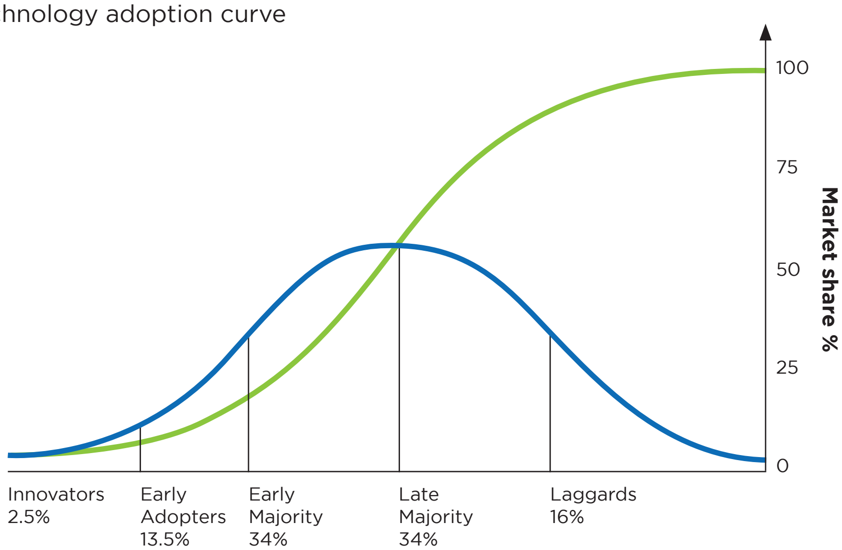
The average age of a Class 8 truck in the U.S. fleet is about seven years, meaning that it takes about 14 years for the entire fleet to turn over. In the light duty segment, the average age of a passenger vehicle is even longer—9 years, meaning about 18 years are needed for complete fleet turnover.

In practice, new technologies do not have such flat profiles for adoption rates. As in other industries, disruptive technologies that capture market share from incumbent technologies grow in a classic "S-curve" pattern (Figure 6).

Support for this outlook is found in the historical example of how the heavy duty Class 8 truck market shifted from gasoline to diesel. In 1950, about 90 percent of vehicles in this market segment were fueled by gasoline. Diesel vehicles captured small but growing percentages of the market over the decades that followed, so that market share rose to about 90 percent by 1970. Diesel continued to capture market share from gasoline and by the 1990s had completely displaced gasoline from this segment.

Diesel faced considerable challenges as a new market entrant competing against a well-entrenched incumbent in gasoline. Diesel engines had higher upfront costs, added more weight to the vehicles, and required the establishment of a new fueling infrastructure to support them. Diesel succeeded in becoming the fuel of choice in the Class 8 segment despite these obstacles, though it took decades to achieve. The position of natural gas vehicles today is in many ways similar to that of diesel Class 8 trucks in the 1950s.

Figure 6.
Disruptive technology adoption curve



19. EIA. (2013). *Natural Gas Consumption by End Use.* Data available at: http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_m.htm
20. Calculation assumes a 7.5 MMBtu/MWh heat rate, 0.65 capacity factor and 800 megawatts of capacity.
21. 2012 Capacity data pulled from SNL Financial database. Subscription service required.

Box 2: It's All about BTUs: Gasoline Gallon Equivalents for CNG and LNG

To provide an apples-to-apples comparison of natural gas, petroleum, and alternative fuels, it is essential to take into account the different energy content—BTUs—of each fuel when comparing prices and costs of VMTs. For example, natural gas is typically measured in cubic feet rather than gallons, and there are about 960 BTU per cubic foot of gas, while a gallon of gasoline has 115,540 BTU/gallon. Therefore, it takes about 120 cubic feet of natural gas to provide the same amount of energy as a gallon of gasoline. The energy content of several transportation fuels and their conversion factors to a gallon of gasoline equivalent are provided in the Table 1.

Table 1.
Energy conversion factors for transportation fuels

Fuel	BTU per Unit of Measure	Unit of Measure	Conversion Factor to Gallon of Gasoline Equivalent
Gasoline	115,400	Gallon	1.000
Diesel	128,700	Gallon	0.897
Compressed Natural Gas	960	Cubic Foot	120.208
Liquefied Natural Gas	84,820	Gallon	1.361
Ethanol	75,700	Gallon	1.524
Propane	83,500	Gallon	1.382

3 Scenarios, Assumptions and Methodology

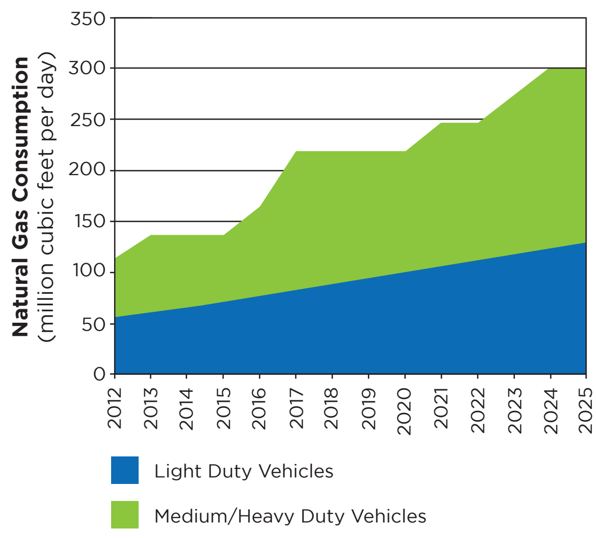
To evaluate the potential price impacts from shifting to NGVs, ACSF and Navigant developed three scenarios of potential NGV growth. The scenarios should not be viewed as predictions of the actual NGV growth trajectory, but are designed to clarify potential natural gas price impacts through 2025 if these scenarios materialize through private and public sector investments. Consequently, we purposely selected aggressive scenarios in terms of NGV growth rates in order to capture an upper bound of price impacts; lower growth rates would result in smaller price impacts.

The three demand scenarios were developed and compared to Navigant's natural gas supply outlook—which serves as the Reference Case for this analysis. Development of the scenarios was based on other forecasts—such as the Energy Information Administration's (EIA) Heavy Duty NGV Potential Case in the Annual Energy Outlook 2012[22]—and data about vehicle characteristics from resources like the Transportation Energy Data Book.[23] Once the assumptions for total NGVs, vehicle miles traveled and fuel efficiency were established, the incremental natural gas demand attributable to the increased growth was calculated. The assumptions for each scenario are described in the sections below and additional information is available in Appendices A and B.

3.1 Reference Case

Navigant publishes a natural gas supply outlook biannually (Navigant's Fall 2012 Outlook);[24] and it serves as the Reference Scenario. The outlook represents Navigant's view of the future natural gas production in North America. In particular, Navigant's Fall 2012 Outlook includes the most current market metrics available including economic indicators and all key supply drivers in the gas market, such as the latest developments regarding North American shale gas production. The latest projections of developments affecting end-user demand—including North American LNG export facilities—are also part of Navigant's analysis.

Figure 7.
Reference Case: NGV fuel consumption



22. EIA. (2012). *Annual Energy Outlook 2012: Issues in Focus.* Available at: http://www.eia.gov/forecasts/aeo/IF_all.cfm
23. Davis, S.C., Diegel, S.W., Boundy, R.G. (2012). *Transportation Energy Data Book, Edition 31.* U.S. Department of Energy. Available at http://cta.ornl.gov/data/tedb31/Edition31_Full_Doc.pdf
24. Pickering, G., Honeyfield, R. (Fall 2012). *North America Natural Gas Outlook, Fall 2012.* Available at: http://www.navigant.com/~/media/WWW/Site/Insights/Energy/NorthAmerNatGasMarketOutlookFall12.ashx

The Reference Case assumptions for light duty natural gas vehicles are consistent with Pike Research's *Light Duty Natural Gas Vehicles*[25] report, which forecasts through 2019. Natural gas demand from NGVs in Navigant's 2012 Outlook is similar to the levels in the EIA's Annual Energy Outlook 2012. Overall, natural gas demand for NGVs increases modestly from around 0.1 billion cubic feet per day (Bcf/d) currently, to 0.3 Bcf/d in 2025 (Figure 7). For comparison purposes, the EIA projects total natural gas consumption at roughly 73.6 Bcf/d in 2025 as compared to approximately 66 Bcf/d in 2012.[26]

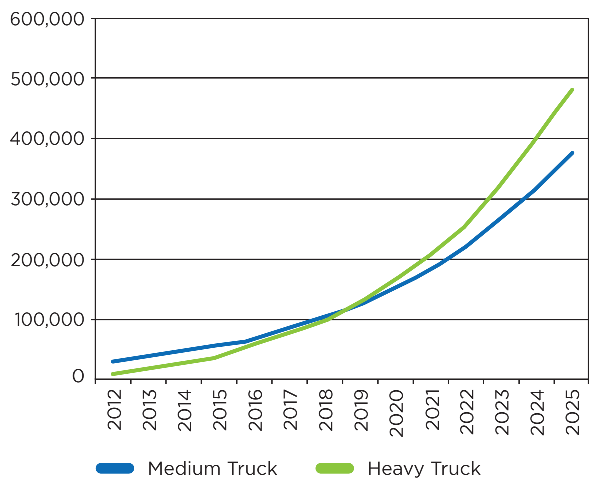
3.2 Heavy Duty Vehicle Potential Scenario

Perhaps the greatest opportunity for NGVs is in the heavy duty segment. That is because long haul trucks typically travel tens of thousands of miles a year while averaging six miles per diesel gallon. This makes CNG and LNG economically appealing due to their lower costs per gallon-equivalent compared to diesel. Accordingly, we developed a scenario to simulate aggressive adoption and utilization of heavy duty NGVs (HDVs). This scenario kept assumptions about light duty NGVs (LDVs), while keeping LDV assumptions static with the Reference Case in order to isolate the price impacts from HDVs.

The Heavy Duty Vehicle Potential scenario developed for this report was based in part on the EIA's Annual Energy Outlook 2012 "Heavy Duty Vehicles Natural Gas Potential Case" (EIA HDV case), and market data from the *Department of Energy's Transportation Energy Data Book*. In this scenario, the HDV segment is broken into a medium duty category and heavy duty category. The medium duty truck category represents Class 3-8 single-unit trucks, which have different characteristics and utilization rates than the heavy duty trucks category that represents Class 7-8 combination trucks.

Annual incremental medium duty and heavy duty truck growth was taken from the EIA HDV case, and annual "vehicle survival rates" from the Transportation Energy Data Book were applied to calculate the total on-road fleet during each year of the scenario.[27] Approximately 40,000 medium duty NGVs are currently in use. The HDV Potential Scenario assumes the total increases to about 375,000 in 2025, while total on-road heavy duty NGVs increases from about 20,000 today to 480,000 in 2025 (Figure 8).

Figure 8.
Number of on-road medium and heavy duty natural gas trucks in the Heavy Duty Potential Scenario



25. Hurst, D., Gartner, J. (2012). *Light Duty Natural Gas Vehicles.* Pike Research.

26. EIA. (2013). *Annual Energy Outlook 2013 Early Release.* Table 13: Natural Gas Supply, Disposition, and Prices.

27. Survival rates are the rates that vehicles from a specific model year (x) remain in service in a later year (x+n). Survival rates for the HDV vehicles was based on the Transportation Energy Data Book table 3.14.

Fuel efficiency characteristics—in miles per gallon equivalent (MPG-E) of gasoline—for each model year of truck (for both medium and heavy duty segments) were based on the EIA HDV case (Table 2). Medium duty NGV trucks were assumed to travel 15,000 miles annually because these classes of vehicles typically travel local routes and return to a hub or centralized station where they are refueled with natural gas. Heavy duty NGV trucks, on the other hand, were assumed to travel 90,000 miles per year to reflect the long-haul nature of the vehicle class. While LNG refueling infrastructure is in the nascent stage of development, it is assumed that the HDV NGVs in the near-term will travel defined routes and corridors, such as using the LNG "Clean Transportation Triangle" connecting Dallas-Fort Worth—Houston—and San Antonio,[28] or the more extensive 110-station national LNG network being installed by Clean Energy Fuels Corp.[29]

3.3 Light Duty Vehicle Potential Scenario

The current market for light duty passenger natural gas cars and trucks is limited mostly to fleet vehicles for government agencies and private companies. This is due to a lack of refueling infrastructure limiting the adoption of NGVs as personal passenger vehicles. NGVs for fleet use are an attractive option because fleet vehicles typically return to a central station where they can be refueled after use. Fleet vehicles also typically have higher VMTs than residential vehicles, and, therefore, fleet managers can realize larger fuel cost savings by switching to natural gas.

To develop the LDV Potential Scenario, ACSF and Navigant assumed continued growth in NGV purchases for fleet use, as well as residential market breakthroughs in certain states beginning in 2018.

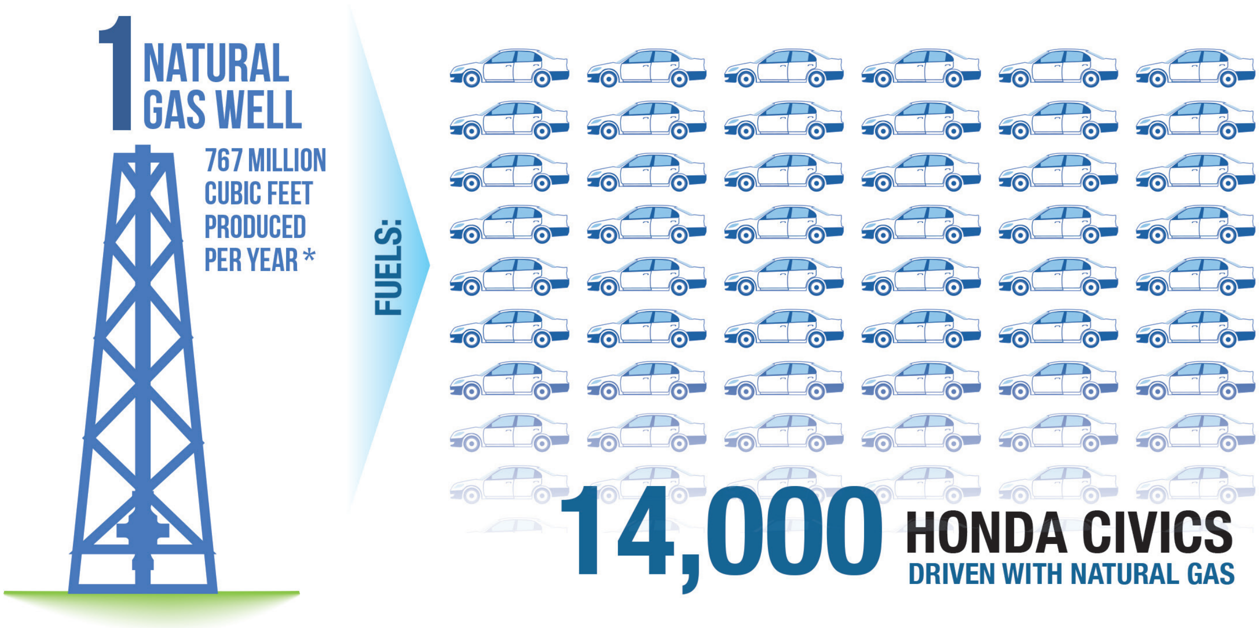
Table 2.
Annual incremental natural gas vehicle additions and fuel economy in the Heavy Duty Potential Case

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Medium Trucks (Class 3-8, Single unit)	Incremental Vehicle Additions	10,000	10,000	10,000	10,000	20,000	20,000	20,000	30,000	30,000	40,000	50,000	50,000	60,000
	MPG-E	9.6	9.76	9.99	10.26	10.58	10.8	10.98	11.01	11.04	11.06	11.07	11.07	11.07
Heavy Trucks (Class 7-8, Combination units)	Incremental Vehicle Additions	10,000	10,000	10,000	20,000	20,000	20,000	30,000	40,000	40,000	50,000	70,000	80,000	80,000
	MPG-E	5.62	6.26	6.35	6.47	6.61	6.68	6.72	6.74	6.77	6.8	6.83	6.85	6.87

28. University of Houston. (2013). *Texas Triangle Project*. University of Houston, Greater Houston Natural Gas Vehicle Alliance. Available at http://etuo.uh.edu/ngva/?page_id=106

29. *See* "Clean Energy Releases Third Edition of "The Road to Natural Gas", Press Release, February 28, 2013 available at http://files.shareholder.com/downloads/CLNE/2354933278x0x638047/d88a5718-5834-428e-a4a0-ff877fa23f1e/CLNE_News_2013_2_25_General_Releases.pdf

Figure 9.
One well = 14,000 Honda Civics driving with natural gas.



* INFOGRAPHIC BASED ON THE AVERAGE OUTPUT OF NATURAL GAS WELLS IN PENNSYLVANIA. DATA FROM PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION.

Compared to the Reference Scenario, the LDV Potential Scenario assumes that beginning in 2018 market barriers are reduced, and incentives for NGVs and home refueling in eight "focus states" lead to stronger growth in light duty NGV sales. Prior to 2018, the LDV Scenario contains the same assumptions for vehicle growth and gas consumption as the Reference Case. In the Reference Case, all new LDV sales are assumed to be for fleet use. The LDV Scenario, on the other hand, assumes the incremental sales between the scenario and Reference Case are for residential or personal use.

The eight focus states are California, Colorado, Ohio, Oklahoma, New York, Pennsylvania, Texas and Utah. The authors of this report view these states as having the greatest opportunity and interest in adopting NGVs. The scenario assumes that by 2025, three percent of the new LDV sales in the focus states are NGVs, and in total, the focus states represent 80 percent of the incremental fuel consumption growth in the U.S. The remaining 20 percent of incremental demand is made up by the remaining 42 states.

Table 3.

Annual incremental natural gas vehicle additions and fuel economy in the Light Duty Potential Case

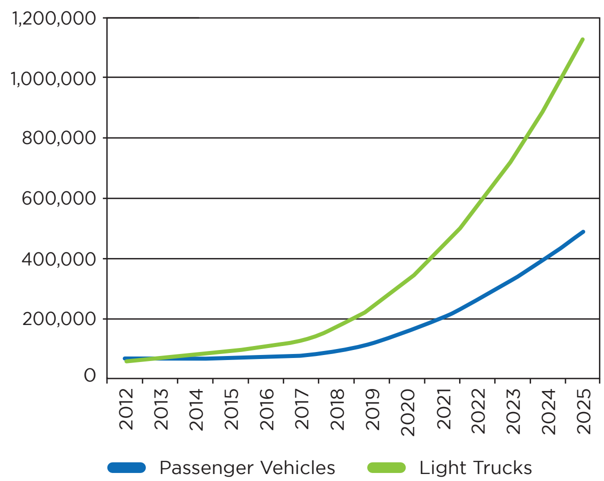
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Passenger Vehicles	Incremental Vehicle Additions	4,600	5,000	5,500	6,000	6,000	19,300	29,200	39,400	49,700	60,000	70,600	81,300	92,300
	MPG-E	26.8	27.4	28.0	29.0	31.7	32.9	34.0	35.4	36.9	38.6	40.4	42.3	44.2
Light Trucks	Incremental Vehicle Additions	13,400	14,800	16,400	18,100	19,900	47,400	68,300	91,200	115,600	141,900	170,100	200,400	228,100
	MPG-E	20.1	20.7	21.4	22.0	23.3	23.7	24.0	24.5	26.1	27.4	28.6	30.0	31.4

The LDV Scenario breaks down light duty vehicles into two segments—passenger vehicles and light duty trucks—to account for the different characteristics and utilization of the vehicle types. Due to the varying VMTs for fleet vehicles versus residential vehicles, a weighted average of annual VMTs by light duty NGVs was calculated.[30] For the fuel economy of the vehicles, CAFE standards for each model year were discounted by 20 percent to account for real-world driving habits (Table 3).[31] Survival rates for each vehicle class were based on the *Transportation Energy Data Book*.[32] Finally, in order to isolate the price impacts attributable to the increased adoption of light duty NGVs, the assumptions for the HDV segment revert back to the Reference Case.

Incremental additions for passenger vehicles increase from 4,600 in 2013 to over 92,000 in 2025. Growth in the light truck segment is even greater, rising from over 13,000 net additions in 2013, to over 228,000 net additions in 2025. In total, the scenario assumes nearly 500,000 passenger NGVs and 1.1 million light trucks are on the road by 2025 (Figure 10). Although the assumed growth is substantial, NGVs still pale in comparison to the total on-road LDVs. For example, in 2010 over 230 million cars were registered in the United States.[33]

Figure 10.

Total on-road light duty natural gas vehicles in the Light Duty Vehicle Potential Scenario



30. Each passenger fleet vehicle is assumed to travel about 24,500 miles per year, and each light truck in a fleet is assumed to travel 27,700 miles per year based on Table 7.3 in the *Transportation Energy Data Book.* Each passenger vehicle for residential use travels roughly 12,000 miles per year, and each residential light truck 11,000 miles per year, based on the *Transportation Energy Data Book's* Tables 4.1 and 4.2.

31. The National Highway Traffic Safety Administration's Final Rule for Model Year 2017 states, "... real-world fuel economy is typically 20 percent lower than the CO2 and CAFE compliance values discussed here." The statement was provided in the Federal Register, page 62630, footnote 11, on October 15, 2012. Available at: http://www.gpo.gov/fdsys/pkg/FR-2012-10-15/html/2012-21972.htm

32. Passenger vehicle survival rates are based on Table 3.12 in the *Transportation Energy Data Book*, while rates for light duty trucks are based on Table 3.13.

33. Davis, S.C., Diegel, S.W., Boundy, R.G. (2012). *Transportation Energy Data Book*, Edition 31, Quick Facts. U.S. Department of Energy. Available at http://cta.ornl.gov/data/tedb31/Edition31_Full_Doc.pdf

3.4 Combined NGV Potential Scenario

The final scenario looks at the combined impact of LDV and HDV growth following the previous cases which only isolated the effects each vehicle segment has on prices. To create this scenario, the incremental gas demand calculations from the Light Duty Vehicle Scenario and Heavy Duty Vehicle Scenario were combined.

The objective of this scenario is to assess the potential market impact of strong growth of NGVs in both the light duty and heavy duty market segments.

3.5 Methodology

Upon developing the scenario assumptions, incremental natural gas demand from the transportation sector was calculated based on the following equation:

NGV Fuel Demand = Number of Vehicles * (Average VMTs / Average Vehicle Fuel Efficiency)

Each vehicle vintage year's fuel consumption was calculated separately to account for changes in vehicles entering and exiting service, fuel efficiency improvements, and the type of vehicle.

Navigant calculated the potential impact on domestic natural gas prices by utilizing GPCM, a commercial partial-equilibrium model. As mentioned previously, Navigant includes their outlook on the natural gas market, and constantly updates the model with recent market data, infrastructure developments and infrastructure capacity. For this study, NGV fuel consumption for each scenario is fed into GPCM and the model outputs include Henry Hub prices, as well as total U.S. natural gas supply and demand projections. (See Appendices A and B for additional information).

4 Results and Conclusion

The incremental natural gas demand attributable to NGVs varied widely among the scenarios. The variation in demand allows for an illustrative range of potential price impacts. The largest potential natural gas demand growth in the transportation sector comes from the heavy duty vehicle segment. Adopting heavy duty NGVs for long-haul trucking can lead to significant gains in natural gas demand—and corresponding reductions in oil consumption—due to the high VMTs and low fuel efficiency of heavy duty vehicles compared to LDVs. These gains in natural gas demand are still small relative to total natural gas demand.

Natural gas demand in the HDV Potential Scenario rose to about 1800 million cubic feet/day (MMcf/d) in 2025, of which LDVs accounted for about 130 MMcf/d of demand while gas demand from HDVs was about 1650 MMcf/d. In the LDV Potential Scenario, passenger cars and light trucks account for about 300 MMcf/d of demand in 2025 and HDVs make up the balance of demand (200 MMcf/d). When combining the LDV and HDV Potential Scenarios into the Combined Scenario, total natural gas demand from the transportation sector equals about 2000 MMcf/d (or 2 Bcf/d). As detailed in Figure 17, this should still be only about 2 percent of the total estimated demand in 2025.

The Reference Case has the lowest demand at about 300 MMcf/d in 2025. Figures 11-15 below illustrate the varying levels of demand from the scenarios.

Figure 11.
Reference Case: NGV fuel consumption

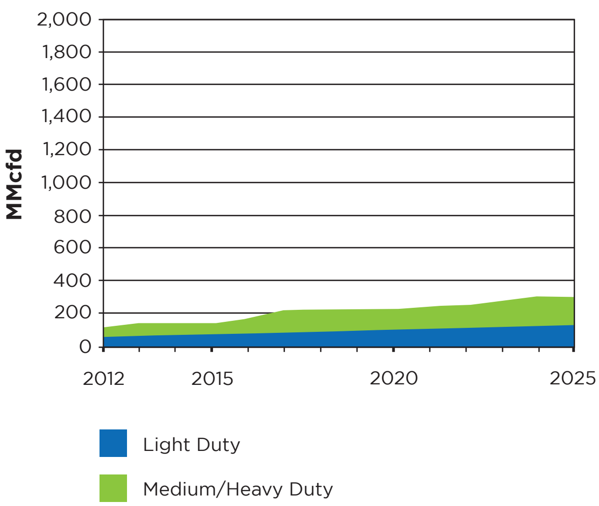


Figure 12.
Light Duty Vehicle Potential Scenario: NGV fuel consumption

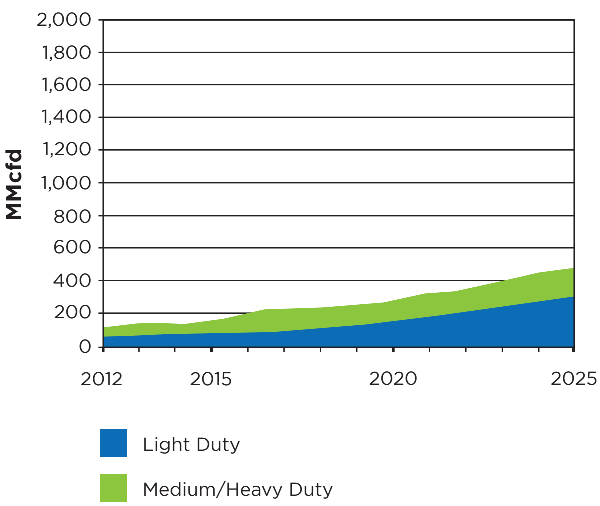


Figure 13.
Heavy Duty Vehicle Potential Scenario: NGV fuel consumption

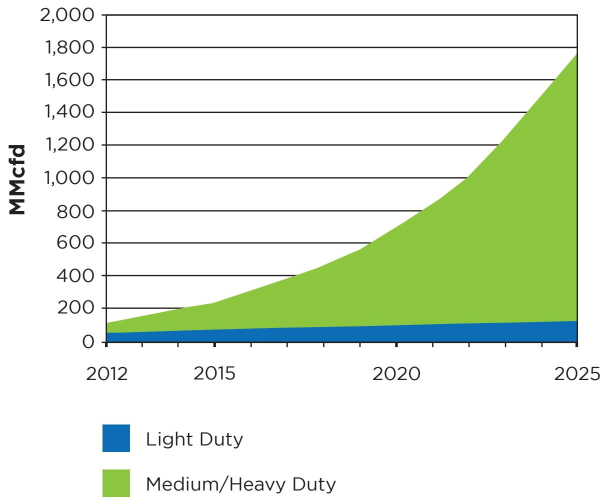


Figure 14.
Combined Natural Gas Vehicle Potential Scenario: NGV fuel consumption

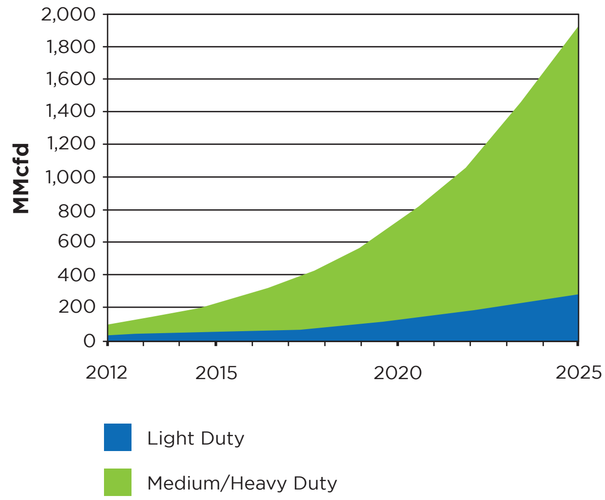


Figure 15.
Total NGV fuel consumption across all scenarios

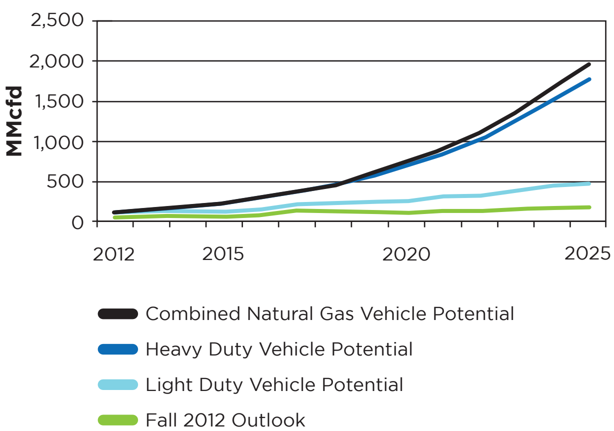
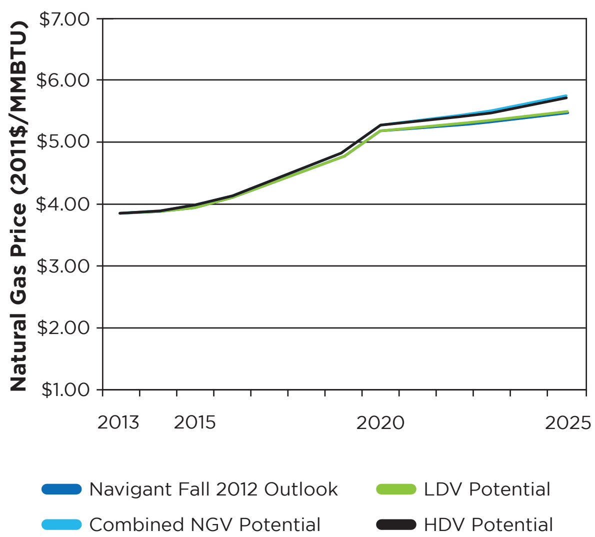


Figure 16.
Natural gas price impacts from NGV scenarios



Natural gas price impacts and effects on gas demand in other sectors varied from di minimis to minor across the scenarios. Increasing growth in light duty vehicles has a minimal impact on natural gas prices by increasing prices by a penny per MMBtu in 2020 and three cents in 2025 relative to the Reference Case (all price results are in 2011 dollars). The model also forecasts slight but larger price increases in the HDV Potential and Combined NGV Potential Scenarios. Increases above Reference Case prices range from about $0.10 in 2020 to about $0.25 per MMBtu in 2025 (Figure 16 and Table 4).

Table 4.
Annual average Henry Hub natural gas prices (2011$/MMBtu)

Year	Navigant Fall 2012 Outlook	HDV Potential	LDV Potential	Combined NGV Potential
2013	3.84	3.84	3.84	3.84
2014	3.88	3.89	3.88	3.89
2015	3.96	3.97	3.96	3.97
2016	4.11	4.13	4.11	4.13
2017	4.33	4.35	4.33	4.35
2018	4.56	4.59	4.56	4.59
2019	4.78	4.84	4.78	4.84
2020	5.17	5.26	5.18	5.27
2021	5.22	5.33	5.23	5.34
2022	5.27	5.41	5.29	5.42
2023	5.31	5.48	5.33	5.50
2024	5.38	5.58	5.40	5.61
2025	5.47	5.72	5.50	5.74

Price increases are expected to be minimal because the United States has vast natural gas resources in shale formations.[34] Natural gas producers can and will bring new supplies to market relatively quickly and at affordable prices to satisfy new demand. In other words, the development of shale gas has flattened the nation's natural gas supply curve.

Price increases are also minimal because the amount of natural gas demand from the transportation sector pales in comparison to the total U.S. natural gas demand—even in the most aggressive Combined NGV scenario. The transportation sector's share of total natural gas demand increases from 0.2 percent in 2013 to 2.3 percent in 2025 (Figure 17). The Combined NGV Potential Scenario 2025 demand equals about 711 Bcf. This is roughly the same as the 684 Bcf used in 2011 by the natural gas pipeline industry to fuel the transportation and distribution of natural gas[35]—a level of consumption that is all but ignored in most natural gas demand surveys.

Although the total transportation sector demand for natural gas remains minimal in all of our scenarios, a shift to natural gas vehicles can still provide meaningful reductions in oil consumption. For example, in the Combined NGV Scenario, consumption of over 180 million barrels of petroleum-based transportation fuels is avoided in 2025, and almost 1 billion barrels cumulatively from 2013-2025 (Figure 18).[36]

In sum, this analysis should give businesses, consumers, regulators and political leaders confidence that moving to NGVs will likely have a minimal impact on prices and competition for natural gas. On the other hand, realization of the most aggressive NGV scenarios in this report would provide significant environmental, economic and energy security benefits.

34. See: University of Texas. (2013). *New, Rigorous Assessment of Shale Gas Reserves Forecasts Reliable Supply from Barnett Shale Through 2030*. Available at: http://www.utexas.edu/news/2013/02/28/new-rigorous-assessment-of-shale-gas-reserves-forecasts-reliable-supply-from-barnett-shale-through-2030/

35. EIA. (2013). *Natural Gas Consumption by End Use.* Available at http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm

36. In 2013, we estimate about 37,000 barrels a day or 13.3 million barrels a year for approximately 193,000NGVs, of which 20,000 heavy duty natural gas trucks offset 7.4 million barrels. By 2025, total NGVs are estimated at 2.4 million, of which 480,000 are heavy duty trucks.

Figure 17.
Natural gas demand by use in the Combined NGV Potential Scenario

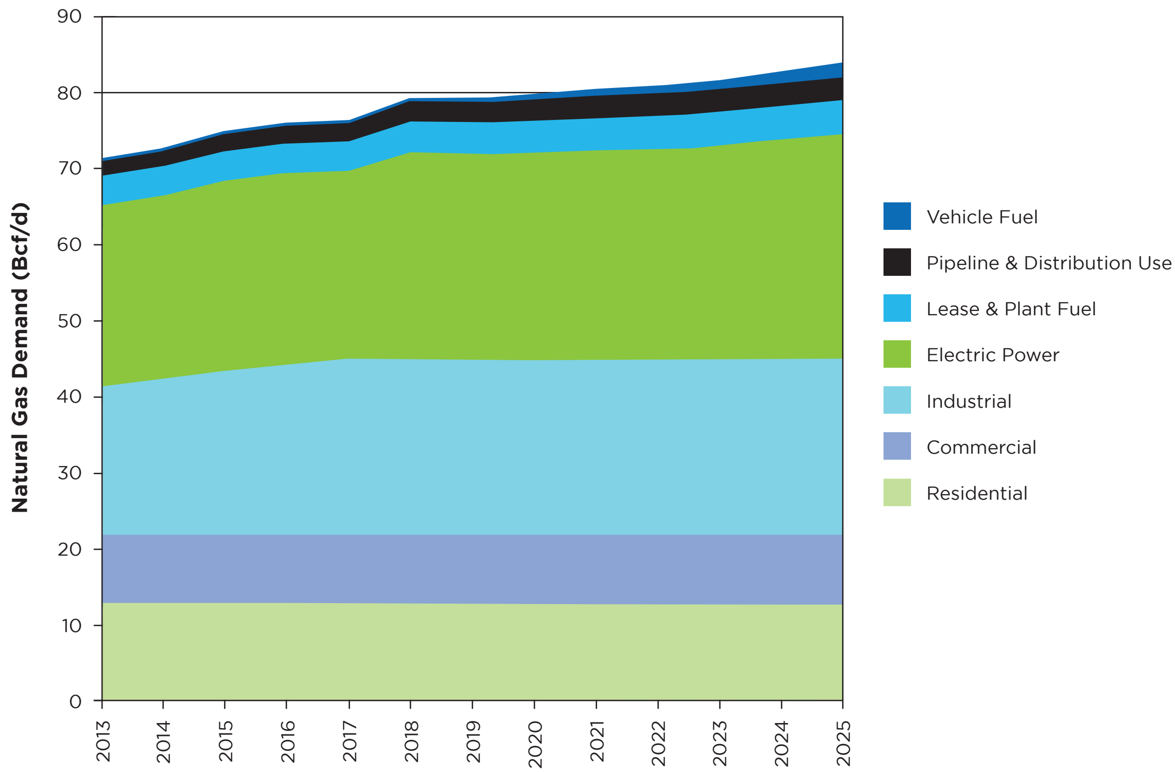
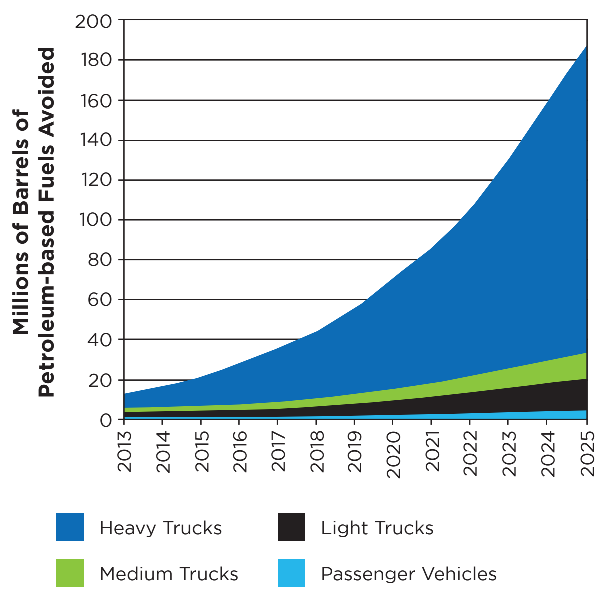


Figure 18.
Petroleum-based fuel avoided annually from shifting to NGVs: Combined NGV Potential Scenario



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- Yacobucci, Brent D. (May 2011). *Natural Gas Passenger Vehicles: Availability, Cost and Performance.* Congressional Research Service, Report 7-5700. Available at: http://www.policyarchive.org/handle/10207/bitstreams/19063.pdf

Appendix A: 6
Assumptions and Result Tables

Table 5.
Combined NGV Potential Scenario: number of natural gas vehicles

	Passenger Vehicles			Light Trucks					
Year	Fleet	Residential	Total	Fleet	Residential	Total	Medium Trucks	Heavy Trucks	Total
2013	59,577	6,620	66,197	61,203	6,800	68,003	39,250	19,750	**193,200**
2014	58,385	8,982	67,368	69,162	10,640	79,802	48,519	29,506	**225,195**
2015	57,740	11,548	69,288	77,817	15,563	93,381	57,806	39,269	**259,744**
2016	57,561	14,390	71,951	87,019	21,755	108,774	67,111	59,037	**306,873**
2017	57,656	17,548	75,204	95,877	29,180	125,058	86,374	78,751	**365,386**
2018	57,120	34,087	91,206	105,541	62,982	168,523	105,573	98,391	**463,693**
2019	57,493	59,726	117,219	113,955	118,380	232,335	124,689	127,936	**602,178**
2020	58,648	94,819	153,467	121,717	196,788	318,505	153,711	167,317	**793,000**
2021	60,211	139,703	199,915	129,029	299,376	428,405	182,558	206,493	**1,017,371**
2022	61,993	194,157	256,150	135,933	425,728	561,661	221,201	255,434	**1,294,446**
2023	63,776	258,410	322,186	142,509	577,426	719,936	269,599	324,050	**1,635,770**
2024	65,390	332,436	397,826	148,650	755,723	904,373	317,671	402,230	**2,022,101**
2025	66,912	415,941	482,854	154,027	957,466	1,111,494	375,358	479,906	**2,449,611**

Table 6.
Combined NGV Potential Scenario: incremental natural gas vehicle sales

Year	Passenger Vehicles	Light Trucks	Medium Trucks	Heavy Trucks	Total
2013	4,560	13,369	10,000	10,000	**37,928**
2014	5,022	14,823	10,000	10,000	**39,845**
2015	5,531	16,434	10,000	10,000	**41,965**
2016	6,048	18,091	10,000	20,000	**54,139**
2017	6,613	19,915	20,000	20,000	**66,529**
2018	19,265	47,448	20,000	20,000	**106,714**
2019	29,219	68,260	20,000	30,000	**147,479**
2020	39,444	91,200	30,000	40,000	**200,645**
2021	49,683	115,644	30,000	40,000	**235,327**
2022	60,045	141,913	40,000	50,000	**291,958**
2023	70,570	170,115	50,000	70,000	**360,685**
2024	81,303	200,380	50,000	80,000	**411,683**
2025	92,291	228,144	60,000	80,000	**460,435**

Table 7.
New vehicle fuel efficiency (all scenarios)

Year	Passenger Vehicles	Light Trucks	Medium Trucks	Heavy Trucks
2013	26.8	20.1	9.6	5.6
2014	27.4	20.7	9.8	6.3
2015	28.0	21.4	10.0	6.4
2016	29.0	22.0	10.3	6.5
2017	31.7	23.3	10.6	6.6
2018	32.9	23.7	10.8	6.7
2019	34.0	24.0	11.0	6.7
2020	35.4	24.5	11.0	6.7
2021	36.9	26.1	11.0	6.8
2022	38.6	27.4	11.1	6.8
2023	40.4	28.6	11.1	6.8
2024	42.3	30.0	11.1	6.9
2025	44.2	31.4	11.1	6.9

Table 8.
Combined NGV Potential Scenario: vehicle miles traveled per vehicle

Year	Passenger Vehicles	Light Trucks	Medium Trucks	Heavy Trucks
2013	23,266	26,006	15,000	90,000
2014	22,843	25,451	15,000	90,000
2015	22,421	24,895	15,000	90,000
2016	21,998	24,340	15,000	90,000
2017	21,575	23,784	15,000	90,000
2018	19,795	21,445	15,000	90,000
2019	18,073	19,183	15,000	90,000
2020	16,699	17,378	15,000	90,000
2021	15,672	16,029	15,000	90,000
2022	14,922	15,043	15,000	90,000
2023	14,363	14,309	15,000	90,000
2024	13,937	13,750	15,000	90,000
2025	13,610	13,320	15,000	90,000

Table 9.
Reference Case: natural gas vehicle fuel consumption (MMcf/d)

Year	Light Duty Vehicles	Medium/ Heavy Duty Vehicles	Total
2013	61	76	**137**
2014	66	71	**137**
2015	71	66	**137**
2016	77	88	**164**
2017	82	137	**219**
2018	88	131	**219**
2019	94	126	**219**
2020	100	119	**219**
2021	106	141	**247**
2022	112	135	**247**
2023	118	156	**274**
2024	124	178	**301**
2025	129	172	**301**

Table 10.
Light Duty Vehicle Potential Case: natural gas vehicle fuel consumption (MMcf/d)

Year	Light Duty Vehicles	Medium/ Heavy Duty Vehicles	Total
2013	61	76	**137**
2014	66	71	**137**
2015	71	66	**137**
2016	77	88	**164**
2017	82	137	**219**
2018	98	131	**229**
2019	119	126	**244**
2020	144	119	**264**
2021	172	141	**313**
2022	203	135	**338**
2023	236	156	**392**
2024	270	178	**448**
2025	306	172	**478**

Table 11.
Heavy Duty Vehicle Potential Case:
natural gas vehicle fuel consumption (MMcf/d)

Year	Light Duty Vehicles	Medium/ Heavy Duty Vehicles	Total
2013	61	96	**157**
2014	66	133	**199**
2015	71	169	**240**
2016	77	236	**313**
2017	82	306	**388**
2018	88	375	**463**
2019	94	474	**568**
2020	100	607	**707**
2021	106	738	**844**
2022	112	903	**1,015**
2023	118	1,131	**1,249**
2024	124	1,386	**1,510**
2025	129	1,644	**1,773**

Table 12.
Combined NGV Potential Case:
natural gas vehicle fuel consumption (MMcf/d)

Year	Light Duty Vehicles	Medium/ Heavy Duty Vehicles	Total
2013	61	96	**157**
2014	66	133	**199**
2015	71	169	**240**
2016	77	236	**313**
2017	82	306	**388**
2018	98	375	**473**
2019	119	474	**593**
2020	144	607	**751**
2021	172	738	**911**
2022	203	903	**1,106**
2023	236	1,131	**1,366**
2024	270	1,386	**1,656**
2025	306	1,644	**1,949**

Table 13.
Reference Case: U.S. natural gas supply disposition (Bcf/d)

	Production			Net Imports					
Year	Shale	Non-Shale	Total Production	Net Pipeline Imports	Net LNG Imports	Total Net Imports	Net Storage	Balancing Item	Available for Consumption
2013	28.1	39.4	67.5	3.5	0.5	4.0	-0.1	0.0	**71.4**
2014	31.0	38.2	69.2	3.2	0.5	3.7	-0.1	0.0	**72.7**
2015	34.3	37.4	71.7	3.0	0.2	3.2	-0.1	0.0	**74.8**
2016	37.1	36.4	73.5	2.7	-0.4	2.3	0.0	0.0	**75.9**
2017	39.6	35.4	75.0	2.7	-1.4	1.3	0.0	0.0	**76.3**
2018	42.8	35.6	78.4	2.7	-2.0	0.6	0.0	0.0	**79.0**
2019	44.5	34.9	79.4	1.6	-2.0	-0.5	-0.1	0.0	**78.8**
2020	46.9	34.8	81.7	1.6	-4.3	-2.7	0.1	0.0	**79.2**
2021	48.6	34.4	83.0	1.1	-4.3	-3.2	0.0	0.0	**79.8**
2022	49.9	33.8	83.7	0.7	-4.3	-3.6	0.0	0.0	**80.1**
2023	51.2	33.3	84.5	0.4	-4.3	-3.9	0.0	0.0	**80.6**
2024	52.5	32.9	85.4	0.4	-4.3	-3.9	0.0	0.0	**81.6**
2025	53.6	32.6	86.2	0.3	-4.3	-4.0	0.0	0.0	**82.3**

Table 14.
Heavy Duty Vehicle Potential Case: U.S. natural gas supply disposition (Bcf/d)

	Production			Net Imports					
Year	Shale	Non-Shale	Total Production	Net Pipeline Imports	Net LNG Imports	Total Net Imports	Net Storage	Balancing Item	Available for Consumption
2013	28.1	39.5	67.5	3.5	0.5	4.0	-0.1	0.0	**71.4**
2014	31.0	38.2	69.2	3.2	0.5	3.7	-0.1	0.0	**72.8**
2015	34.3	37.4	71.8	3.0	0.2	3.2	-0.1	0.0	**74.9**
2016	37.2	36.4	73.6	2.8	-0.4	2.3	0.0	0.0	**76.0**
2017	39.7	35.4	75.2	2.7	-1.4	1.3	0.0	0.0	**76.5**
2018	42.9	35.7	78.6	2.7	-2.0	0.7	0.0	0.0	**79.3**
2019	44.7	35.0	79.7	1.6	-2.0	-0.4	-0.1	0.0	**79.2**
2020	47.2	35.0	82.1	1.7	-4.3	-2.6	0.1	0.0	**79.6**
2021	48.9	34.6	83.5	1.2	-4.3	-3.1	0.0	0.0	**80.4**
2022	50.3	34.0	84.4	0.7	-4.3	-3.5	0.0	0.0	**80.8**
2023	51.7	33.6	85.3	0.5	-4.3	-3.8	0.0	0.0	**81.5**
2024	53.2	33.3	86.5	0.5	-4.3	-3.8	0.0	0.0	**82.8**
2025	54.5	33.1	87.6	0.4	-4.3	-3.8	0.0	0.0	**83.7**

Table 15.
Light Duty Vehicle Potential Case: U.S. natural gas supply disposition (Bcf/d)

	Production			Net Imports					
Year	Shale	Non-Shale	Total Production	Net Pipeline Imports	Net LNG Imports	Total Net Imports	Net Storage	Balancing Item	Available for Consumption
2013	28.1	39.4	67.5	3.5	0.5	4.0	-0.1	0.0	**71.4**
2014	31.0	38.2	69.2	3.2	0.5	3.7	-0.1	0.0	**72.7**
2015	34.3	37.4	71.7	3.0	0.2	3.2	-0.1	0.0	**74.8**
2016	37.1	36.4	73.5	2.7	-0.4	2.3	0.0	0.0	**75.9**
2017	39.6	35.4	75.0	2.7	-1.4	1.3	0.0	0.0	**76.3**
2018	42.8	35.6	78.4	2.7	-2.0	0.6	0.0	0.0	**79.1**
2019	44.5	34.9	79.4	1.6	-2.0	-0.5	-0.1	0.0	**78.9**
2020	46.9	34.8	81.8	1.6	-4.3	-2.6	0.1	0.0	**79.2**
2021	48.7	34.4	83.0	1.1	-4.3	-3.2	0.0	0.0	**79.9**
2022	50.0	33.8	83.8	0.7	-4.3	-3.6	0.0	0.0	**80.2**
2023	51.3	33.3	84.6	0.4	-4.3	-3.9	0.0	0.0	**80.7**
2024	52.6	33.0	85.6	0.4	-4.3	-3.9	0.0	0.0	**81.7**
2025	53.7	32.7	86.4	0.3	-4.3	-4.0	0.0	0.0	**82.4**

Table 16.
Combined Natural Gas Vehicle Potential Case: U.S. natural gas supply disposition (Bcf/d)

	Production			Net Imports					
Year	Shale	Non-Shale	Total Production	Net Pipeline Imports	Net LNG Imports	Total Net Imports	Net Storage	Balancing Item	Available for Consumption
2013	28.1	39.5	67.5	3.5	0.5	4.0	-0.1	0.0	**71.4**
2014	31.0	38.2	69.2	3.2	0.5	3.7	-0.1	0.0	**72.8**
2015	34.3	37.4	71.8	3.0	0.2	3.2	-0.1	0.0	**74.9**
2016	37.2	36.4	73.6	2.8	-0.4	2.3	0.0	0.0	**76.0**
2017	39.7	35.4	75.2	2.7	-1.4	1.3	0.0	0.0	**76.5**
2018	42.9	35.7	78.7	2.7	-2.0	0.7	0.0	0.0	**79.3**
2019	44.7	35.0	79.7	1.6	-2.0	-0.4	-0.1	0.0	**79.2**
2020	47.2	35.0	82.2	1.7	-4.3	-2.6	0.1	0.0	**79.7**
2021	49.0	34.6	83.6	1.2	-4.3	-3.1	0.0	0.0	**80.5**
2022	50.4	34.1	84.4	0.7	-4.3	-3.5	0.0	0.0	**80.9**
2023	51.8	33.6	85.4	0.5	-4.3	-3.8	0.0	0.0	**81.7**
2024	53.2	33.4	86.6	0.5	-4.3	-3.8	0.0	0.0	**82.9**
2025	54.6	33.2	87.7	0.4	-4.3	-3.8	0.0	0.0	**83.9**

7 Appendix B: Navigant Scenario Development and Methodology

7.1 Navigant North American Natural Gas Market Outlook, Fall 2012

Navigant North American Natural Gas Market Outlook, Fall 2012 (Navigant Fall 2012 Outlook) served as the reference case for this study. The Navigant Fall 2012 Outlook was released in December 2012, and represents Navigant's view of the future natural gas markets in North America. Navigant's Fall 2012 Reference Case assumes similar levels of NGV demand as the EIA Annual Energy Outlook 2012 Reference Case with levels increasing very moderately over the forecast period from around 0.1 Bcf/d currently to 0.3 Bcf/d by 2025. The assumptions for light duty natural gas vehicles are consistent with the conclusions from the report, "Light Duty Natural Gas Vehicles", by Pike Research—a part of Navigant's Energy Practice. The Pike Research report includes an outlook for U.S. light duty natural gas vehicle sales to 2019. Vehicle sales have been trended forward to 2025 and have been related to NGV consumption. Additionally, Navigant's market model used to prepare the Navigant Fall 2012 Outlook incorporates the most current market metrics available including the latest economic indicators and all key supply drivers in the gas market including the latest developments regarding North American gas shale and other developments in the associated gas oil plays in the U.S., developments affecting end-user demand, and North American LNG exports. The forecast was prepared on an annual basis through 2035 and a portion of the forecast from 2013 to 2025 was used to support this study.

7.2 Heavy Duty Vehicle Potential

In this scenario, Navigant assumes strong heavy duty natural gas vehicle growth. The assumptions for this scenario are based on the EIA's Annual Energy Outlook 2012 "Heavy Duty Vehicles Natural Gas Potential Case", which has total natural gas consumption in the transportation sector increasing from current levels to 2.2 Bcf/d by 2025. EIA's census region level demands for NGV consumption has been used to allocate NGV gas consumption into census regions. All other inputs have remained the same as in the Reference Case (Navigant Fall 2012 Outlook). The key objective of this scenario is to assess the incremental market impact of strong heavy duty vehicle natural gas consumption upon the 'market' as measured in the Reference Case.

7.3 Light Duty Vehicle Potential

For this scenario Navigant assumes strong light duty natural gas vehicle growth. The key objective of this scenario is to assess the incremental market impact of strong light duty vehicle natural gas consumption upon natural gas fuel demand projected in the Reference Scenario. Compared with the Reference Scenario (Navigant Fall 2012 Outlook), this scenario assumes that, starting from 2018, a total of eight 'focus states' (CA, CO, OH, OK, NY, PA, TX and UT) will have enough barriers removed, coupled with incentives and home refueling, which lead to a stronger growth in light duty natural gas vehicle sales. Navigant assumes that the NGV sales in the 'focus states' grow to 3 percent of all new vehicle sales in those states. To regionalize the light duty natural gas vehicle incremental fuel consumption, Navigant assumes that 80 percent of the incremental fuel consumption growth in the U.S. is in 'focus states'. Other states will also experience growth in the incremental light duty natural gas vehicle fuel consumption and account for the remaining 20 percent of U.S. incremental consumption. Navigant also assumes that 100 percent of the incremental vehicle sales, measured against the Reference Scenario, are for residential vehicles. Prior to 2018 light duty NGV sales from the Reference Scenario are used. All the assumptions for heavy duty natural gas vehicles have been kept the same as those in the Reference Scenario.

7.4 Combined Natural Gas Vehicle Potential

The last scenario developed for the study represents the most aggressive of all four cases. In this scenario, the assumptions for heavy duty natural gas vehicles are adopted from the second scenario, Heavy Duty Vehicle Potential; and the assumptions for light duty vehicles are consistent with those used in the third scenario, Light Duty Vehicle Potential. The key objective of this scenario is to assess the potential market impact of strong growth of natural gas vehicles in both light duty vehicles and heavy duty vehicles.

7.5 Summary

The following chart outlines the relative growth projections used in the study:

Table 17.
Scenario assumptions

	Heavy Duty		Light Duty NGV Growth	
Scenario	**Moderate**	**Aggressive**	**Moderate**	**Aggressive**
Reference Case (Navigant Falls 2012 Outlook)	●		●	●
Heavy Duty Vehicle Potential		●	●	●
Light Duty Vehicle Potential	●			
Combined NGV Potential		●		

7.6 Number of Natural Gas Vehicles

The overall methodology for projecting the number of on-road natural gas vehicles in each vehicle group (passenger vehicles, light trucks, medium trucks and heavy trucks) is that the total number of vehicle stock in each year is calculated as the total number of vehicle stock in the previous year plus the vehicle new sales volume, minus the number of scrapped vehicles in the current year.

Moderate assumptions for light duty vehicle incremental sales volumes are based on data from the Pike Research report—*Natural Gas Passenger Cars and Light Duty Pickup Trucks, SUVs, Vans, and Light Commercial Vehicles: Global Market Analysis and Forecasts.* Aggressive scenario for light duty vehicle incremental sales volumes assumes that eight 'focus states' (CA, CO, OH, OK, NY, PA, TX and UT) will have stronger growth in light duty natural gas vehicle sales starting from 2018. The NGV sales in the 'focus states' grow to 3 percent of all new vehicle sales in those states. Assumptions for medium/heavy duty vehicle incremental sales volumes are based on data published in EIA Annual Energy Outlook 2012.

7.7 New Vehicle Fuel Efficiency

For light duty vehicles, the projection of new vehicle fuel efficiencies is based on the latest Corporate Average Fuel Economy (CAFE) standards issued by the National Highway Traffic Safety Administration. To account for the difference between lab-setting CAFE figures and real-life fuel economy, a 20 percent discount is applied to the published CAFE standards when used for fuel consumption calculation.

For medium/heavy duty vehicles, future new vehicle fuel efficiencies are based on the assumptions in EIA Annual Energy Outlook 2012.

7.8 Vehicle Miles Traveled

Light duty vehicles (passenger vehicles and light trucks) consist of residential vehicles and fleet vehicles; the latter are used much more heavily than the former. Therefore for light duty vehicles, the average vehicle miles traveled per vehicle per year is forecasted as the weighted average of the vehicle miles traveled in each group of vehicles, in accordance with the changing mix between residential vehicles and fleet vehicles.

Within each vehicle category (residential passenger vehicles, fleet residential vehicles, residential light trucks, fleet light trucks, medium trucks and heavy trucks), the average vehicle miles traveled per year per vehicle are assumed to stay at today's levels.

7.9 Natural Gas Fuel Consumption

For the study, natural gas vehicles are assumed to consume natural gas fuels only. Natural gas fuels consumption is calculated based on the following equation:

NGV Fuel Demand = Number of Vehicles x Vehicle Miles Traveled / Vehicle Fuel Efficiency

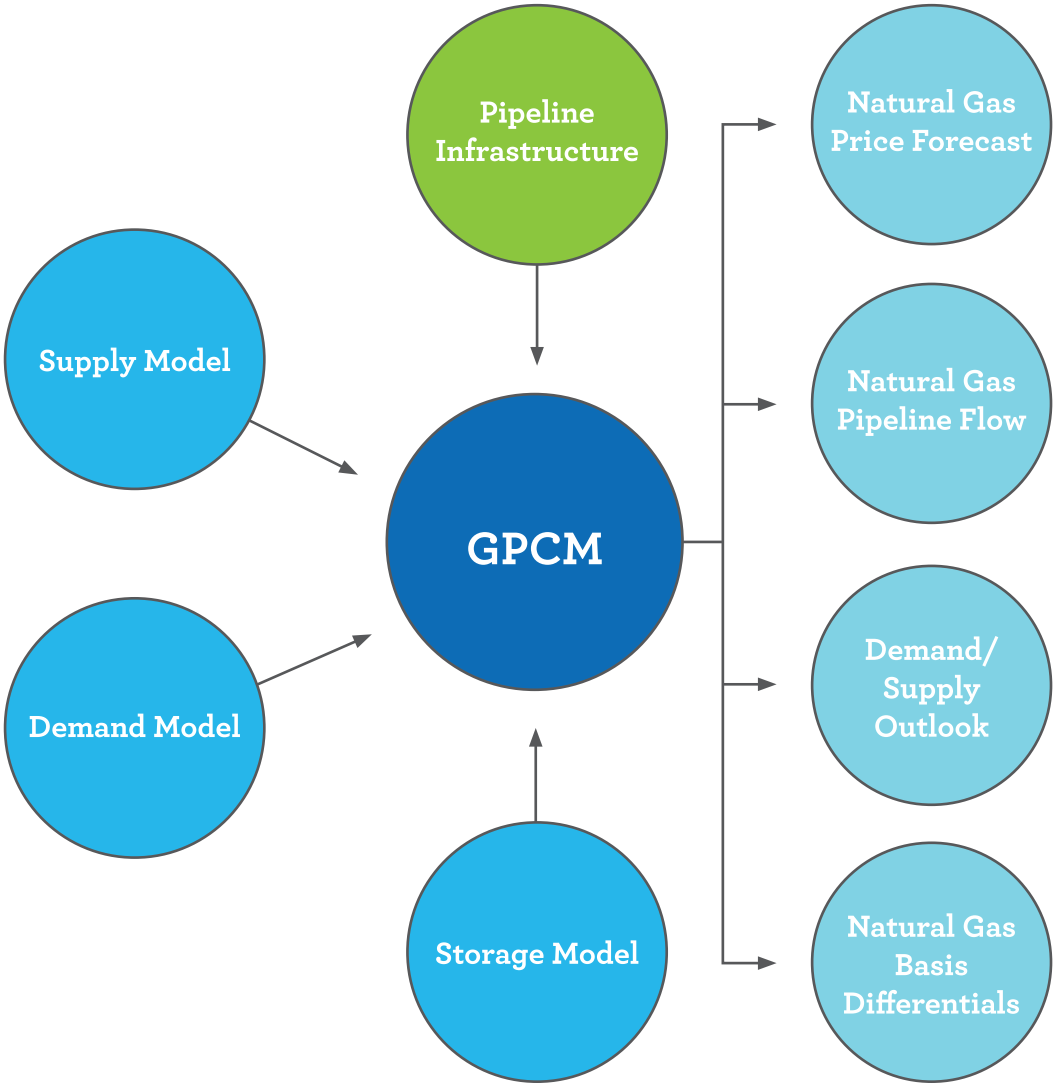
Within each vehicle group (passenger vehicles, light trucks, medium trucks and heavy trucks), every vintage year's vehicles' fuel consumptions are calculated separately. In the last step, fuel consumptions from different vintage years are summed up for the total consumption. .

7.10 Potential Impact on Domestic Natural Gas Prices

Navigant licenses GPCM, a commercial partial-equilibrium model, to model the North American gas marketplace and infrastructure. Navigant applies its own analysis to provide macroeconomic outlook and natural gas supply and demand data for the model, including infrastructure additions and configurations, and its own supply and demand elasticity assumptions. Forecasts are based upon the breadth of Navigant's view, insight and detailed knowledge of the U.S. and Canadian natural gas markets. Adjustments are made to the model to reflect accurate infrastructure operating capability as well as the rapidly changing market environment regarding economic growth rates, energy prices, gas production growth levels, sectoral demand and natural gas pipeline, storage and LNG terminal system additions and expansions. To capture current expectations for the gas market, this long-term monthly forecast is combined with near term NYMEX average forward prices for the first two years of the forecast.

In this study, NGV fuel consumptions calculated for each scenario are fed into GPCM, see Figure 19.

Figure 19.
GPCM Model Process



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