Canadian Energy Research Institute

North American Natural Gas Market Dynamics:
Natural Gas Vehicles – A Review

Jon Rozhon

Study No. 123 – Section IV

March 2011

CANADIAN ENERGY RESEARCH INSTITUTE

Relevant • Independent • Objective

NORTH AMERICAN NATURAL GAS MARKET DYNAMICS:
NATURAL GAS VEHICLES – A REVIEW

North American Natural Gas Market Dynamics:
Natural Gas Vehicles – A Review

Copyright © Canadian Energy Research Institute, 2011
Sections of this study may be reproduced in magazines and newspapers with acknowledgement to the Canadian Energy Research Institute

Study No. 123 – Section IV
ISBN 1-896091-97-0

Author: Jon Rozhon

Acknowledgements: The author of this report would like to extend his thanks and gratitude to everyone involved in the production and editing of the material, including, but not limited to Peter Howard and Megan Murphy

CANADIAN ENERGY RESEARCH INSITTUTE
150, 3512 – 33 Street NW
Calgary, Alberta T2L 2A6
Canada
www.ceri.ca

March 2011
Printed in Canada

Table of Contents

LIST OF FIGURES v
LIST OF TABLES vii
SUMMARY OF CONTENTS 1
INTRODUCTION 2
AN IMPORTANT DISTINCTION 3
THE NATURAL GAS VEHICLE SITUATION IN THE US 4
NGV Cars in the US 4
US – What are the Next Steps? 5
Pickens' Plan 6
Challenges to Implementing the Pickens' Plan 7
The Pickens Plan: A Quantitative Analysis 8
Pickens Plan Contingencies 12
THE NATURAL GAS VEHICLE SITUATION IN CANADA 16
Canada – What are the Next Steps? 18
The Roadmap 19
Challenges to Implementing the Roadmap 21
NGV Market Potential in Canada 22

List of Figures

Figure 1 Worldwide NGV Deployment 3
Figure 2 "18-Wheeler" Vehicle Fleet – EIA Scenario 9
Figure 3 "18-Wheeler" Vehicle Fleet – Pickens Plan 10
Figure 4 BPD Oil Usage for Trucking Fleet – Pickens Plan 10
Figure 5 CO2 Emissions – EIA Scenario 11
Figure 6 CO2 Emissions Reduction Under the Pickens Plan 11
Figure 7 Oil Costs for Heavy Trucks w/ and w/o Pickens Plan Implementation 12
Figure 8 Oil Usage for Trucking Fleet 13
Figure 9 Emissions 14
Figure 10 US Crude Consumption and Use, Based on 19,000,000 bpd 15
Figure 11 EIA NGV Truck Sales Projections 16
Figure 12 NGV Truck Estimates – Canada 25
Figure 13 NGV Truck GHG Benefits – Canada 26
Figure 14 NGV Truck Estimates – United States 27
Figure 15 NGV Truck GHG Benefits – United States 28

List of Tables

Table 1 Pickens Plan Statistics Compared to EIA Data 7
Table 2 Application Ranking Table 20
Table 3 IRR Summary for "Very Good" Ranked End-Use Applications (British Columbia, 2011) 21
Table 4 Estimated NGV Market Potential in Canada 22

North American Natural Gas Market Dynamics: Natural Gas Vehicles – A Review

Summary of Contents

This paper considers the case for Natural Gas Vehicle (NGV) integration into the North American medium- heavy-truck transportation fleet. It concludes that integration will occur on a much smaller scale than envisioned by prominent advocates of NGVs like T. Boone Pickens.

The paper begins with an assessment of the state of NGV usage and development throughout the world, noting that over the past decade NGVs have gained in popularity in areas such as Europe, Latin America, and the Indian subcontinent. Conspicuously, NGVs have not seen such growth in North America, where production and sales of vehicles has stagnated since a mini-boom in the 1970s. Reasons for this include lack of investment in infrastructure, limited vehicle choice, and high initial vehicle purchase costs.

Recently, there have been calls to revisit implementation of NGVs in the North American transportation sector. In the United States, there is momentum building behind the idea of improving energy security through exploiting abundant domestic gas resources. In Canada, the motivation is similar: to diversify the national fuel supply away from crude-based fuels.

This paper considers in detail two prominent energy plans that promote NGV development in North America – the Pickens Plan and NRCan's recently released *Natural Gas Use in the Canadian Transportation Sector.* Both strategies have their strengths: the Pickens Plan offers a grand vision of a US highway system dominated by NGVs; the NRCan "Roadmap" provides compelling economic and business arguments for promoting NGV usage and for developing NGV infrastructure along existing transportation corridors.

The final chapter offers three scenarios for NGV heavy and medium truck integration into the US and Canadian transport sector. Each scenario considers integration over the next decade. The summary below indicates the following:

a) Under any of the considered scenarios, increased natural gas usage is modest. At no point would it surpass 10 percent of 2009 total gas usage in either country.
b) GHG benefits are also modest,[1] with Canadian emissions reductions approaching Copenhagen targets by 2020 in the High case. US High case projections surpass Copenhagen standards by 2020.

[1]The emission goals stated here are 17% less than the US and Canadian 2005 emissions levels for the transportation sectors in each country. Copenhagen, a non-binding agreement, calls on both countries to reduce absolute emissions 17% below 2005 levels.

USA	Total Vehicles	Total Energy Use (Bcf)	Avg Yearly GHG Benefit (Mt CO_2e)	Potential GHG Benefit in 2020 (Mt CO_2e)	Copenhagen 2020 Emission Goal (Mt CO_2e)
High	800,000	18,155	44.4	95.9	79.1
Mid	300,000	6,808	16.7	36.0	79.1
Low	62,785	1,425	3.5	7.5	79.1

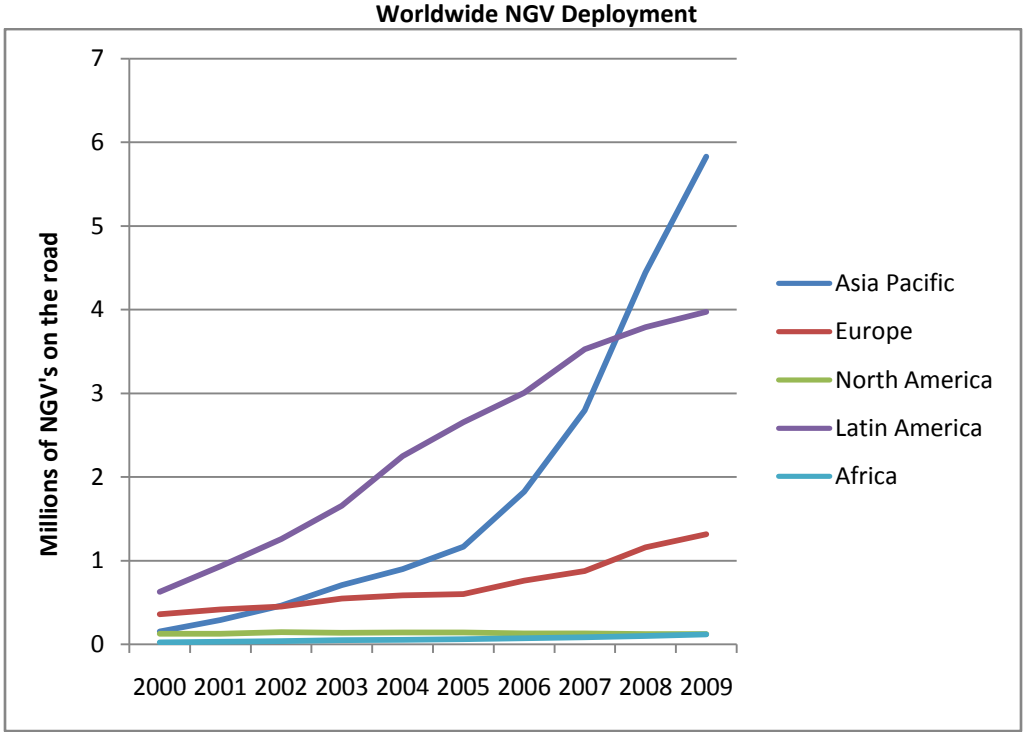
Canada	Total Vehicles	Total Energy Use (Bcf)	Avg Yearly GHG Benefit (Mt CO_2e)	Potential GHG Benefit in 2020 (Mt CO_2e)	Copenhagen 2020 Emission Goal (Mt CO_2e)
High	53,981	1,225	3.0	6.5	6.6
Mid	25,191	572	1.4	3.0	6.6
Low	10,796	245	0.6	1.3	6.6

Introduction

Technology has been available for over a century to compress natural gas and use it as a fuel in vehicles. In recent years, though, use of natural gas, especially in its compressed form (CNG), has surged throughout the developing world, with infrastructure being built; natural gas fueled cars, trucks, and even tuk tuks being assembled, and gasoline-to-natural gas conversion kits being sold as never before. Worldwide growth in Natural Gas Vehicles (NGVs) has averaged 20.8 percent per annum since 2000,[2] with Pakistan, Argentina, Iran, Brazil, and India leading the way. However, in North America over that same time span there has been a slight decline in the number of NGVs being driven. The majority of North American NGVs are fleet vehicles – garbage trucks, taxi cabs, buses – with individually-owned NGVs being driven only within small pockets of the continent. According to the Energy Information Administration (EIA), natural gas represents a mere 3 percent of fuel used for transportation in the US.[3] Figure 1 makes clear this disparity between world regions in CNG use for transportation:

[2]This statistic provided by *International Association for Natural Gas Vehicles*. Downloaded December 19, 2010
[3]EIA. *Annual Energy Review*, 2011. http://www.eia.doe.gov/oiaf/aeo/gas.html Downloaded December 19, 2010

Figure 1
Worldwide NGV Deployment



Source: iangv.org

An Important Distinction

CNG and LNG are not terms that can be used interchangeably. Though both fuels are natural gas, they are different in volume. CNG is compressed through pressure while LNG is natural gas that is liquefied through cryogenics. As a result, the tanks holding these fuels are different, and the infrastructure requirements for refueling are different, too. There are certain transportation conditions where CNG is a preferable fuel to LNG and others where LNG makes more sense.

The LNG fuel tank is a cryogenic tank and costly to manufacture. However, the advantage of LNG systems is that the density of the fuel is similar to that of gasoline and diesel, denser in volume than CNG by a factor of 600.[4] Because more fuel can be carried in LNG tanks than in CNG tanks, LNG is preferable to CNG for long-distance truck transportation; less time spent at refueling points means that trucks can stay on the road longer.

The problem with LNG, especially in Canada, is that there is presently a lack of facilities, and it is not a simple matter to make LNG available across the nation. Today in Canada, there are only three facilities capable of providing fueling services for transport trucks: one in British Columbia, one in Ontario, and another in Montreal.[5] All three are peak shaving facilities for electricity generation, so LNG refueling of trucks is not their intended business. Only one, the FortisBC facility in Vancouver, currently has regulatory approval to refuel trucks. In the future, if Canada's natural gas production increases and LNG export facilities are built, it is possible that these facilities could have truck refueling ports. However, that would enable LNG trucks to operate only within a certain

[4] Natural Gas Use in the Canadian Transportation Sector. Natural Resources Canada. December 2010. Page 11. http://oee.nrcan.gc.ca/transportation/alternative-fuels/resources/pdf/roadmap.pdf
[5] Ibid, Page 9

range of these port facilities, making LNG service throughout the country a difficult goal to achieve. It is worth noting that LNG truck traffic is increasing in countries such as Japan, India, and China, where coastal LNG facilities are commonplace.

CNG, on the other hand, is more readily available to the consumer because of the existing gas lines throughout the North American continent. In fact, there are some people, small in number, who have refueling facilities at their homes, and such a facility can be installed easily for a cost of about $5,000. CNG is also safer to use than gasoline because natural gas is lighter than air, and in case of a leak, the gas disperses easily into the atmosphere.

Conversions from gasoline to CNG are relatively straightforward and inexpensive. However, as alluded to earlier, the lower density of CNG makes the fuel practical for transportation across shorter distances where a large fuel tank is not necessary.

The Natural Gas Vehicle Situation in the US

There are several reasons why NGVs have not gained in popularity in the United States the way they have in other parts of the world. First of all, CNG infrastructure is minimal within North America. In other countries such as Pakistan and India, there have been large infrastructure development programs, and CNG refueling facilities have sprung up everywhere. However, in the United States, of the 1,300 established CNG facilities (serving 110,000 vehicles), more than half are not accessible to the public – designated instead for the refueling of fleet vehicles.

Governments in other countries have encouraged CNG use by subsidy: fuel price subsidies, fuel conversion kit subsidies, and NGV purchase subsidies. Attempts to implement similar policies in the United States have so far failed to capture the public imagination. For example, in 2008 in California, the electorate was presented with Proposition 10, a plan to subsidize the construction of CNG stations throughout the state and to offer discounts to people buying the vehicles; the plan was defeated, with 60 percent of people voting against it.[6] There is, nonetheless, a $4,000 federal tax credit in the United States available to NGV purchasers – among other modest state and local subsidies. Pending federal legislation could provide a significant boost to CNG, with customer rebates ranging from $8,000 to $64,000 on offer and a total of $2 billion in loans available to manufacturers.[7] There appears to be bipartisan support for this legislation, and it could pass in 2011.

NGV Cars in the US

For almost a decade, there has been only one model of car offered for sale in the United States that meets the criteria for the national tax credit: the Honda Civic GX. And this points to another reason why the North American public has not embraced NGVs. There is simply a lack of choice for vehicles. The Civic GX, even with the tax credit, is more expensive than the Civics that run on conventional fuel, and anecdotal evidence suggests that the GX does not perform up to the same standards as the other Civics.[8] The car also requires a home fueling apparatus, adding $5,000 to the cost of the vehicle, because of the scarcity of public CNG filling stations. All of that having been said, Honda is planning to double yearly production of the vehicle from 2,000 to 4,000 units over the coming two to

[6]Note that this plan was promoted by Texas oil tycoon T. Boone Pickens and a great deal of the opposition to the plan was political in nature, with much mistrust voiced over Pickens' motives http://articles.latimes.com/2008/sep/25/local/me-pickens25

[7] http://www.bloomberg.com/news/2010-11-17/u-s-natural-gas-vehicle-law-may-pass-congress-this-year-pickens-says.html

[8] http://www.hybridcars.com/news/honda-continues-cng-powered-civic-shadow-hybrids-and-evs-28596.html

three years.[9] The car manufacturer believes that new refueling infrastructure will be built outside of California, thereby expanding the market for NGVs. Indeed, this year GM has also begun building NGVs, offering customers an option to have CNG engines installed on the chassis of Suburban and Express models[10].

Why are Honda and GM optimistic about the future of NGVs in North America? NGVs have much going for them. Cleaner-burning natural gas engines generally last longer than gasoline engines with less maintenance required. NGVs run more efficiently than gasoline powered vehicles, with fuel costs as much as 40 percent less.[11] Carbon emissions are far lower for the NGVs than for diesel or gasoline engines, and in a world where carbon constraints are likely to increase, this is an important consideration. From an energy security point of view, with domestic shale gas production holding such tremendous promise as a future fuel source, it is almost assured that the United States could reduce its reliance on oil imports from foreign countries by introducing NGVs on a large scale throughout the country. Bipartisan support for CNG and LPG (Liquefied Petroleum Gas) development in both chambers of the US Congress indicates that funding will become available, meaningful manufacturing and purchase incentives will be put in place, and further infrastructure will be built.

US – What are the Next Steps?

At present, there are a number of calls to action for development of cleaner-burning fuel development. In 2008, former US Vice President Al Gore presented a plan to convert the country to 100 percent renewable energy by 2018. At about the same time, Texas oilman T. Boone Pickens presented "The Pickens Plan", a strategy to bring more renewables and domestically-produced hydrocarbons into the energy mix. President Obama has voiced support of the Pickens Plan and echoed Al Gore when he declared in 2008: "… for the sake of our economy, our security, and the future of our planet, I will set a clear goal as president: In 10 years, we will finally end our dependence on oil from the Middle East".[12]

The US has a considerable distance to travel in order to meet the goals of any of those plans within the next 7 to 8 years (the time remaining for President Obama's pledge to come to realization). The Energy Information Administration (EIA), in its early release of the 2011 Annual Energy Outlook, is not forecasting a sea change in the nation's use of energy over the next decade; after an initial post-recession period of solid economic growth, steady consumption or slow growth in consumption is predicted for various commodities including coal, oil, and gas until 2018 and more rapid growth expected for the period between 2018 and 2035.[13] This indicates that Vice President Gore's plan is untenable barring a sudden, dramatic change in policy direction and a rapid, radical rebuilding of the nation's energy infrastructure. President Obama could end dependence on oil from the Middle East either by sourcing crude elsewhere or by large-scale switching to alternative energies – or by some combination of the two.

---

[9]http://articles.latimes.com/2008/sep/25/local/me-pickens25p://www.hybridcars.com/news/honda-continues-cng-powered-civic-shadow-hybrids-and-evs-28596.html Downloaded December 19, 2010

[10]http://www.cngva.org/en/home/vehicles--stations/passenger-vehicles.aspx

[11]According to the USDoE, in January 2011, on a gasoline gallon equivalent basis, CNG cost $1.93, while diesel cost $3.09 and gasoline cost $3.08; CNG fuel costs, as of this writing, are approximately 37% less than either of these crude-based fuels. http://www.afdc.energy.gov/afdc/pdfs/afpr_jan_11.pdf

[12]Speech accepting the Democratic Party nomination as 2008 Presidential candidate. http://uspolitics.about.com/od/speeches/a/obama_accept.htm

[13]The EIA assembles its yearly energy outlook assuming no new policy direction or legislation. Thus, recently announced plans such as *The Proposed Rule for Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium-and-Heavy-Duty Engines and Vehicles* (EPA & NHTSA) and the *Corporate Average Fuel Economy (*CAFE) standards are not incorporated into the outlook, and they will not be incorporated until more plan specifics become available. Pickens Plan-inspired legislation is now under consideration by US federal lawmakers.

However, it is not a simple matter to find markets in other regions of the world to replace the approximately 5 MMbpd of oil that the US imports from the Middle East. And as noted above, the road to large-scale alternative/renewable energy is long. Achieving President Obama's energy goals appears more difficult with each passing day.

Pickens' Plan

However, this has not stopped T. Boone Pickens from offering to meet that goal. The Pickens Plan, as delineated on its website, provides a rationale for embracing alternative energy but lacks specific written detail on how to do it. On the site there is YouTube video footage of Pickens in interviews or presenting speeches, and it is in these video clips that most of the plan detail can be found. The plan is, first and foremost, a strategy to ensure security of domestic energy supply. Pickens tells Americans that by importing oil from the Middle East, or "the enemy", the US is funding both sides of the war in Iraq.[14] He also points out secondary benefits from replacing OPEC oil imports with other forms of energy, especially plentiful domestic natural gas: gas is cheaper per BTU than oil; establishing a much larger natural gas industry will promote US employment growth; there is little in the way of refining that needs to be done for natural gas; and, of course, natural gas combustion produces fewer emissions than gasoline or diesel fuel.

Pickens believes that the plan can be implemented and reach the goal of eliminating OPEC imports within seven years. Essential to this is to grab the "low hanging fruit" first, and the lowest, ripest fruit on the branch is the US trucking fleet. By converting the nation's "18-wheelers" to LNG or CNG, Pickens believes that requirements of OPEC oil could be reduced by 50 percent. The other 50 percent could be eliminated easily through conversion to gas of a percentage of America's other 250 million vehicles, not to mention replacement of gas and diesel powered vehicles to other energy sources; Pickens specifies batteries, hybrid power, ethanol, biofuels, propane, and butane.

It is beyond the scope of this study to discuss the geopolitical repercussions of the US moving away from Middle East oil, though it is highly likely that alternative markets for that oil could be found in places such as Asia and Europe. However, it is interesting to consider the implications for carbon emissions, natural gas production, and consumption if the Pickens Plan, or something similar, were implemented.

Following in Table 1 are the numbers Pickens uses to make his arguments as compared to 2009 Data from the EIA:

[14] See the videos on Pickens' website. http://www.pickensplan.com/#

Table 1
Pickens Plan Statistics Compared to EIA Data

Statistic	Pickens Plan	EIA[15]
US Oil Consumption	21 MMbpd	18.81 MMbpd
Percentage of World Production	25%	25.39%
US Oil Imports	13 MMbpd	11.691 MMbpd
US Oil Imports from OPEC	**5 MMbpd**	**4.776 MMbpd**
US Heavy Diesel Truck Fleet "18-wheelers"	8 million	8.65 million
Total oil consumption thru Heavy Truck Fleet	2.5 MMbpd	2.16 MMbpd
Total vehicles in US (besides heavy trucks)	250 million	231.34 million
Approximate Price of 1mcf Natural Gas	$5	$6.47
Approximate Price of equivalent diesel fuel	$21	$17.27

For the most part, Pickens' numbers resemble those of the EIA. However, he significantly underestimates the cost to the consumer of natural gas. The EIA shows that prices for natural gas vehicle fuel in the US have been trending upwards, from $7.16/Mcf in 2004 to $11.75/Mcf in 2008 (the last year for which prices were available at the time of this writing). For people with residential refueling capability, the average price for delivery in 2009 was $11.97/Mcf.

In 2009, the citygate average price, i.e., the price at the point where gas leaves transportation pipelines and moves into distribution pipelines, was $6.47/mcf. This number, it should be noted, takes into account the effects of the recession. Significant assumptions must therefore be made in order to visualize a future scenario in which Pickens' $5/mcf price occurs. First, it is necessary to assume that domestic shale gas will ultimately turn out to be as plentiful and as inexpensive to produce as gas companies now hope. Secondly, the infrastructure put in place over the next decade will need to contribute to a significant improvement in distribution efficiencies. Both the EIA and Pickens demonstrate that a price gap exists between natural gas and diesel/gasoline, but while Pickens claims natural gas to be about 25 percent of the price of diesel/gasoline, the EIA shows that natural gas is approximately 65 percent of the price of diesel/gasoline. Table 1 above assumes the 2009 city-gate price, giving Pickens considerable benefit of the doubt and a natural gas price that is roughly 37 percent of the diesel/gasoline price.

Challenges to Implementing the Pickens' Plan

In the United States today, there are 159,000 filling stations,[16] and according to the Diesel Technology Forum, 42 percent of those stations serve diesel – a total of 66,780 stations. The US highway infrastructure and Interstate system is vast – over 46,000 miles of Interstate freeways and 110,000 miles of other highways. In order to cover the lower 48 states and to continue to serve the trucking fleet as it has been served by diesel infrastructure, at least 66,000 stations will require either CNG or LNG fueling equipment or both. It is also important to take into account that CNG does not produce the same BTU's on a volume basis as diesel or gasoline, so long haul trucks will require extra fuel storage tanks, more filling stations, or a combination of the two. Consider that Pakistan today

[15] 2009 statistics
[16] http://tonto.eia.doe.gov/tools/faqs/faq.cfm?id=25&t=10

runs more CNG vehicles than any other country; consider also that Pakistan only has 2,600 filling stations to serve its NGV fleet and a comparatively smaller geographical area to cover than the US. The enormity of the task to convert US diesel infrastructure to natural gas therefore becomes apparent – nothing of this scale has been attempted elsewhere in the world. No matter the number of long distance trucks converted – whether it is the 8,000,000 that T. Boone Pickens suggests or half that number or ten percent of that number – the filling station infrastructure requirements will change little. If trucks are to reach the far corners of the country, natural gas facilities will be required wherever diesel facilities are now found.

There must be motivation for the transportation sector to switch from diesel to natural gas. Indeed, diesel could be legislated out of the marketplace. Tax rebates or subsidies are other options – incentives rather than government fiats – to remove some of the price hurdles.

Presently, trucking firms pay a premium of more than $40,000 for a long-haul natural gas vehicle. With the $64,000 tax credit to be offered through pending federal legislation, that would make up the price difference between the diesel and natural gas options. Then, coupled with fuel savings, natural gas trucks begin to appeal to customers. There is not right now any NGV resale market to speak of, though, and this causes problems for trucking companies that try, as part of their business strategy, to sell their trucks once the vehicles have reached a certain mileage threshold – thereby salvaging some value near the end of the trucks' lifespan. The resale market should develop as the above-mentioned incentives see success in growing the natural gas market, but as of today lack of a resale market is yet another reason why NGVs are difficult to market.

How many trucks will the US be able to manufacture and get on the road over the next 7 years? Presently there are a few North American manufacturers of large truck CNG and LNG engines: Paccar, Incorporated and Cummins Inc. build conventionally-fueled, hybrid, LNG and CNG engines for trucks like Kenworth and Peterbilt. Ford and its Volvo subsidiary are also in the business. Westport Innovations, Inc. is another notable company that specializes in hybrid, LNG, and CNG engines. But the market is still small: the EIA reports that in 2009 only 496 medium and heavy natural gas powered trucks were sold in the US.

This does not mean, however, that an entirely new industry has to be started from nothing or that the existing truck engine manufacturing industry has to be completely retooled. In fact, there are few differences between a CNG and a diesel engine. The CNG engines produced by Westport/Cummins, for example, are essentially diesel engines, built on the Cummins diesel platform. The manufacturer makes ignition system modifications (CNG vehicles require spark, whereas diesel engines operate with compression ignition), changes some fuel system parts, and alters the Electronic Control Module.[17] Otherwise, CNG and diesel engines are identical. LNG engines, too, are similar to conventional engines (though the fuel tanks are different). There is no reason to believe that production of NGV engines in North America and abroad cannot be ramped up in a short period of time if adequate incentives are provided. But the issue becomes, to what extent can production grow?

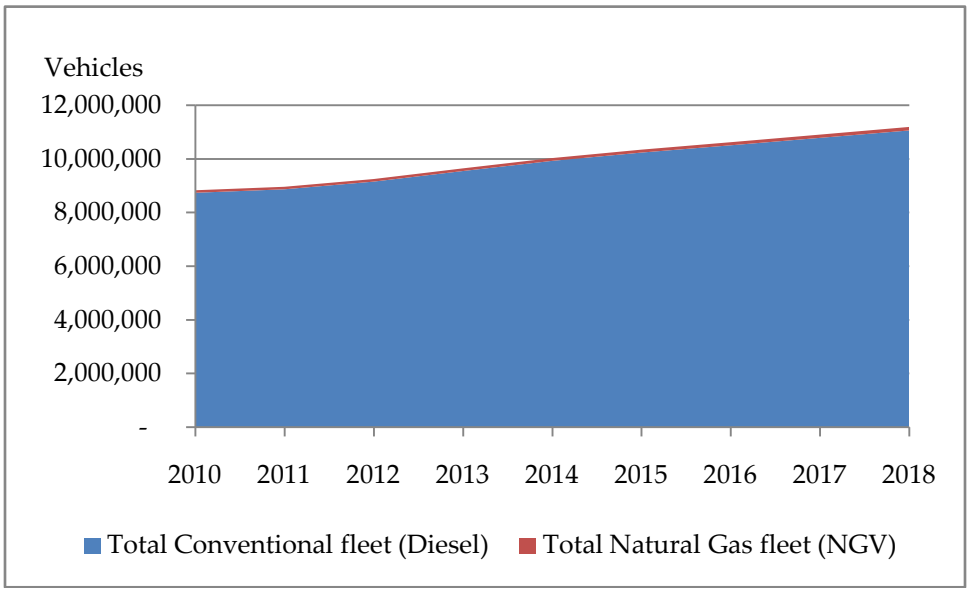
The Pickens Plan: A Quantitative Analysis

With this question in mind, we move to examining possible quantitative outcomes of the Pickens Plan, a strategy that demands very much very quickly in terms of production growth and infrastructure development. We have used the EIA's 2011 Annual Energy Outlook forecast as a baseline for examining the Plan. As stated earlier, the EIA

[17] http://www.cumminswestport.com/customer/faq.php

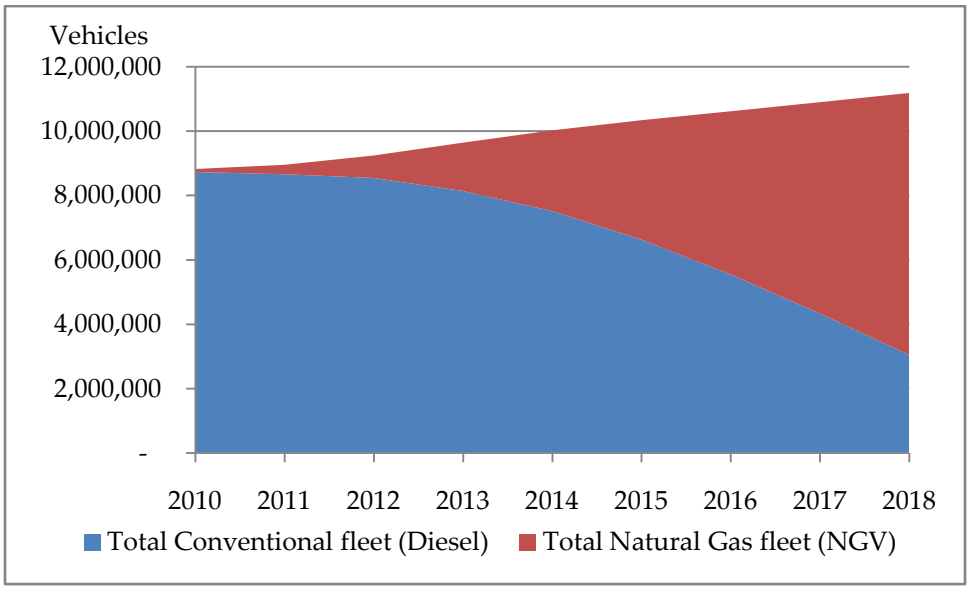
assumes no fundamental changes in policy; the report predicts slow, steady growth in medium and heavy long-haul (i.e., "18 Wheelers") transportation over the next eight years (see Figure 2). The trucking fleet grows from 8,860,000 vehicles in 2011 to 11,055,000 in 2018.

Figure 2
"18-Wheeler" Vehicle Fleet – EIA Scenario



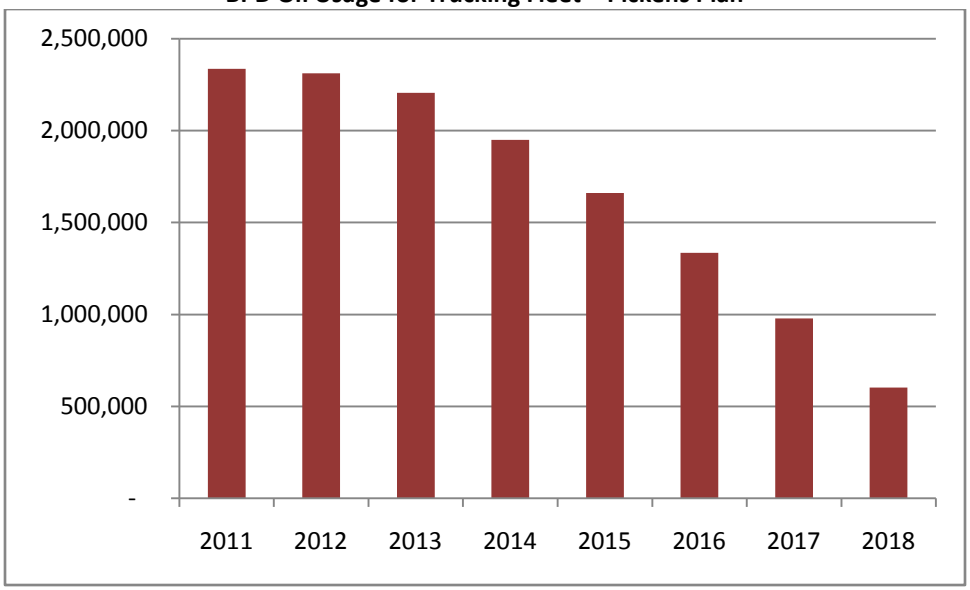
Recall that the Pickens Plan calls for the replacement of 8,000,000 diesel and gasoline-fueled long haul trucks with natural gas-powered vehicles within the next eight years. Rather than presume a straight line addition of 1,000,000 NGV trucks per year, we assume that in the early years only 5-10 percent of the 8,000,000 total could be realistically replaced but that the percentage would grow in later years as infrastructure is built and engine production is ramped up. We also use the EIA's estimate that the size of the overall fleet will increase over the next eight years to over 11,000,000 trucks. Thus, by 2018, under the Pickens Plan, dramatic changes occur: with 8,000,000 natural gas powered-trucks on the highways of America, the diesel fleet is reduced to some 3,000,000 vehicles (see Figure 3).

Figure 3
"18-Wheeler" Vehicle Fleet – Pickens Plan



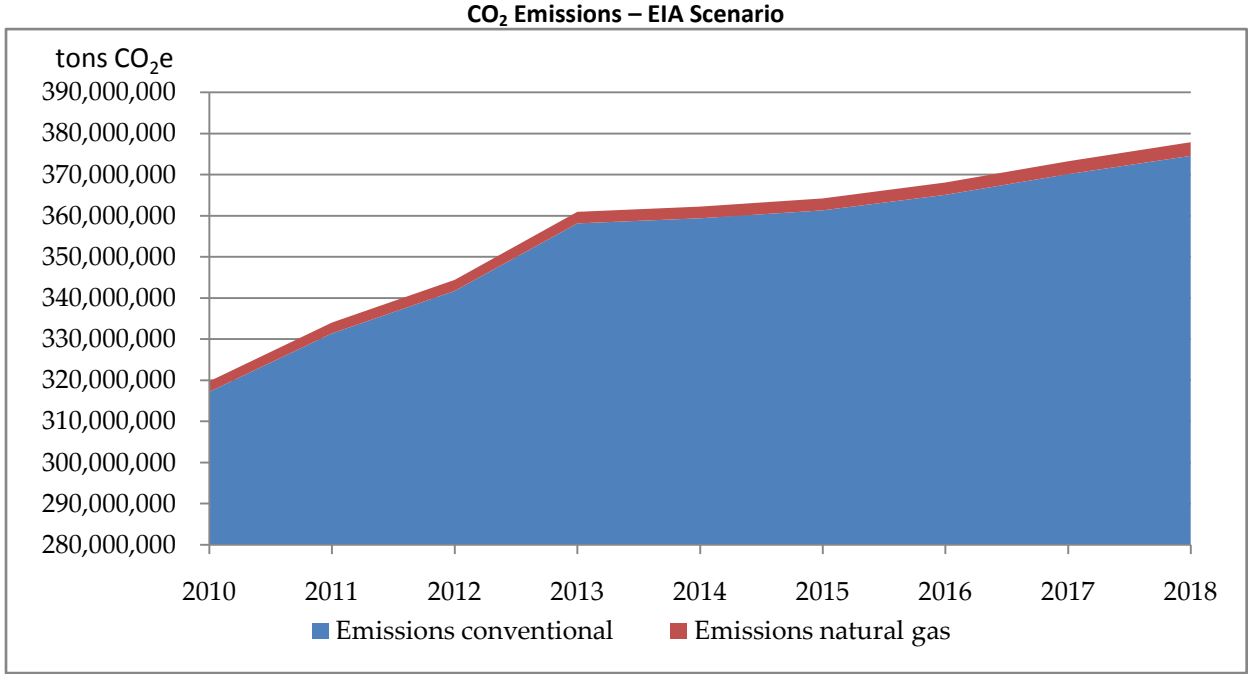
The Pickens Plan aims to eliminate 2.5 million bpd of oil usage through truck conversions, approximately half of the amount that the US imported from OPEC countries in 2008. Figure 4 shows that a more realistic figure is approximately 1.8 million bpd – short of the goal, but a substantial cut nonetheless. And as mentioned above, these cuts in oil usage are achieved with the total truck fleet numbers increasing to more than 11 million vehicles.

Figure 4
BPD Oil Usage for Trucking Fleet – Pickens Plan



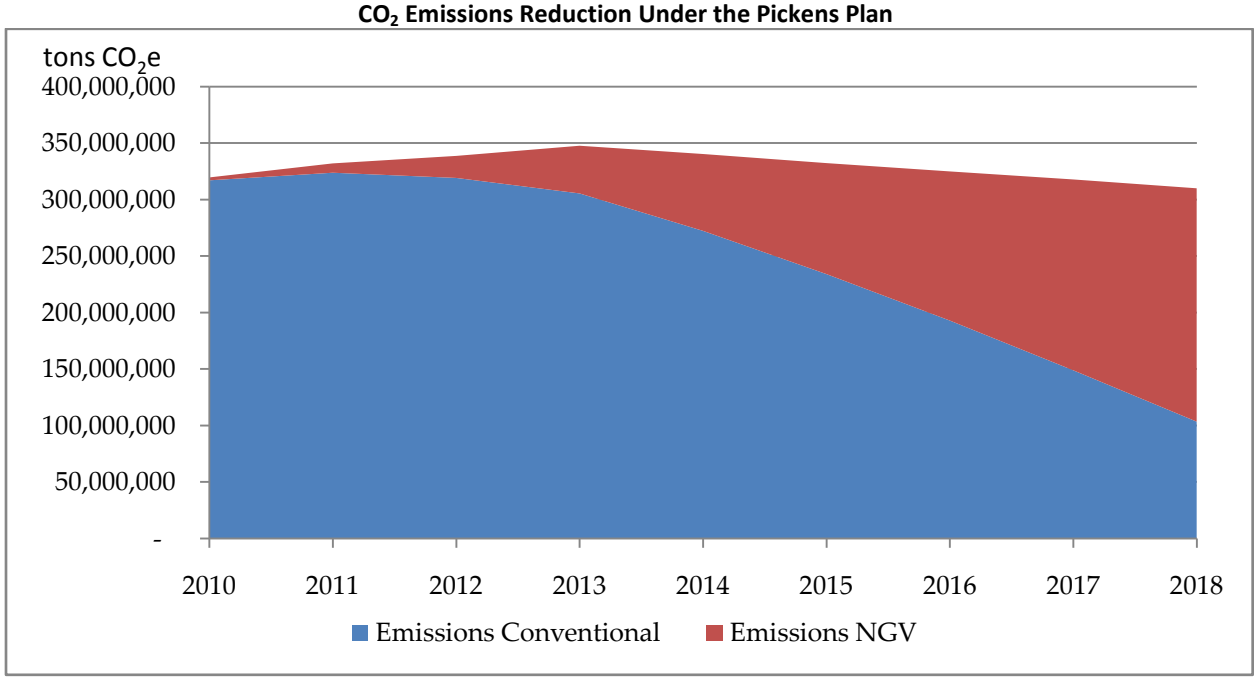
As shown in Figure 5, CO_2 emissions, according to the EIA baseline numbers, should grow at a quick rate until 2013, and then at a lesser pace until 2018. Note that natural gas emissions remain a small percentage of the overall CO_2 emitted by long-haul trucks over the time period.

Figure 5
CO_2 Emissions – EIA Scenario



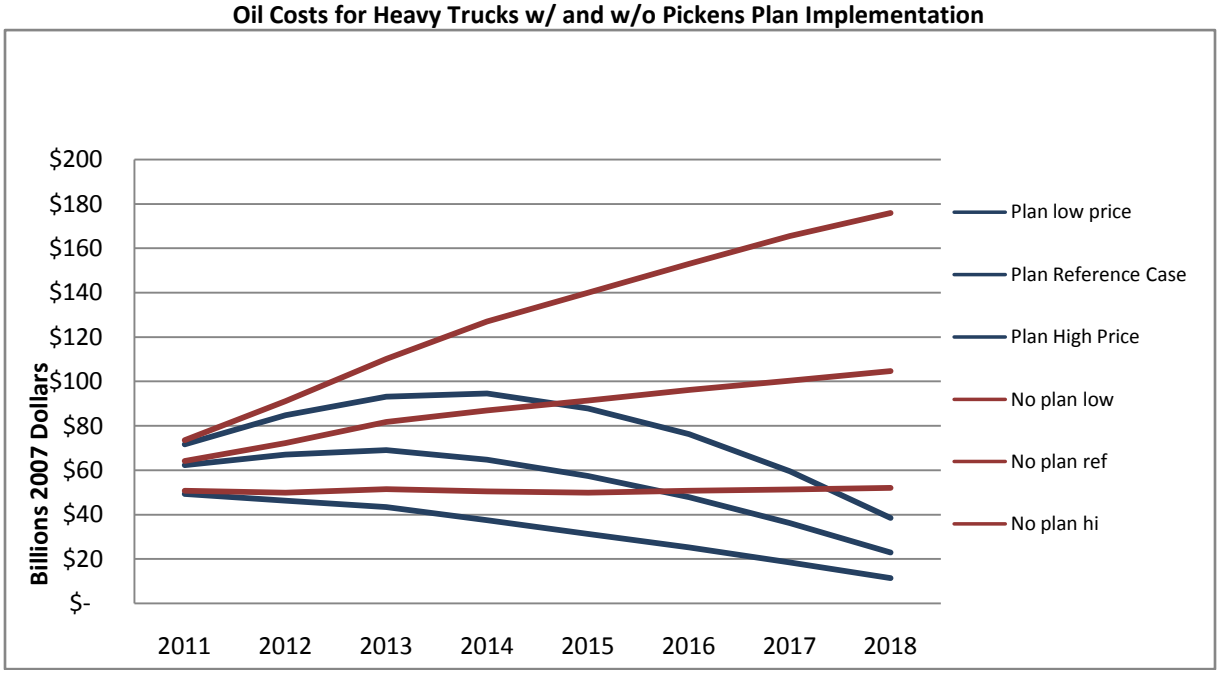
Under the Pickens Plan, emissions decrease significantly as the fleet converts to natural gas (Figure 6). By 2018, emissions levels with 11,000,000 trucks on the road are lower than the emissions levels in the last year of US economic growth prior to the recession – 2008 – when there were 8,700,000 trucks on US highways (310,000,000 tons CO_2e in 2018; 342,000,000 tons CO_2e in 2008).

Figure 6
CO_2 Emissions Reduction Under the Pickens Plan



Another area where the Pickens Plan would have a remarkable effect is on the amount of money spent on the oil supplies needed for refining into diesel fuel and gasoline to fuel heavy trucks (see Figure 7). According to IEA estimates on the future price of oil (estimates which vary significantly from high price case to reference case to low price case), with Plan implementation, oil costs could peak at $94 billion/year (in 2007 dollars) in 2014 but could fall to as low as $11 billion/year in 2018. The worst-case scenario after implementation of the Plan would be a bill for $38 billion oil supply cost in 2018.

Figure 7
Oil Costs for Heavy Trucks w/ and w/o Pickens Plan Implementation



Pickens Plan Contingencies

The Pickens Plan is bold, and it asks much of industry, government, and the public. It is entirely plausible that the Plan may not unfold as envisioned due to legislative compromise, public opposition, or a number of other possibilities. We have therefore examined other possibilities for conversion of medium and heavy gasoline and diesel trucks to natural gas, including replacing 6 million, 4 million, 2 million, and 800 thousand vehicles. In all cases, we use the EIA's vehicle growth rates for 2011-2018, and gradually bring the NGVs into the fleet the same way we did for the Pickens Plan – fewer vehicles in the early years and more in the later years. The results are as follows:

Oil usage would drop below 2008 levels (2.4 MMbpd) in all cases but one, as would be expected in any case where gasoline and diesel powered vehicles are being replaced by alternatively fueled vehicles (see Figure 8). But in terms of emissions (Figure 9), only the Pickens Plan and a plan replacing 6 million gas and diesel vehicles with 6 million natural gas vehicles would see trucking fleet emissions fall below 2008 levels by 2018. Because NGV CO_2 emissions are 70 to 75 percent of diesel or gasoline vehicles (we use 75 percent to be conservative in our estimates), and because the overall heavy truck fleet will increase over the next 8 years, overall emissions too will likely rise initially in all but the two most drastic scenarios – conversion of 6 million vehicles, or full implementation of the Pickens Plan with its conversion goal of 8 million trucks.

Figure 8
Oil Usage for Trucking Fleet

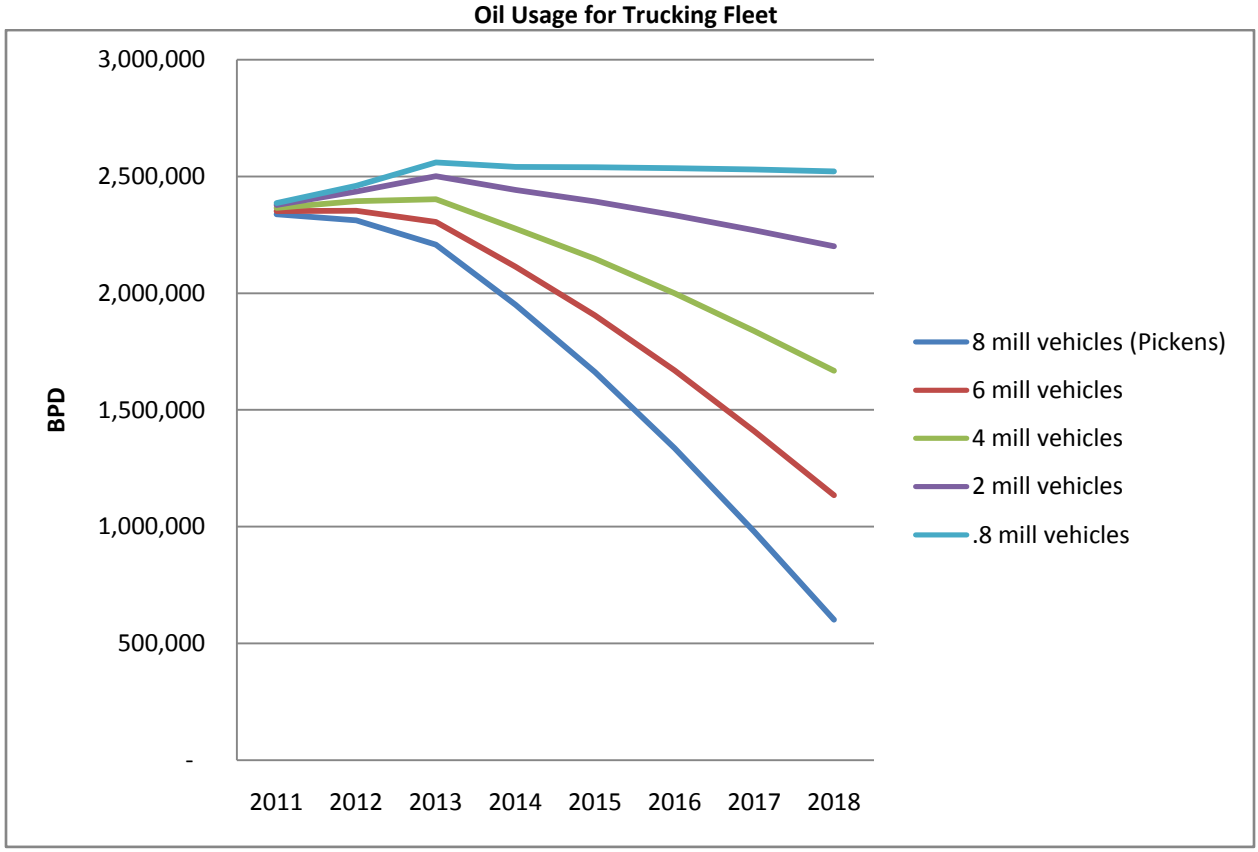
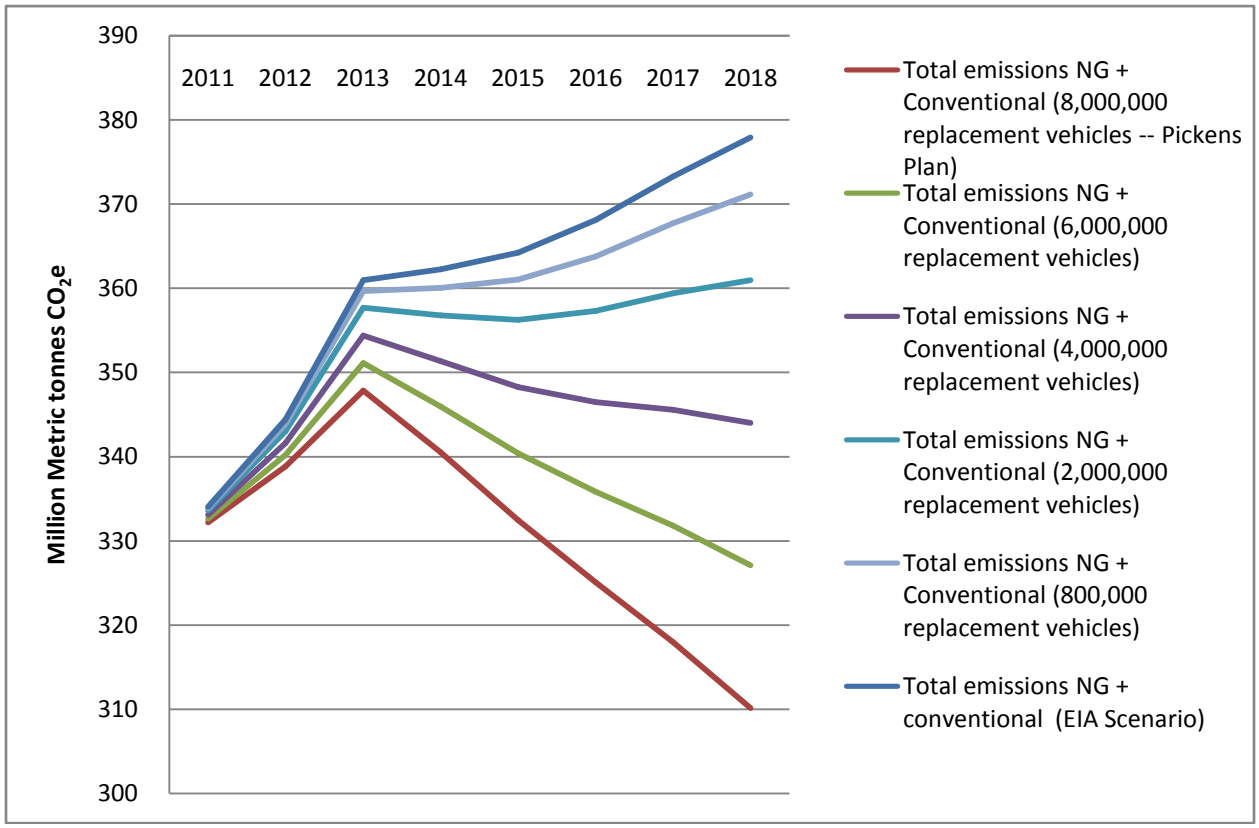


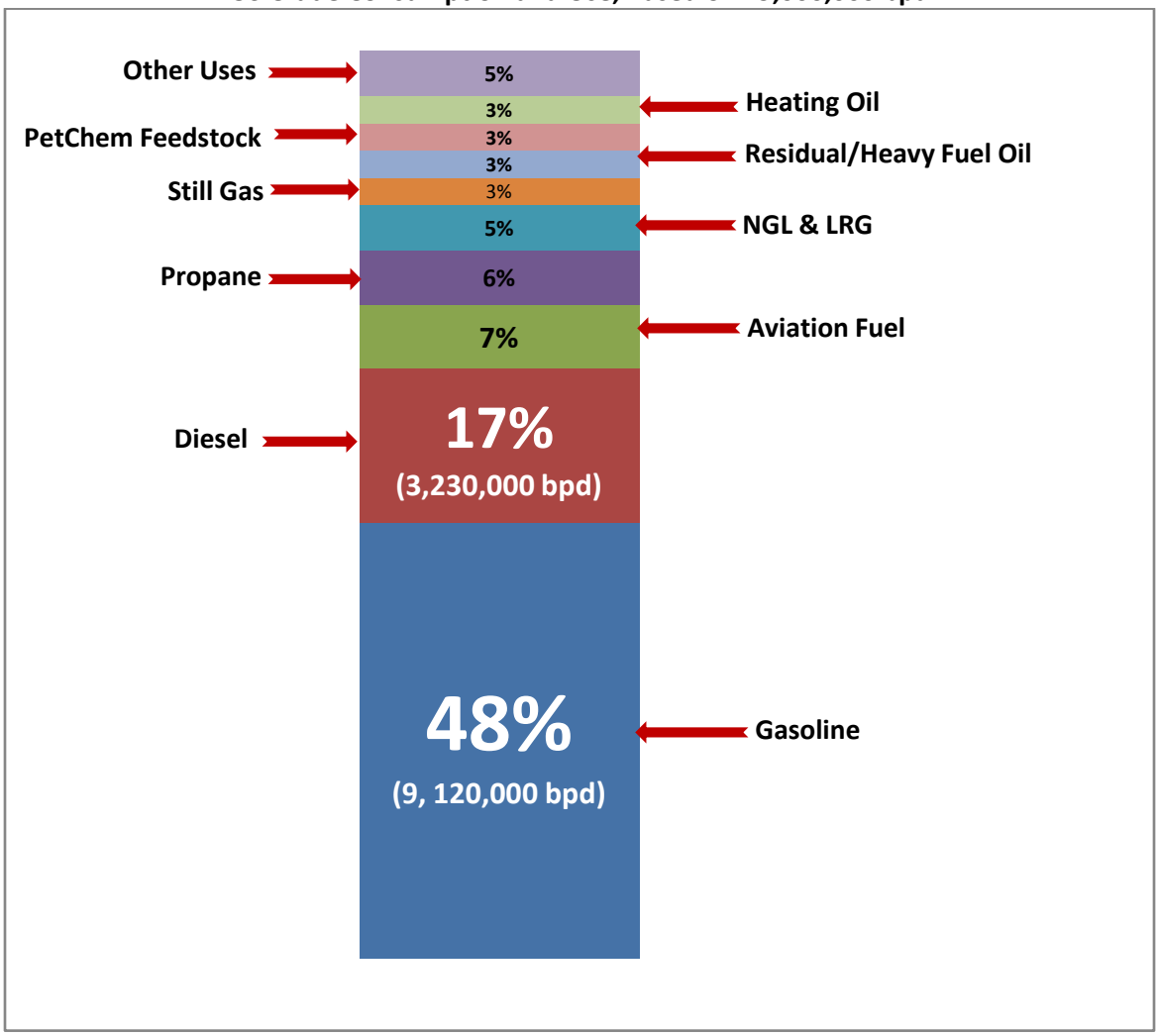
Figure 9
Emissions



It is worth noting at this point that as large as the US trucking fleet is, and as challenging the task of conversion to gas may be, the amount of America's total daily consumption of oil that is used for heavy truck transportation is in the range of 20-25 percent of the national total, depending on the year and the state of the economy. Figure 10 below assumes 19,000,000 bpd (2010 consumption was 19,100,000 bpd[18]) in US oil consumption from both domestic and foreign sources. Not only does this chart offer insight into the vast presence of petroleum in so many areas of the US economy, it also demonstrates that there are many areas beyond transportation where fuel switching could have a material effect on oil imports and emissions. As Pickens states, the large truck fleet represents the "low hanging fruit" but there is plenty more fruit higher up the tree.

[18] http://www.eia.doe.gov/emeu/steo/pub/contents.html

Figure 10
US Crude Consumption and Use, Based on 19,000,000 bpd



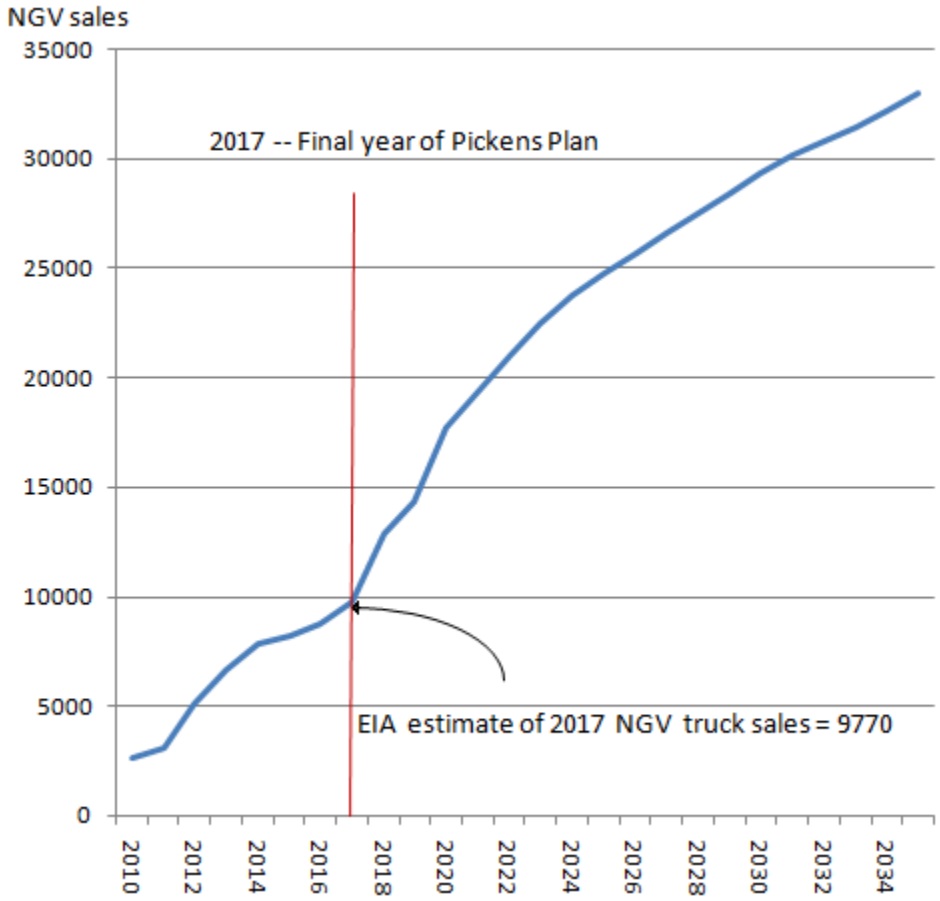
As of this writing, no major legislation has been passed by congress putting in place tax credits, subsidies, or other incentives to build NGV infrastructure and to manufacture natural gas engines or conversion kits on a large scale. T. Boone Pickens stated on his website that he expected such legislation to pass last year. He mentioned more recently that the American Petroleum Institute, in its current "State of American Energy" report, acknowledges the presence of vast reserves of shale gas in the continental US but does not mention conversion of the trucking fleet to NGVs.[19] Pickens attributes this to the API being run and financed by multinational energy companies with considerably more foreign (i.e., oil) than US (i.e., gas) interests. What this also suggests is that the Pickens Plan, as it stands, is not universally supported and that a watered-down version may be the only way for a natural gas vehicle-based energy plan to become accepted and implemented.

Without the implementation of a Pickens Plan, or something similar, the EIA nonetheless foresees growth in the purchase and usage of natural gas-powered medium and heavy trucks (see Figure 11). Over the next decade, sales

[19] http://www.pickensplan.com/boonecam/

of these vehicles are forecast to move from a total of 1,955 vehicles sold in 2009 to 9,770 vehicles sold in 2017. This is an increase of almost 5 times over the course of the decade but still nothing close to the number of sales required to see a total of 8,000,000 natural gas powered trucks traveling on US highways by the end of that time span.

Figure 11
EIA NGV Truck Sales Projections



The Natural Gas Vehicle Situation in Canada

Many of the same reasons why NGV popularity has remained low in the United States also apply to Canada. Technology has not always performed well in the past, and the costs to purchase and run NGVs have been higher than those to run gasoline or diesel vehicles. Infrastructure development occurred in the 1980s and 1990s, backed by governmental R&D support, and this helped establish many Canadian companies as world leaders in NGV technology.[20] However, the infrastructure has not been sustained, and today there are approximately 80 publically accessible CNG facilities remaining across the nation (there was at one point over 130) – almost half located in the metro-Toronto area. Most natural gas facilities in Canada no longer cater to the larger fleet vehicles, such as buses and trash collection trucks, as poor experience with older technologies caused the market for these vehicles to decline. As of 2010, there were approximately 150 transit buses and 45 school buses still operating on

[20] Natural Gas Use in the Canadian Transportation Sector. Natural Resources Canada. December 2010. Page 7 http://oee.nrcan.gc.ca/transportation/alternative-fuels/resources/pdf/roadmap.pdf

natural gas.[21] Inasmuch as there has been a recent market for natural gas-powered vehicles in Canada, it has been mostly a niche market: natural gas-driven ice resurfacers and forklifts are commonplace now because they offer a good solution to indoor air quality issues.

Two questions arise: Why was there at one point a concerted effort in Canada to develop infrastructure and increase NGV usage? And why after that initial effort did the entire NGV industry enter a period of decline?

The answers to these questions can be approached by examining the historical context. In the aftermath of oil price shocks in the 1970s and continued concern that physical supplies of hydrocarbons were limited, the world entered an era of heightened energy awareness. Canada was no exception, with the National Energy Program (NEP) of 1980 announcing a movement towards nationalization of Canada's oil and gas resources, nationwide energy conservation efforts, and encouragement to develop alternatives to traditional energy usage.

The early 1980s also presented an opportune moment for Canada to take advantage of its rich natural gas resources. World oil prices were high and natural gas held a considerable price advantage over gasoline and diesel. The NEP and other federal and provincial policies and programs supported NGV R&D over those years. However, as NRCan states in its Roadmap document, the precipitous drop and continued low oil prices over the 1980s and early 1990s caused the natural gas price advantage to fall, NGV costs rose as technology was changed to meet more stringent emission requirements, R&D subsidies and efforts declined, and public refueling station usage dropped as fewer new NGVs took to the road. In total, there are 12,000 NGVs operating on Canada's roads today, which is only about one third of the peak number in 1995 when 35,000 NGVs were in operation; today's Canadian total represents just over 10 percent of the current US total of 110,000 vehicles.[22]

In 2011 the time appears ripe for a new era of NGV development in Canada. Some of the historical arguments for NGVs have returned: once again a wide gap has opened between natural gas and crude oil prices, with gas now representing excellent value. Many experts believe that this spread will continue into the foreseeable future. Moreover, Canada's domestic gas situation is robust, with decline in the Western Canadian Sedimentary Basin being offset by exciting new British Columbia shale gas plays. Energy self-sufficiency is a means to mitigate the energy security risks that exist when energy is sourced from various regions throughout the world, and the abundance of natural gas is now providing a way for Canada to enhance its energy security risk position.

Environmentalism provided early impetus for North American research in the use of NGVs. Urban pollution was at all time highs in the 1970s with cities such as Lows Angeles notorious for poor air quality. Over time, measures were taken and technological solutions were implemented (elimination of lead in vehicle fuels, development of catalytic converters, for example) to improve the situation in both the US and Canada. R&D began on transportation alternatives, including battery, propane, hydrogen, and natural gas powered vehicles.

There remain today strong environmental reasons for Canada to consider these types of vehicles, but the reasons themselves have changed. As mentioned in the discussion on the US situation, the world is moving towards an era of carbon constraints – mid-century carbon reduction recommendations as outlined by the IPCC and other organizations, are stringent, and if they are to be met will require a massive change in the way society uses fossil fuels and alternative forms of energy. Moving from gas and diesel to other fuels, including natural gas, is one way

[21] Canadian Natural Gas Vehicle Association. www.cngva.org
[22] International Association of Natural Gas Vehicles. http://www.iangv.org/tools-resources/statistics.html

to lessen the impact of that change. Governments throughout Canada are recognizing the need to start to take action, so Quebec now offers tax breaks for LNG trucks, and British Columbia has legislated the *Clean Energy Act*, which also encourages natural gas use.[23] If, as has happened in the past, the Canadian federal government plans to follow the United States in environmental legislation, and if Pickens Plan-style legislation is passed in the US, a resurgent natural gas vehicle industry will be a likely, even inevitable, outcome.

Canada – What are the Next Steps?

Motivation within Canada to convert vehicles to natural gas has differed from the motivations driving the Pickens Plan. Pickens puts forward a national security argument first and foremost, making the assertion that America is funding both sides of the Iraq war. Pickens also argues for the development of an All-American natural gas industry. Further down the list are references to lower fueling costs for consumers and overall emissions reductions. In essence, the Pickens plan is an appeal to the American people, a challenge to find ways to meet a specific target of 8 million NGV trucks by 2017. The goal is clear. The means are vague, but the assumption is that those details can be worked out along the way if the abilities and know-how of the American people are engaged.

In Canada, just as in the US, there has been interest in expanding NGV usage throughout the country. Rather than looking to implement the ideas of one or two energy visionaries, though, in Canada there has been a consensus-based approach, with the federal government acting as facilitator, to assemble a national NGV plan.

In December 2010, the *Natural Gas Use in the Canadian Transportation Sector Deployment Roadmap* was published by Natural Resources Canada.[24] These results came after a roundtable was conducted earlier in the year by the Deputy Minister of Natural Resources Canada, a forum that included federal and provincial government officials, industry representatives and end-user groups, environmentalists, NGO's, and members of academia. This group offered the following four-point rationale for the Canadian transportation sector to switch to natural gas from Crude Oil–based fuels:

1) **Diversify fuels**. Increased natural gas usage will serve to diversify the fuel supply for the transportation sector; 99 percent of its present fuel supply is crude-based.
2) **Reduce vehicular impact on the environment**. Natural gas vehicles emit substantially less GHG's than diesel or gasoline, thereby reducing the impact that vehicular transportation has on the environment. In a country where GHG's have increased 26 percent between 1990 and 2006, and 90 percent of that increase is attributable to vehicular transport, cars and trucks are a highly visible reminder of the growing problem of pollution.[25]
3) **Take advantage of plentiful gas**. Natural gas has almost always traded at a discount to oil in terms of energy content; presently, natural gas offers exceptional value as the spread between gas and oil has widened over the past few years. Canada holds vast deposits of gas.
4) **Meet carbon goals**. As legislated carbon constraints begin to be applied to the transportation sector, increased gas usage can help satisfy the new regulations.

Though overall Canadian national security and the nation's energy security are implicit concerns in all aspects of this rationale, especially the first and third points, these are not the primary motives expressed by the Canadian

[23] NRCan (2010).
[24] The Roadmap may be accessed at http://oee.nrcan.gc.ca/transportation/alternative-fuels/resources/pdf/roadmap.pdf
[25] Globe and Mail. March 10, 2011. "Convenience, cost, and just a little bit of conscience". Page A10

government or the other roadmap stakeholders. There has been overall agreement among a variety of Canadian individuals, companies, governments, and other organizations on a way forward for gas, indicating a national plan may be effectively implemented in the foreseeable future.

The Roadmap

The first paragraph of the Roadmap's Executive Summary states the reasons why the roundtable was struck in the first place – it was essentially an exercise in risk mitigation: "Unlike most other sectors of the Canadian economy… transportation relies on a single energy source (crude oil-based fuels)" (ix). With increasingly loud calls from Copenhagen and elsewhere to reduce worldwide carbon emissions, Canada was feeling pressure to do so. Add to that the recent growth in Canada of proved gas supply, thanks to improved shale gas recovery techniques, and it appeared to be the right time to address the issue of transportation's singular dependence on crude oil. As alluded to earlier, the world geopolitical situation, while important, was not a primary factor in the Canadian decision to start a serious discussion on natural gas, differing in that key respect from other recent proposals such as President Obama's call to end reliance on oil from the Middle East and the even more assertive nationalism inherent in the Pickens Plan. The goal of the Roadmap is simply "to identify the optimal use of natural gas in Canada's transportation sector"(2).

Moving from rationales to plan mechanics, however, the Canadian Roadmap is similar to the Pickens Plan on one essential point: both strategies envision conversion of the heavy trucking fleet as central to any meaningful new use in the transport sector of the domestic gas resource. The Roundtable examined the potential for increased natural gas use in a number of vehicle segments, including "light-, medium-, and heavy-duty vehicles, as well as marine vessels and locomotives", and their criteria were "technology availability, market potential, environmental benefits, energy use, and economic impact" (5). Their conclusion, like Pickens' conclusion about the US, was that medium and heavy duty vehicles hold the greatest potential within Canada for conversion to natural gas fuel.

The Roadmap is different because it does not propose conversion for the heavy truck fleet nationwide, as Pickens advocates. Instead it sees a better prospect in a "focus on return-to-base and corridor fleets". This is a plausible solution to the infrastructure problem. If natural gas infrastructure is first built along the country's busiest trucking corridors, and not throughout the rest of Canada, costs are better controlled. Furthermore, this is the direction that trucking in Canada is taking in general: "over the past decade, the structure of the trucking industry has swung increasingly toward return-to-base operations as opposed to long distance hauling" (NRCan 23). Radically new business models do not have to be designed and developed in order for NGVs to move into the existing trucking industry. It should be noted, however, that further study of traffic in Canada's main transportation corridors is required: "There is no data available that identifies what portion of Canada's medium- and heavy- vehicle population operates in return-to-base mode or along regional corridors" (44).

An important element of the Roundtable's report is the value proposition analysis, a task that was assigned to Change Energy, Incorporated and Sproule Forecasting, companies that hold a proprietary lifecycle costing model and a forecasting model, respectively. The Change Energy model combines all "incremental operating and capital costs, as well as any differences associated with engine efficiencies and operating practices". The model calculates all natural gas costs – everything from fuel costs to fueling station amortization – and compares them to diesel fleet ownership costs (19-20). This provides analysts with Fuel Value Index (FVI), a simple tool to compare applications. Any NGV application with an FVI below 1 compares less than favorably with the same diesel application; any NGV application with an FVI higher than 1 compares favorably with diesel. The study was limited

to vehicles operating in return-to-base and regional corridor fleets, and the areas under consideration were the four major provinces in which major trucking corridors exist: Ontario, Quebec, British Columbia, and Alberta.

The Roundtable determined the top 13 applications in Canada for NGVs as follows:

TABLE 3 Application Ranking Table

APPLICATION	FLEET SIZE	MILEAGE (km/YEAR)	RANK	COMMENTS (FVI RANGE)
LNG Highway Heavy Tractor RTB	Large – 200	200,000	1	Very Good 1.01–1.63
LNG Urban Heavy Tractor RTB	Large – 200	140,000	2	Very Good 0.90–1.45
LNG Highway Heavy Tractor COR	Large – 200	200,000	3	Very Good 0.89–1.43
CNG Transit Bus RTB	Large – 150	55,000	4	Very Good 0.84–1.29
CNG Refuse – Private RTB	Large – 100	30,000	5	Good 0.70–1.04
CNG Urban Heavy Tractor RTB	Large – 200	60,000	6	Good 0.70–1.03
CNG Vocational – High-Use RTB	Large – 100	50,000	7	Fair 0.65–1.01
LNG Port Drayage RTB	Large – 200	60,000	8	Fair 0.63–1.03
CNG Refuse – Public RTB	Large – 100	20,000	9	Weak 0.48–0.85
CNG Vocational – Medium-Use RTB	Large – 100	30,000	10	Weak 0.45–0.74
CNG School Bus RTB	Large – 100	15,000	11	Very Weak 0.31–0.61
CNG Port Drayage RTB	Large – 200	20,000	12	Very Weak 0.31–0.57
CNG Vocational – Low-Use RTB	Large – 100	15,000	13	Very Weak 0.23–0.46

Ranking categories relative to average FVI values:

FVI > 1.05 Very Good
FVI > 0.85 but < 1.05 Good
FVI > 0.75 but < 0.85 Fair
FVI > 0.60 but < 0.75 Weak
FVI > 0.60 Very Weak

The fleet sizes and mileage assumed for the above applications were used for modelling purposes and may vary among fleets.

Source: Change Energy Inc. (2010)

The above Table shows that the top 6 applications have an FVI range that is comparable to the diesel value proposition. LNG return-to-base heavy tractors that travel primarily on highways (FVI range between 1.01 -1.63) can compete with diesel in all circumstances accounted for within the proprietary model, while the other five can compete with diesel only under certain circumstances.

However, the above table is based on a 10-year timeline; it is common practice for trucking fleets to sell vehicles in 3 to 5 years after initial purchase in order to recoup some of the initial investment. Bearing this in mind, the Roundtable produced the following table with 5 and 10 year IRR values and payback times to be expected in British Columbia:

TABLE 4 IRR Summary for "Very Good" Ranked End-Use Applications (British Columbia, 2011)

FVI RANKING	APPLICATION	FLEET SIZE	CAPITAL INVESTMENT	5-YEAR	10-YEAR	PAYBACK (YEARS)
1	LNG Highway Heavy Tractor (return-to-base) ($0.80 million station; $2.05 million vehicle increment)	30	$2.85 million	48%	58%	1.77
2	LNG Urban Heavy Tractor (return-to-base) ($4.13 million station; $13.66 million vehicle increment)	200	$17.79 million	18%	30%	3.10
3	LNG Highway Heavy Tractor (corridor) ($5.78 million station; $13.66 million vehicle increment)	200	$19.44 million	19%	32%	2.98
4	CNG Transit Bus (return-to-base) ($3.06 million station; $6.75 million vehicle increment)	150	$9.81 million	0%	13%	7.32

Source: Change Energy Inc. (2010)

According to these figures, the top three highway applications for NGVs all offer payback either before or well within the 3 to 5 year timeline that most trucking companies keep their vehicles. This is a strong endorsement for the value proposition of natural gas trucks, assuming the British Columbia statistics can be extended to the rest of Canada.

There are already some small-scale, real-life examples of natural gas vehicles demonstrating their value. EnCana and Enbridge, two major natural gas producers, have converted much of their own return-to-base truck fleets to natural gas. According to Oilweek, Enbridge has been running 95 percent of its own fleet on natural gas for over 20 years, converting its vehicles with aftermarket natural gas conversion kits. They see payback between 1.5 and 3 years on those investments, mostly through fuel cost savings. EnCana has established both private and public natural gas filling stations and is growing its natural gas fleet: "EnCana has its business units buy the trucks. The internal rate of return on the vehicles is between 20 and 30 per cent… a 50-100 vehicle filling station can cost anywhere from $900,000 to $1.4 million… the price per litre comes to 20-40 per cent less than gasoline."[26]

Challenges to Implementing the Roadmap

With both NRCan's theoretical work and the practical experience of companies like Enbridge and EnCana demonstrating the present day economic feasibility of NGVs – feasibility that comes before any widespread implementation of carbon taxes which will, presumably, make NGVs even more economically attractive – what is preventing the transportation sector from fully embracing these vehicles? NRCan makes a compelling case for market failure in Canada's transportation sector, or, at least some formidable barriers to entry for natural gas vehicles. They list four conditions as being necessary for market failure: perceived risk associated with early adoption, imperfect information, lack of choice, and externalities (39). In fact, all four of these conditions are present in Canada today (and the US, for that matter), and at least the first two conditions point to a lack of education about the vehicles rather than any kind of inefficient use of financial resources; participants in the marketplace need to know what they are getting into before money will be spent.

NRCan recommends, therefore, "market intervention by a range of stakeholders, including governments, industry, and other key organizations" (44). The tools at stakeholders' disposal are:

[26] Oilweek, March 2011. "Natural Selection" p. 46-47.

1) Fiscal measures such as tax measures and cash rebates
2) Regulation such as fuel economy and GHG regulations, and low carbon fuel standards
3) Information – top-down educational strategies such as information provided through websites, and bottom-up educational strategies such as informational "hubs," networks of people tasked to provide educational support and education to targeted audiences in specific regions
4) Research, Development, and Demonstration (RD&D) such as the National Renewable Energy Laboratory's Natural Gas Engine Research and Development Program.

These measures are required to move NRV's into Canada's trucking corridor over the short term. Long term feasibility will depend in large part on how policy develops – if, for example, diesel is legislated out of the marketplace because of emissions concerns, natural gas will take its place. If a laissez-faire approach to energy policy is taken, then the relative price of natural gas to diesel will determine the long term competitiveness of both fuels.

NGV Market Potential in Canada

NRCan is conservative in its estimates of NGV total market penetration over the next decade. While across the border T. Boone Pickens calls for a replacement of the entire US heavy trucking fleet, NRCan proposes a 10 percent NGV medium- and heavy- truck penetration rate in Canada in order to meet Canada's 2020 GHG emissions goals. NRCan states that a 15 percent penetration rate would increase natural gas use by 122.5 bcf/year, which is about 6 percent of the nation's natural gas total use in 2009 (44).

TABLE 2 Estimated NGV Market Potential in Canada

ANNUAL NG TRUCK SALES AS % OF TOTAL SALES	TOTAL NG VEHICLES OVER 10 YEARS	ENERGY USE (THOUSANDS DLE)	ENERGY USE (Bcf)	ANNUAL GHG BENEFIT (Mt CO_2e)
1%	3,599	238,668	8.2	0.1997
3%	10,796	716,003	24.5	0.5992
5%	17,994	1,193,338	40.8	0.9986
7%	25,191	1,670,673	57.2	1.3981
10%	35,987	2,386,676	81.7	1.9973
15%	53,981	3,580,014	122.5	2.9959

1. Assumed 70 percent Class 8; 30 percent Class 3–7 based on historical split in sales.
2. Fuel use for Class 8 estimated at 78,800 diesel litres/year @39.4 DLE/100 km.
3. Fuel use for all other estimated at 37,300 diesel litres/year @ 62 DLE/100 km.
4. Carbon benefit based on GHGenius values of 25 percent for Westport LNG system and 18 percent for Cummins Westport engine.
5. Class 8 estimated 200,000 km/year and 72-tonne GHG reduction.
6. All other medium-and heavy-duty vehicles estimated at 60,000 km/year and 17-tonne GHG reduction.

Source: Calculated based on data from Canadian Vehicle Manufacturers Association and GHGenius (version 3.16b)

Conclusions

NGVs in the United States

The Pickens Plan is epic in scope and fearless in its approach to the great energy problems of the day: energy security, diversification of fuel sources, and emissions. It also promises development of a stronger US-based natural gas industry and a new dawn for domestic vehicle manufacturing. However, there is too much going against the Pickens Plan, especially the portion that concerns NGVs, for it to be implemented in its present form – a replacement of 8,000,000 diesel or gasoline-fueled heavy trucks by 2017. Pickens' original geopolitical justification is certainly subject to debate, but that is only part of the issue. Many other items must fall into place before the plan could ever work:

a) policy must be developed and comprehensive legislation passed, yet this is not a simple task as the failure of Proposition 10 in California indicates.
b) Related to policy and legislation are carbon price instruments, long a spur for alternative energy R&D in Europe and elsewhere. They could serve a similar purpose in the US, but carbon taxes exist only at the municipal and county levels; no overarching state- or federal-level instruments are in place within the US, and do not yet appear to be in the offing.
c) Fuelling infrastructure must be built, but to date, little has been done in this area; blanket coverage of the lower 48 states by LNG and CNG facilities is a daunting prospect, the likes of which has never been attempted before.
d) Though NGV engine manufacturing exists and conversion kits are available, supply capability must be ramped up significantly. To move from the yearly manufacture of hundreds of NGV engines to hundreds of thousands, or even millions, is not possible without massive external support. This level of support does not yet exist in the US.
e) An educational plan and various incentives need to be implemented in order to change the mindset of industry and the public towards NGVs. No NGV industry can ever be built unless tax incentives and rebates are in place to remove the very high financial barriers to entry. People also need to understand the trade-offs and benefits of NGVs before they can be expected to embrace the technology and invest in it, making education a fundamental prerequisite.

The Pickens Plan is more of a call to arms than it is a considered, fleshed-out national energy strategy.

The other significant plan under analysis in this report, NRCan's *Natural Gas Use in the Canadian Transportation Corridor*, is almost a polar opposite to the Pickens Plan — it does not pretend to be all-encompassing but instead offers a detailed strategy for the Canadian transportation sector, backed by considered quantitative analysis; however, NRCan's work has not captured the public imagination in Canada to the same extent that the Pickens Plan has done in the US. The Roadmap suggests policy options to governments and recommendations to industry in order to mitigate early investment and adoption risk. It offers business modeling, education and outreach analysis, and R&D proposals. The Roadmap also defines roles for all major stakeholders in the process. What it does not provide, however, is the element of human persuasion that a Pickens Plan affords, the force of personality that can drive forward even the most flawed and under developed of strategies.

The great insight, the idea that brings feasibility to NGV development in Canada, is the Roundtable's recommendation to introduce NGVs to certain busy transportation corridors – as opposed to comprehensive NGV coverage over the entire nation. The Roundtable notes that there is a trend within the transportation industry to realize efficiencies through return-to-base operations rather than long haul trucking. In terms of IRR, the Roundtable affirms that the 8 top-ranked applications all involve return-to-base or corridor operations. Infrastructure either exists already or can be developed and used optimally for these purposes. For each of the 4 top-ranked applications, there is a strong case for NGV corridor infrastructure development being a solid investment, preferable to the existing diesel infrastructure (22).

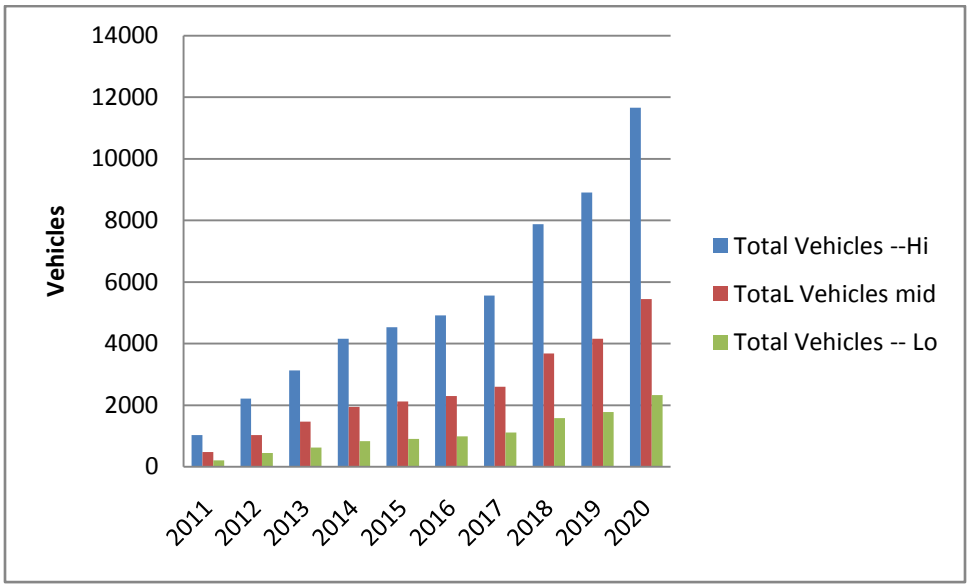
The Roundtable states that "there is no data available that identifies what portion of Canada's medium-and heavy-duty vehicle population operates in return-to-base mode or along regional corridors". Studies have been conducted in the US, but the most recent, a study of the I-10 corridor, was undertaken in 2003, almost a decade ago. Further research is required to quantify with detailed accuracy any future transport needs for these corridors. For that reason, this study deals with national averages rather than with corridor-specific information to reach some general, independent conclusions on the feasibility of NGV adoption to the US and Canadian medium- to heavy- trucking fleet.

The US, like Canada, sees heavy truck traffic in various corridors. The Lows Angeles-to-Chicago corridor is a significant long-haul route, through which a substantial amount of goods moves every year.[27] Los Angeles, through its port, acts as a major access point to Asian manufacturing and markets. Chicago, on the other end of the corridor, serves as a hub for the entire northeast US. There is another cross-country corridor serving the south, the I-10, which stretches from California, through Texas and the Gulf Coast states, ending in Miami, Florida. Other shorter corridors, such as the I-5, serving the states of Washington, Oregon, and California, and the northeast corridor between Boston and New York, see steady and dense truck transport traffic on a daily basis. The above corridors already see sizeable return-to-fleet traffic and are prime candidates for NGV infrastructure establishment.

To analyze the possibilities for NGV penetration in Canada, we refer to the Roadmap, and have developed three scenarios: High, Mid (base case), and Low. NRCan's highest estimate for NGV truck presence on Canada's roads is a 15 percent market penetration. For the base case scenario, we take 7 percent market penetration, and for the Low case we presume 3 percent penetration. The maximum number of vehicles added to the nation's trucking fleet would be an average of about 5,000 per year in the High case scenario, and the minimum would be just over 1,000 in the Low case scenario (see Figure 12).

[27] NCHRP Report 399: Multimodal Corridor and Capacity Analysis Manual. National Cooperative Research Highway Program. Transportation Research Board. National Research Council. 1998.

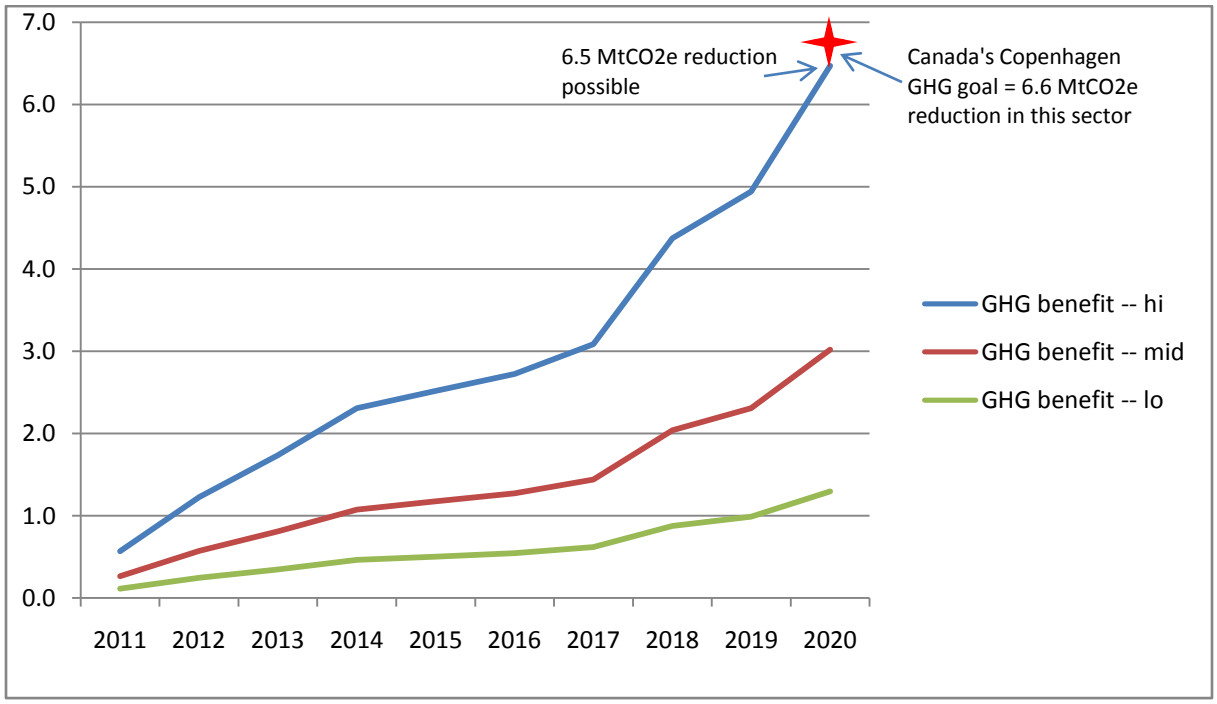
Figure 12
NGV Truck Estimates - Canada



For diversification of fuel, a stated aim in the Roadmap process, the High case would see NGV trucks consume an average of 122.5 bcf of natural gas per year over the next ten years, which "represents about 6 percent of Canada's 2009 domestic natural gas consumption (44)". Assuming a modest yearly increase in penetration, consumption could be as low as 23 bcf/year in 2011, increasing to as much as 246 bcf by 2020. The Mid and Low cases would not make anywhere near as strong an impact on fuel diversification, with yearly averages of approximately 57 bcf/year and 24.5 bcf/year.

Canada's Copenhagen GHG goal, the same goal agreed to by the US, is to lower overall GHG emissions by 2020 to 17 percent below 2005 levels. Only in the High market penetration scenario does Canada approach its medium and heavy truck emissions target, as Figure 13 indicates.

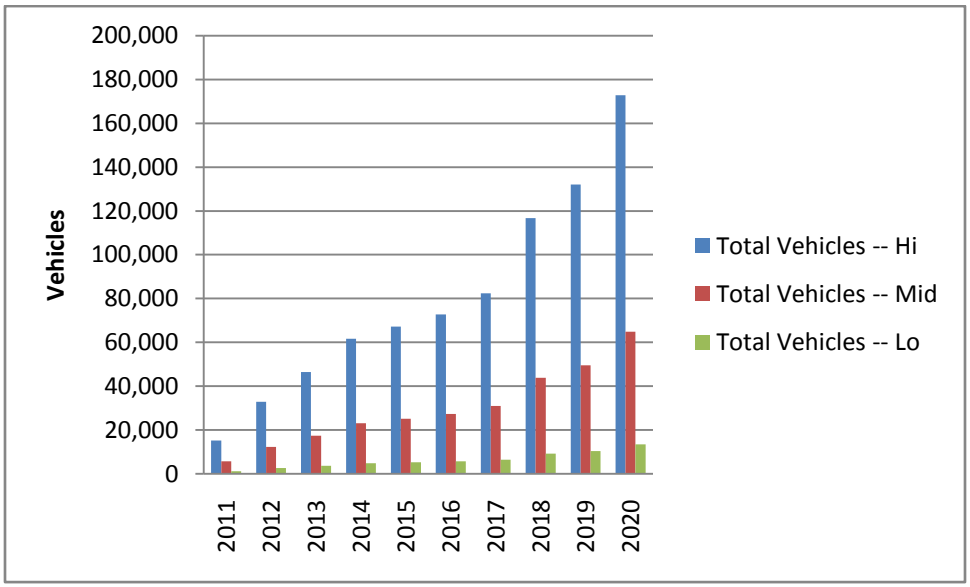
Figure 13
NGV Truck GHG Benefits - Canada



For the High case scenario in the United States, we consider a NGV market penetration of 10 percent of a total of 8,000,000 medium and heavy trucks – 800,000 NGV vehicles entering and staying within the transportation system over the next decade. This represents less than 10 percent of the Pickens Plan market penetration (which is scheduled to be fully implemented before 2018 instead of 2020). For the Low case scenario, we use the EIA estimates of market penetration to 2021, a very conservative assessment that does not provide for any possible legislative change during the forecast period. The EIA foresees a total of 62,785 NGV entering the transportation system over the next decade for a much more modest market penetration rate – only about 7 percent of the High case scenario.[28] As a Mid, or base case scenario, we estimate a total of 300,000 natural gas powered trucks in use on US highway corridors over the next decade (see Figure 14).

[28]We base this analysis on EIA estimates of new vehicle sales, assuming that original NGV owners will hold their vehicles for 4 to 6 years and subsequent owners will keep their vehicles in service for an additional 4 to 6 years. Thus, over the next decade, we assume 100% of all NGVs sold will remain road worthy and in use.

Figure 134
NGV Truck Estimates – United States

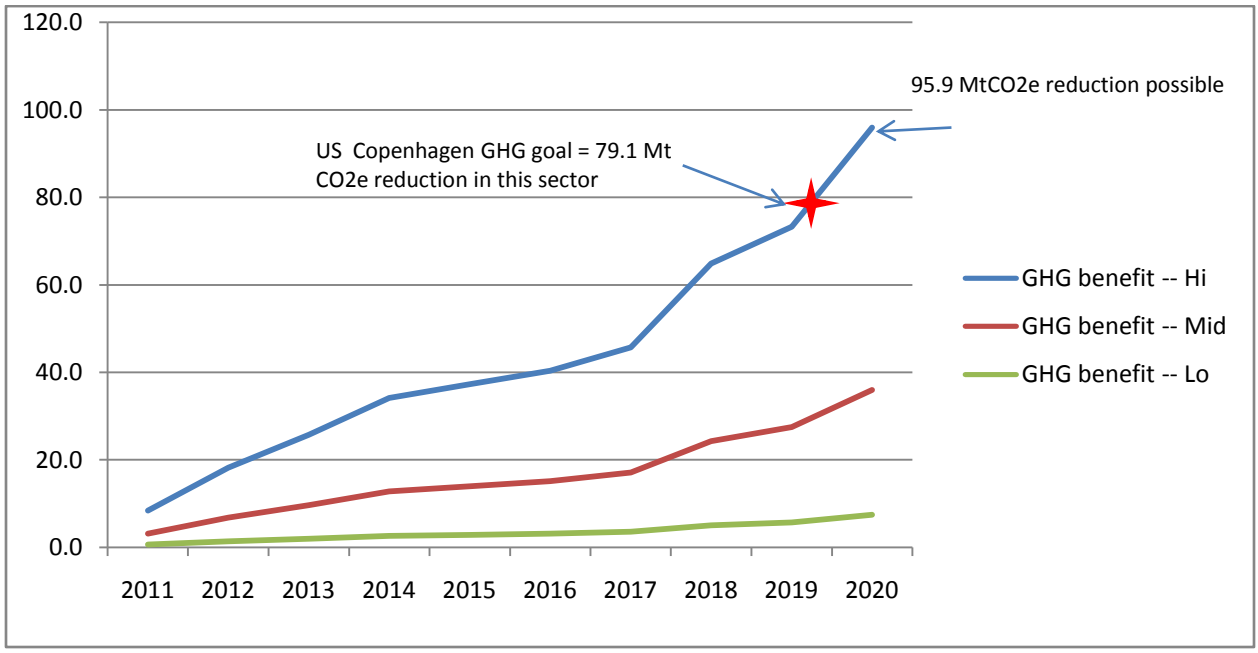


In terms of general energy security, of establishing a much greater domestic natural gas industry, and of weaning America off of Middle East oil, these three scenarios offer modest adjustments to the status quo. None compares to the massive degree of change promised by implementation of the Pickens Plan, however. The High case scenario sees over the next decade an average of 1.8 Tcf/year of gas consumed by natural gas trucks, which represents less than 8 percent of US 2009 domestic natural gas consumption.[29] Assuming the same modest yearly increase in penetration as assumed for Canada, US consumption could be as low as 344.9 bcf/year in 2011, and as high as 3.921 tcf/year by 2020. Again, as with Canada, the US Mid and Low cases would not make a material impact on energy security or on developing the US domestic natural gas industry. Yearly averages for those two cases are calculated to be 680 bcf/year and 142 bcf/year in natural gas consumption, respectively.

As mentioned above, the US Copenhagen GHG goal is exactly the same as that agreed to by Canada – to lower overall GHG emissions to 17 percent below those of 2005 by 2020. Our calculations show that the US trucking industry would need to reduce yearly emissions by 79.1 $MtCO_2e$ in order to achieve that objective for the heavy truck transport sector. In the High case scenario, the goal would be approached in 2019 and exceeded in 2020. However, the Mid case and the Low case (which is an EIA forecast) would not come close to the Copenhagen 2020 target for the sector (see Figure 15).

[29] BP Statistical Review of World Energy, 2010. www.bp.com

Figure 15
NGV Truck GHG Benefits – United States



For development of NGVs and infrastructure in both countries, there exists a wide gulf between what is desirable and what is possible. The grandiose Pickens Plan cannot be implemented without a revolution in the way the US deals with energy in general and transportation in particular. Even the far more conservative NRCan Roadmap does not offer meaningful diversification of Canada's transportation fleet fuels; integrating NGVs into the fleet at the rates advocated within the Roadmap will not liberate the trucking industry from its reliance on crude-based fuels.

That being said, the Pickens Plan has succeeded in raising public awareness of NGVs, and the NRCan Roadmap has helped to identify the most feasible means of integrating NGVs into the transportation sector – specifically, in truck transportation along certain corridors. CERI analysis shows that desired cuts in emissions levels can be realized in both countries through NGV integration into the transport sector, but only with considerable effort on the part of industry and governments. Energy security can be enhanced through increased usage of domestically-produced natural gas but not to the point where either country can insulate itself from geopolitical risk. As with most alternatives to conventional energy usage, natural gas vehicles do not provide any "silver bullet" answers, but they can and will provide partial solutions to ongoing energy problems.