



# Study of Opportunities for Natural Gas in the Transportation Sector

## Submitted to

Natural Resources Canada

## Submitted by

Marbek

March 2010

This study provides the perspective of numerous stakeholders. The contents, conclusions and recommendations are not necessarily endorsed by participating organizations and their employees or by the Government of Canada.

222 Somerset Street West, Suite 300  
Ottawa, Ontario, Canada K2P 2G3  
Tel: +1 613 523-0784  
Fax: +1 613 523-0717  
[info@marbek.ca](mailto:info@marbek.ca)  
[www.marbek.ca](http://www.marbek.ca)

# Executive Summary

## *Background and Objectives*

This report provides an assessment of the potential use of natural gas as an alternative fuel across the transportation sector. This includes the on-road and off road, marine, rail, and indoor equipment sectors. The report has been prepared for the Fuels Policy and Programs (FPP) division of Natural Resources Canada (NRCan).

The objectives of this study were:

- To explore and analyze the potential for the use of natural gas in support of the Government of Canada's policy objectives for the transportation sector.
- To conduct a study that includes research and information gathering to inform the development of a Canadian strategy for the use of natural gas in the transportation sector.
- To identify and explore other potential future applications for natural gas in the Canadian context within the transportation sector.

A preliminary assessment of previous, existing and future market and technology trends in North America and more specifically in Canada and consultation with Natural Gas Vehicle (NGV) industry stakeholders showed that the more promising NGV market segments are likely to consist of the following:

- Heavy duty and medium duty, including line haul trucking (fleets), return-to-base trucks, transit buses, refuse trucks
- Light duty fleets. Examples are taxis and courier services
- Marine vessels
- Rail (locomotive)
- Indoor industrial vehicles, including forklifts and ice re-surfacers.

These segments were selected to be included in the study of financial, environmental and achievable potentials.

## *Current Market*

The Canadian market for NGVs has stagnated and is lagging far behind other countries. This is due to a variety of factors, including past price volatility and problems with NGV technologies in some sectors. The concurrent lack of availability of vehicles and of fuel continues to act as a "chicken and egg" barrier to further development.

## *Lessons Learned from Previous Programs*

A variety of programs and policies to encourage the development of NGVs have been implemented in Canada and around the world, with varying levels of success. Key lessons include:

- Need for a stable and predictable price advantage for natural gas – mechanisms to manage risk are needed
- Technologies need to be commercially and financially viable on their own – government support should help overcome barriers but should be temporary

- Programs are more likely to be successful if federal, provincial and municipal governments cooperate
- Support is needed both for vehicles and for fuelling infrastructure.

### *Fuel Supply*

The increased access to unconventional gas (in particular to shale gas) appears likely to lead to a surplus in North America by 2020. This surplus is not yet reflected in official forecasts and is subject to some uncertainty, including potential environmental concerns that could constrain the potential.

Current retail fuel supply is characterized by a lack of availability and a lack of competition. As a result, prices are higher than they need to be.

The analysis indicates that investments in fuelling infrastructure could be financially attractive even with somewhat lower prices. However, the business case depends on access to a sufficient market. Thus, potential investors may require assistance to deal with risk and to overcome the initial period of market development.

### *Technology Trends*

The study indicates that NGV technologies are proven and commercially available for all market segments, except rail. In all cases, there remain incremental costs, but opportunities to reduce these costs are being pursued.

Emerging technologies, particularly in the HDV/MDV sector are particularly promising, with new developments signaling that tailpipe emissions are being reduced to a level that could eliminate the need for some of the costly exhaust after treatment components used by conventional fuel vehicles.

### *Environmental Analysis*

The environmental analysis showed that GHG emissions can be reduced by 15-25% depending of the vehicle segment (greater reductions of up to 88% are possible by using biogas). The greatest reductions occur in medium and heavy duty, light duty and refuse truck segments.

It was also noted that NGVs offer other environmental advantages in several segments. In particular the reduction of CACs is important for indoor equipment.

The use of biogas is attractive for municipal fleets that are seeking to drastically reduce GHG emissions while using a locally available fuel source.

### *Financial Analysis*

The financial analysis showed that all NGV segments could potentially be viable without incentives, except the refuse truck segment.

- The forklift segment offers the best return, almost 45%.
- Line haul, transit bus, LDV and marine segments offer attractive returns, in the range of 20%. Because of the large sums involved, the marine scenario is particularly attractive in terms of the absolute dollars.

- The Return-to-Base HDV scenario and the ice resurfacer scenario are only marginally viable, in the range of 10-15% return.
- The refuse truck segment could be financially viable if capital cost increment could be reduced, say by \$15,000.

Several of the segments/scenarios (e.g. refuse, ice resurfacer) have important non-financial advantages that could improve their prospects.

### *Barriers and Solutions*

Despite their technical, financial and environmental benefits, NGVs still face formidable market and non-market barriers. Each of these barriers can be overcome but this will require concerted action by all stakeholders, including governments and industry. In particular a comprehensive communications strategy will be needed to overcome a lack of awareness, understanding and confidence on the part of stakeholders.

### *Achievable Potential*

A number of segments of the market have the potential to see modest NGV penetration, notably the HDV segment.

Achieving this potential will require governments to play an active role, taking the lead in coordinating the actions of other players and providing targeted incentives for both vehicles and fuelling infrastructure.

If realized, this potential increase in NGV penetration would displace up to 850 million litres of conventional fuels per year and reduce GHG emissions by more than 2 megatonnes per year, by 2020.

# Table of Contents

<b>Executive Summary .....</b>	<b>i</b>
<b>1 Introduction.....</b>	<b>4</b>
1.1 Background .....	4
1.2 Objectives and Scope .....	4
1.3 Approach.....	5
1.4 Organization of the Report .....	7
<b>2 Overview of International and Domestic NGV Markets.....</b>	<b>8</b>
2.1 Global Markets.....	8
2.2 Canadian Market.....	9
<b>3 Program History and Lessons Learned.....</b>	<b>11</b>
3.1 History and Current Programs .....	11
3.2 Lessons Learned from Programs.....	15
<b>4 Fuel Supply .....</b>	<b>18</b>
4.1 Upstream Supply and Demand .....	18
4.2 Fuel Delivery .....	22
4.3 Biogas .....	26
<b>5 Technology Trends.....</b>	<b>28</b>
5.1 Heavy and Medium Duty Vehicles.....	28
5.2 Light Duty Vehicles.....	29
5.3 Marine.....	29
5.4 Rail.....	30
5.5 Indoor Equipment.....	30
<b>6 Environmental Analysis.....</b>	<b>32</b>
6.1 Greenhouse Gas (GHG) Emissions .....	32
Criteria Air Contaminant (CAC) Emissions.....	36
<b>7 Financial Analysis.....</b>	<b>37</b>
7.1 Financial Scenarios.....	37
7.2 Results.....	39
7.3 Sensitivity Analysis .....	40
7.4 Implications.....	42
<b>8 Barriers and Solutions.....</b>	<b>43</b>
8.1 General.....	43
8.2 Heavy and Medium Duty Vehicles.....	45
8.3 Light Duty Vehicles.....	46
8.4 Marine.....	47
8.5 Rail.....	47
8.6 Indoor.....	48
<b>9 Achievable Potential .....</b>	<b>49</b>
9.1 Policy Options .....	49

9.2	Recommended Strategy .....	50
9.3	Results - Heavy and Medium Duty Vehicles .....	51
9.4	Results - Light Duty Vehicles .....	53
9.5	Results - Marine .....	54
9.6	Results - Rail .....	54
9.7	Results – Indoor Equipment.....	54
9.8	Fuel Displacement and GHG Emission Reductions.....	55
<b>10</b>	<b>Conclusions.....</b>	<b>56</b>
<b>Appendix A</b>	<b>International NGV Programs.....</b>	<b>A-1</b>

## Glossary of Technical Abbreviations

AFV	Alternative fuel vehicle
CAC	Criteria air contaminants
CNG	Compressed natural gas
DPF	Diesel particulate filter
GGE	Gallons gasoline equivalent
GHG	Greenhouse gases
GVW	Gross vehicle weight
GVWR	Gross vehicle weight rating
HDV	Heavy duty vehicle
HP	Horsepower
HPDI	High pressure direct injection
LCD	Local (natural gas) distribution company
LDE	Litres Diesel equivalent
LDV	Light duty vehicle
LGE	Litres Gasoline equivalent
LNG	Liquefied natural gas
MDV	Medium duty vehicle
NG	Natural gas
NGV	Natural gas vehicle
OEM	Original equipment manufacturer
QVM	Qualified vehicle modifiers
SCR	Selective catalytic reduction
SI	Spark ignited
VRA	Vehicle refuelling appliance

# List of Exhibits

Exhibit 1 Natural gas vehicle statistics – countries with 0.5 million or more NGVs.....	8
Exhibit 2 Summary of US Incentives and Associated Laws.....	14
Exhibit 3 Natural gas demand forecast in Canada (from National Energy Board 2009 Reference Case).....	19
Exhibit 4 Natural gas demand forecast in North America (from World Energy Outlook 2009)...	19
Exhibit 5 Natural gas production forecast in North America (from World Energy Outlook 2009).....	20
Exhibit 6 Natural gas demand forecast in Canada (from World Energy Outlook 2009).....	20
Exhibit 7 LNG Price Components .....	25
Exhibit 8 CNG Price Components.....	26
Exhibit 9 Different Processing Paths for Biogas.....	27
Exhibit 10 GHG emissions calculated for heavy duty trucks (23% reduction for LNG in comparison with diesel).....	33
Exhibit 11 GHG emissions calculated for medium duty trucks (19% decrease for CNG, 23% decrease for LNG in comparison with diesel).....	33
Exhibit 12 GHG emissions calculated for light duty vehicles (23% decrease for CNG in comparison with gasoline).....	34
Exhibit 13 GHG emissions calculated for refuse trucks (19% decrease for CNG, 82% decrease for wood-based biogas, 88% decrease for landfill gas in comparison with diesel) .....	34
Exhibit 14 GHG emissions calculated for marine – Liquids and bulk freight (16% decrease for LNG in comparison with heavy fuel oil).....	35
Exhibit 15 GHG emissions calculated for marine – General cargo and containers (18% decrease for LNG in comparison with marine diesel).....	35
Exhibit 16 GHG emissions calculated for rail freight (19% decrease for LNG in comparison with rail diesel).....	36
Exhibit 17 Financial Scenarios for NGV Segments .....	38
Exhibit 18 Financial Viability Results.....	39
Exhibit 19 Simple Payback Results.....	39
Exhibit 20 Internal Rate of Return Results.....	40
Exhibit 21 HDV/MDV Cost Curves.....	40
Exhibit 22 Refuse Truck Cost Curves.....	41
Exhibit 23 LDV .....	41
Exhibit 24 Marine.....	41
Exhibit 25 General Market Barriers for all NGV Segments.....	43
Exhibit 26 General Non-market Barriers for all NGV Segments .....	45
Exhibit 27 Barriers in the Heavy and Medium Duty Segment .....	45
Exhibit 28 Barriers in the Light Duty Segment.....	46
Exhibit 29 Barriers in the Marine Segment.....	47
Exhibit 30 Barriers in the Rail Segment.....	47
Exhibit 31 Barriers in the Indoor Segment.....	48
Exhibit 32 Achievable potential for the medium and heavy duty NG vehicles .....	53
Exhibit 33 Achievable potential for the light duty NG vehicles .....	54
Exhibit 34 Achievable potential for indoor NG vehicles.....	55
Exhibit 35 Incremental fuel displacement for all NGV segments based on the achievable potential.....	55
Exhibit 36 Incremental GHG emissions reduction for all NGV segments based on the achievable potential.....	56

# 1 Introduction

## 1.1 Background

Natural gas (NG) offers several potential advantages as a lower carbon transportation fuel compared to gasoline, diesel, and other traditional fuels. These include:

- Lower GHG emissions
- Lower emissions of criteria air contaminants (and lower associated abatement costs)
- Opportunity for greater fuel diversification and thus advantages to expand security of supply (particularly with the lower cost of natural gas)
- Economic benefits in the form of industrial development and the creation of new employment opportunities.

The present report is an assessment of the potential use of natural gas as an alternative fuel across the transportation sector. This includes the on-road and off road, marine, rail, and indoor equipment sectors. The report has been prepared for the Fuels Policy and Programs (FPP) division of Natural Resources Canada (NRCan).

Factors driving the need for this assessment include:

- The Government of Canada’s Copenhagen Accord Commitment to reduce GHG emissions by 17 percent below 2005 levels by 2020;
- The need to displace the use of carbon intensive fossil fuels (i.e. gasoline and diesel) and diversify the nation’s energy supply;
- The need to improve overall air quality;
- Potential economic benefits.

The circumstances under which natural gas might successfully be used as an alternative fuel in Canada are discussed.

## 1.2 Objectives and Scope

The objectives of this study are:

- To explore and analyze the potential for the use of natural gas in support of the Government of Canada’s policy objectives for the transportation sector.
- To conduct a study that includes research and information gathering to inform the development of a Canadian strategy for the use of natural gas in the transportation sector.
- To identify and explore other potential future applications for natural gas in the Canadian context within the transportation sector.

The work entailed four main components:

- A review of the lessons learned from programs and activities in Canada (at the federal and provincial levels) and internationally.
- A review of the current prospects for natural gas and natural gas vehicles in a variety of transportation applications – taking into account changes in the overall market for NG, advances in technology and other drivers.

- Identification of the technical, economic and achievable potential for NG in transportation applications, taking into account relative costs and benefits (market costs, non-market costs), as well as barriers and policy/program opportunities to overcome barriers.
- Consultation with key stakeholders to refine the analysis and findings.

## 1.3 Approach

### 1.3.1 Segments

Potentially all on-road and off-road vehicles can be driven on some form of natural gas fuel. However, a preliminary assessment of previous, existing and future market and technology trends in North America and more specifically in Canada and consultation with NGV industry stakeholders showed that the more promising NGV market segments are likely to consist of the following:

- Heavy duty and medium duty, including line haul trucking (fleets), return-to-base trucks, transit buses, refuse trucks
- Light duty fleets. Examples are taxis and courier services
- Marine vessels
- Rail (locomotive)
- Indoor industrial vehicles, including forklifts and ice re-surfacers.

These segments were selected to be included in the study of financial, environmental and achievable potentials.

Other segments of potential interest include surface mining applications and privately owned light duty vehicles. NGV application in mining relies mainly on the oil sands industry in Western Canada and other open pit mining activities which, overall, constitute a smaller potential compared to the other segments included in the present analysis. Privately owned passenger cars constitute a large share of light duty vehicles. However, the limited choice of NGV technology and vehicle models offered by Original Equipment Manufacturers (OEMs) in this area, as well as the expectation of fierce competition with the upcoming electric and plug-in-hybrid-electric passenger cars, ethanol and second generation biofuels make NG inroads in the passenger vehicle market potentially difficult.

### 1.3.2 Sources

The study relied on a variety of information sources, including:

- Information provided by NRCan on NGV background, government programs and reports
- Research on recent NGV activities, R&D projects, NG upstream and retail markets
- Published reports by a variety of international, US and Canadian agencies, including National Energy Board and International Energy Association
- Documentation and verbal communications with a variety of industry stakeholders and experts, including the Canadian Natural Gas Vehicle Alliance (CNGVA), various CNGVA, members, International Association for Natural Gas Vehicles (IANGV), and NGV technology suppliers
- Marbek in-house knowledge in the area of policies and programs, alternative fuels policies and programs, NGV technologies and natural gas upstream, distribution and retail infrastructure

### 1.3.3 Analysis

Our methods included a variety of qualitative and quantitative approaches:

- **Policies and Programs History.** We analyzed Canadian federal and provincial policies and programs, and well as international programs and policies including USA, South Asia, South America and Europe, and analyzed the lessons learned.
- **Technology Trends.** We assessed technological maturity and commercial viability of various NGV technologies, NG fuel availability including supplies, distribution and pricing schemes.
- **Financial Analysis.** We used spreadsheet financial analysis to determine the economic viability of each NGV market segment. For the analysis of fuel supply investments, we looked at prices in the retail market place and considered a breakdown of cost components to calculate the residual profit/markup. For the analysis of vehicle acquisitions, we used information on incremental capital costs, fuel use and savings to determine payback, net present value and the internal rate of return. We also conducted a sensitivity analysis to develop a variety of cost curves – illustrating the variability of payback periods for NGVs under different conditions.
- **Environmental Analysis.** We used GHGenius version 3.16 for light duty vehicle emissions, and version 3.17 for medium and heavy duty, marine and rail freight. Version 3.17 has the functional unit of tonne-km and is adapted to freight applications.
- **Achievable Scenarios.** We used the information on the financial viability, the environmental advantages and the barriers and potential solutions, along with our internal expertise and experience to develop scenarios describing both a baseline and a realistic but relatively ambitious achievable scenario for each market segment. Where applicable, this was done on a bottom-up basis looking at individual market segments and regions, which were then extrapolated to the rest of Canada. As the level of analysis is superficial, these should be considered illustrative scenarios only.
- **Policy Analysis.** Based on a barriers analysis, we identified the steps that needed to be taken to allow commercially available and financially viable opportunities to be realized. Based on our understanding of the policy and market context, we proposed typical government interventions that were likely to be needed to deliver the achievable scenarios. If necessary, we adjusted both the interventions and the scenarios to reflect a realistic view. Once again, this should be viewed as illustrative.
- **Fuel Displacement and GHG Reductions.** The achievable potential was used to calculate the fuel displacement and the corresponding GHG emission reductions. GHG emission reductions were calculated using emission factors obtained from Canada’s GHG Inventory<sup>1</sup>.

### 1.3.4 Consultations

In addition to the contacts undertaken for information collection (see sources above), further discussions were conducted with a small group of industry stakeholders. Draft versions of the key findings were provided and feedback was obtained from representatives of:

- Westport Innovations
- Gaz Metro
- Enbridge
- Encana
- Canadian Natural Gas Vehicle Alliance (CNGVA)

<sup>1</sup> National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990–2007, Environment Canada

## 1.4 Organization of the Report

This report is organized as follows:

- Section 1 gives an introduction to the study, including objectives and scope, a definition of NGV technology and market segments and the approach used to perform the study.
- Section 2 gives an overview of international and domestic NGV markets.
- Section 3 describes the history of important Canadian federal and provincial programs, as well as significant international programs. A summary of the lessons learned from these programs is given.
- Section 4 deals with natural gas fuel delivery for transportation use, including upstream supply, distribution infrastructure, retail and pricing. A brief description of biogas (bio-methane from landfill and agri-waste) application in transportation is included.
- Section 5 gives a summary of technological trends in NG vehicles for each segment.
- Section 6 explains the environmental impacts of using NG in transportation, including GHG and CAC emissions.
- Section 7 presents the financial analysis including scenarios, results, sensitivity analysis and implications.
- Section 8 gives a list of general and segment-specific market and non-market barriers to the development of a sustainable NGV market.
- Section 9 describes our assessment of the achievable potential in the context of various policy options for the promotion of NGVs. This includes a description of the scenarios, along with the associated fuel displacement and GHG emission reductions.
- Section 10 presents the conclusions of the study.

## 2 Overview of International and Domestic NGV Markets

### 2.1 Global Markets

Historically, prospects for NG as a transportation fuel have to some extent followed an inverse relationship with the price of oil. When the price of oil (and gasoline/diesel) rose in the late 70s and early 80s, markets for NG and NGVs appeared more promising. However, the extended period of low prices from the late 1980s to the early 2000s, made it difficult for NG to compete as a transportation fuel. Even with higher prices for traditional fuels, NG prospects have not been as promising because (until recently) of supply concerns and because other fuels or other technologies have appeared more promising.

As of December 2009, there were more than 11 million NGVs on the roads worldwide<sup>2</sup>. Globally, the use of natural gas as a road-transport fuel currently accounts for only 1% of total gas consumption. The global average growth rate in the number of NG vehicles between 2000 and 2009 has been 28.7%, with Asia-Pacific and North America ranking the highest and the lowest, with +50.9% and -0.1% growth rate respectively. This trend is expected to continue at an average rate of 3.7% per year to 2030, with most of the growth coming from non-OECD countries, which already account for most gas use for road transport.

Exhibit 1 shows the list of countries with more than 0.5 million NGVs, which consists of Pakistan, Argentina, Iran, Brazil, India, and Italy.

**Exhibit 1 Natural gas vehicle statistics – countries with 0.5 million or more NGVs<sup>3</sup>**

Rank	Country	Natural Gas Vehicles	Refuelling Stations	Year data received
1	Pakistan	2,400,000	3,105	2008
2	Argentina	1,807,186	1,851	2008
3	Iran	1,734,431	1,079	2008
4	Brazil	1,632,101	1,704	2008
5	India	725,000	520	2008
6	Italy	580,000	730	2008

The majority of natural gas vehicles worldwide are cars, but buses account for much of the consumption, and two- and three-wheelers powered by CNG are prominent in Pakistan, India and some Southeast Asian countries. In India, all public transport vehicles in New Delhi are required to be powered by CNG.

Most light-duty NGVs are converted gasoline-powered vehicles, though an increasing number of vehicles worldwide are being manufactured to run on CNG.

<sup>2</sup> International Association for Natural Gas Vehicles - IANGV

<sup>3</sup> International Association for Natural Gas Vehicles – IANGV – December 2009.

In North America, interest in promoting NGVs is growing in the United States, driven by low prices and the perception that indigenous supplies are ample.

The potential exists for much faster growth in this sector, but it hinges on stronger policy action (on environmental and energy-security grounds) to promote investment in distribution infrastructure and switching by consumers to natural gas vehicles.

A summary on international NGV development activities is presented in Appendix A.

## 2.2 Canadian Market

In worldwide classification, Canada ranks 29<sup>th</sup>, with about 12,000 NGVs.<sup>4</sup> This number includes 300 heavy-duty vehicles, 150 urban transit buses, 45 school buses, 9,450 light duty cars and trucks and 2,400 forklifts and ice-resurfacers. The total fuel use in all NGV markets in Canada was 1.9 PJ in 2007 (or 54.6 million litres of gasoline equivalent), down from 2.6 PJ in 1997.<sup>5</sup>

### *Medium and Heavy Duty Fleets*

There are an estimated 300 heavy duty vehicles using CNG in Canada (LNG is not yet used as a transportation fuel in Canada). The heavy duty engine industry is located in the Vancouver, BC area and is largely represented by Cummins Westport and Westport Innovations. Cummins-Westport's ISL G engine has been integrated into products offered by 15 North American truck, bus, and specialty vehicle OEMs including Freightliner, Mack, and Peterbilt.<sup>6</sup> Although there are few vehicles in Canada, there are currently 1,200 heavy duty engines in California and 18,000 in China manufactured by these two companies. The heavy duty engine market has a good potential growth overseas. However, the cost of key components such as LNG tanks, injectors and CNG tanks needs to come down for market to grow without incentives.

There are 150 urban transit buses in Canada. This market is in rapid decline due to the previous poor experience of transit companies that used the older technology. With recent technological advances at both domestic and global levels, the transit bus market is expected to have good a growth potential due to fairly high gas use and the possibility of central refuelling. Manufacturers such as Ontario Bus Industries, New Flyer and MCI have the capacity to supply CNG buses. However, there are barriers to overcome before market can be renewed in Canada. The main barriers are discussed in Section 8 of the report.

There are only 45 school buses in Canada. This market used to be large in the Prairies, but has lost to diesel competition in recent years. School buses are ideal for slow-fill, return to base situation but conversion cost must be reduced for the market to grow.

It should be noted that there could be a possible renewed interest in CNG as diesel emissions system costs rise to meet 2010 standards. On the other hand, there are only 12 private fleet stations left in Canada, including 2 serving transit buses.

---

<sup>4</sup> Data obtained in December 2009.

<sup>5</sup> (a) Statistics Canada, *Report on Energy Supply-Demand in Canada 1990–2007*, Ottawa, February 2009; (b) Natural Resources Canada, *Transportation End-Use Model*, Ottawa, August 2009.

<sup>6</sup> From consultations with Cummins-Westport, March 2010

### ***Light Duty Vehicles***

The light duty market, including cars and trucks, has declined from 30,000 vehicles in the early 1990s to 9,450 currently. No OEM products are available in North America, except for the Honda Civic GX which is only available in the US market.

Several small to medium size upfitters are located in US, however there are no Qualified Vehicle Modifiers (QVM) serving OEMs in Canada. The conversion cost of light duty NGVs has been inflated by generous US incentives, which makes the market penetration of such vehicles difficult in Canada.

Heavier light trucks (8,500-10,000lb GVW) are increasingly diesel powered and have less potential for NGV.

There are only 72 public NG stations in Canada, which is down from 134 in 1997. There are 22 public refuelling stations in British Columbia, 12 in Alberta, 10 in Saskatchewan, 27 in Ontario and 1 in Quebec.

### ***Industrial Indoor Vehicles***

Industrial indoor vehicles currently have a small share of the market, with about 2,400 forklifts and several hundred ice-resurfacers. NG competes successfully with LPG for indoor warehousing and manufacturing markets and ice resurfacers are already largely NG powered. Some of the advantages of NG in indoor vehicles are: lower fuel cost, ease of conversion, improved indoor air quality, and suitability to the smaller end of the market (30-50HP engines). Additionally, the use of NG eliminates the need for swapping of batteries in electric vehicles or handling of heavy LPG tanks. One disadvantage with NG indoor vehicles is the limited OEM product availability. Another disadvantage is the limited number of vehicle refuelling appliances (VRAs). This number is estimated at 485 units currently in use.

It should be noted that there is no VRA manufacturing facility in Canada at the present time, since the only Canadian VRA manufacturer has gone out of business. However, this is expected to be a temporary situation, as a new owner is preparing to offer VRAs to the Canadian market. The global market for indoor industrial vehicles is largely dominated by Korean manufacturers. Among other OEMs and manufacturers, Toyota produces a factory-direct natural gas forklift. In Canada, Westport Innovations has recently started to produce natural gas engines for forklifts.

## 3 Program History and Lessons Learned

### 3.1 History and Current Programs

#### 3.1.1 Canada – Federal

##### *History*

Over the years, the federal government has played an active role in setting up NGV codes and standards that govern vehicle conversions and station design and siting. At the same time, the implementation and enforcement of these codes and standards has principally been a provincial and local government concern. The federal government also assisted NGV technology and market readiness by providing technical performance data from demonstrations and safety testing, and by providing a federal view through the Canadian General Standards Board (CGSB) committees that produced vehicle and fuel standards. Key initiatives included:

- **Natural Gas Vehicle Grant Program (NGVGP).** The NGVGP was established in 1983. This was a \$25 million – 5 year grant program that offered up to \$500 per vehicle converted. Another program, Natural Gas Station Program (NGSP) offered up to \$50,000 towards the construction of private or public NGV fueling stations.
- **Federal R&D.** The federal government supported NGV technology research and development in the areas of NGV fuelling systems, injection technology, tank material technology, and manufacturing capacity development. Examples of successful results of this support include:
  - Commercial NG injection system by Ortech and GFI/Teleflex;
  - Dual fuel (NG/diesel) injection technology at the University of British Columbia
  - Founding of Westport Innovations
  - Lightweight carbon fibre wound storage tanks
  - Canadian NG transit bus manufacturing capacity development
- **Other R&D.**
  - Energy, Mines & Resources (EMR - the forerunner of NRCan) and the Ontario government also supported R,D&D of NGVs in the early 80's, including a new technology for NG injection for engines at the Ontario Research Foundation (ORF). ORF was privatized later to form Ortech, and was subsequently acquired by Bodycote.
  - Building on R&D support from the federal and BC governments, the University of BC Department of Mechanical Engineering developed bi-fuel NG/diesel fuel injection systems in early 1980's that were a leading clean technology. This technology was acquired by Westport Innovations in 1995 and is now being successfully marketed in major markets such as in California and several other US states, China, and some of the European countries such as Italy.
  - From 1986-1990, under the Enderdemo Program, EMR funded up to 36% of the \$975,000 NG/diesel demonstration project in BC.

- **Canada-US Cooperation.** The federal government entered into cooperation on technology demonstrations with California, US DOE and NYSEDA between 1983 to 1990. Canadian and US OEM vehicle programs during 1987-1993 supported development of factory-produced NGVs, e.g. the Chrysler minivan, which achieved Ultra Low Emission Vehicle (ULEV) status in the US; the federal government also supported the participation of GFI in the Ford Qualified Vehicle Modifier (QVM) program. This consisted of GFI converting Ford vehicles to NG, but with Ford selling and servicing the vehicles through its dealer network, as if they were factory-produced vehicles. In the 1996 model year, Chrysler and Ford between them offered a wide range of vehicles with a NG option, e.g., large sedan, a minivan, full size vans, and full size pick-up trucks.

Despite these efforts by the federal government and others, the NGV market did not prove to be sustainable. The deregulation of the NG industry influenced the NGV market significantly. A previous National Energy Policy (NEP) rule that NG prices would be pegged at 65% of the price of oil no longer held in the deregulating energy industry. In addition, the economics of NG for transportation became gradually less favourable as oil prices were gradually decreasing and stabilizing through the late 1980s and early 1990s.

### 3.1.2 *Canada – Provincial*

#### *History*

The Canada-Alberta accord was an important driver for the NGV market. In addition to funding the extension of NG pipelines in ON and QC, the program included incentives for market development, such as transportation. The Market Development Incentives Payments (MDIP) was funded from a special federal levy on AB gas producers. When the NG lateral pipeline program was terminated with the end of the National Energy Policy, \$35 million remained in the fund, which was held in escrow by the federal government. Following negotiations with AB, the remaining MDIP funds were to be used to continue funding NGV and station grants in provinces where AB gas was consumed, i.e. East of AB.

The Federal government cooperated with Ontario, Quebec, Saskatchewan, Alberta and British Columbia, through a liaison process with these provinces that had some incentives for NG (grants and fuel tax waivers). In the case of BC, there was a federally funded program outside of MDIP that worked to increase NG, depending on the availability of funds. Both the BC government and BC Gas contributed to this program by providing their own funding.

The Ontario government had a NGV research program during the early 1980s. It funded gaseous fuel projects, including the gaseous fuel injection system. The Ontario Ministry of Transportation (MTO), with support from EMR, pioneered NG as a fuel for transit buses with Ontario Bus Industries (OBI) in the early 80s and a number of municipal transit fleets bought these buses. Ontario and EMR funded R&D of compression equipment for the quick refuelling stations, which involved the compressor manufacturers. Two Canadian companies with federal research funding, certified and applied advanced high-pressure NG tanks. In the late 1980s, research focused on scaling-up the gaseous fuel injection technology for large engines so that buses and other HDVs could reliably and efficiently use NG instead of diesel.

### *Current Situation*

Provincial incentives currently in place include sales tax relief measures in Ontario and BC. Both of these supports will be lost in 2010 when the provinces transition to the Harmonized Sales Tax (HST).

- Ontario currently offers \$1,000 PST rebate for light duty NGVs, as well as 100% PST rebate for NG transit and shuttle buses.
- BC currently offers \$1,000 social service tax exemption for light duty NGVs, and up to \$10,000 social service tax exemption for NG buses.

It is worth noting that there will be an uneven treatment of transportation fuels, with the transition to HST in BC, as conventional, higher carbon fuels (gasoline, diesel) will be exempt from the provincial portion of the HST while alternative, lower carbon fuels (natural gas, propane, hydrogen, electricity) will not be exempt.

The Ontario Ministry of Transportation (MTO) also has in place a Green Commercial Vehicle Program that provides 1/3 of the capital premium incentive funding to a maximum of \$15K for Class 3-7 commercial vehicles. This program is scheduled to run until March 2012, but may end sooner due to financial pressures.

Quebec has funding in place to support energy efficiency initiatives, which may in the future be made available for LNG truck activities (e.g., Robert Trucking).

### **3.1.3** *International*

A summary of the history and current initiatives in selected countries is included here. Additional details are provided in Appendix A. Selected highlights of these initiatives are given below.

#### *United States*

Like Canada, the U.S. has had a variety of initiatives and programs (both federal and state) but has had limited success in fostering a sustainable NGV market. Currently, a renewed effort is underway, with substantial incentives through a variety of means, including the Clean Cities program and the American Recovery and Reinvestment Act (ARRA).

Currently, a variety of incentives are available for NG fuel, vehicles, and infrastructure. Federal income tax credits are also available to offset the cost of each of these options. In addition, many states and air quality districts offer incentives, and some utilities offer preferential gas rates to customers with a small home refueling appliance sold under the name “Phill”. Key incentives and associated laws are listed in Exhibit 2.

## Exhibit 2 Summary of US Incentives and Associated Laws

Incentive Type	Federal Law	Provision
Fuel	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, P.L. 109-59 (8/10/05) (SAFETEA LU)	Excise tax credit, paid from the General Revenue Fund, for an alt. fuel sold for use or used as a fuel to operate a motor vehicle. For NG, the credit is \$0.50 per gge <sup>7</sup> of CNG and \$0.50 per LNG. (Note: motor fuel excise tax rate for CNG/LNG is on parity with that for other motor fuels). Eligible entity if liable for reporting/paying the federal excise tax on the fuel or if a nonprofit tax-exempt entity that fuels on site.
Fuel	Emergency Economic Stabilization Act/Energy Improvement and Extension Act of 2008 P.L. 110-343 (10/3/08)	Section 204 amended the expiration date for the existing alternative fuel excise tax credit from September 30, 2009 to December 31, 2009.
Vehicle	Energy Policy Act of 2005, P.L. 109-58 (8/8/05)	A qualified alt. fuel motor vehicle tax credit is available for the purchase of a new, dedicated, or repowered/converted AFV <sup>8</sup> . It is for 50% of the incremental cost of the vehicle (if meets federal EPA or CARB emissions standards), plus an additional 30% if the vehicle meets certain tighter emission standards (e.g., EPA's Tier 2, Bin 2 standard for LDVs). These credits range from \$2,500 to \$32,000, depending on the size of the vehicle. The credit is effective on purchases made after December 31, 2005, and expires on December 31, 2010. In addition, (reduced) tax credits are also available for certain mix-fuel or dual-fuel vehicles having a GVWR <sup>9</sup> ** of more than 14,000 pounds. The vehicle must be capable of operating on a "combination of an alternative fuel and a petroleum-based fuel."
Infrastructure	Energy Policy Act of 2005, P.L. 109-58 (8/8/05)	Income tax credit available - 30% of the cost of NG refueling equipment, up to \$30,000 in the case of large stations and \$1,000 for home refueling. Effective on purchases placed in service after December 31, 2005, and expires on December 31, 2010 (extended by Emergency Economic Stabilization Act).
Infrastructure	American Recovery & Reinvestment Act of 2009, P.L. 111-5 (2/17/09)	This act increases the value of the credit for the purchase of equipment used to store and dispense qualified alt. fuels, placed in service during 2009 and 2010. The credit is \$50,000 or 50% of the cost for business and \$2,000 or 50% of the cost for home refueling.

### Pakistan

Pakistan has the largest total number of NGV fleets in circulation for public transportation. Free market consumer price of CNG, Natural gas tariff for CNG linked to petrol, priority of natural gas connection for CNG, and exemption of import duty and sales tax on import of machinery and kits are examples of NGV policies in Pakistan.

<sup>7</sup> Gallons of Gasoline Equivalent

<sup>8</sup> Alternative Fuel Vehicle

<sup>9</sup> Gross Vehicle Weight Rating

## *Argentina*

Argentina is second only to Pakistan in the number of NGVs. The Government facilitated the installation of the equipment needed for service stations and created a program for several hundred taxis in Buenos Aires to convert to natural gas. The savings was enough to convince car owners to convert their vehicles, which in turn prompted more service stations to offer natural gas. A large portion of their public transportation system has also been converted to CNG, encouraged by government-enforced financial incentives.

## *Brazil*

Brazil ranks third in the world for number of NGVs and for number of refuelling stations. Most of the NGVs now are aftermarket converted taxis or commercial MDVs.

Success factors in the growth of the NGV market have included: government incentives; sound regulation, standards and certification; good distribution infrastructure; competitive price of fuel; environmental performance<sup>10</sup>.

## *India*

India provides a well known example of a mandate – the public bus system in Delhi, which is required to use CNG. In July 1998, the Supreme Court of India ordered the CNG program for Delhi. Government support was provided through further measures, such as: Sales tax exemption on conversion kits; Concessional custom duty on CNG conversion kits; Allotment of land for CNG stations and pipelines on priority basis; Banning old vehicles from registering in Delhi.

## *Europe*

Gasoline in Europe sells for over \$8 per gallon (about 4.5 liters), therefore a government mandate to motivate conversion to alternative fuels is unnecessary. Nonetheless, financial incentives from the government to pay for as much as 75% of conversion costs, and environmental concerns provide further incentives among the European community. Italy has the largest number of CNG vehicles in Europe and is the 4th largest country in the world for CNG vehicles on the road. Germany, Poland and France are rapidly working to catch up with Italy.

## **3.2 Lessons Learned from Programs**

Several lessons can be learned from the previous and existing programs implemented in Canada and around the world. These can be categorized as considerations regarding technology and markets.

In the area of NGV technology, the experience suggests that continuous efforts in development of NGV technology are vital to market success.

- Overall, fast-changing emission standards and dropping oil prices hurt NGV in the mid-1990s.

---

<sup>10</sup> <http://www.iangv.org/tools-resources/ngvs-by-country/brazil.html>

<http://www.ngvglobal.com/brazils-sulgas-offers-incentives-to-boost-natural-gas-conversions-0629>

R.Fernandes, IBP NGV Committee, Brazil NGVs: Beyond a million, NGV-2006, November 7 –9 Cairo, Egypt

- NGV R&D did not keep pace with the emission standards, resulting in increased costs of compliance and OEMs pulling out of the market.
- NGV did not adapt to the emerging vehicle and engine technology
- Huge OEM and government effort should be made to improve new vehicle GHG and CAC emissions
- Natural CAC advantage of NG diminished with new rounds of emission standards
- More drivetrain competition emerged in all markets - hybrids, PHEVs, diesel, GDI and variants

In the area of market development, the following lessons can be drawn:

- Fuel availability, fuel price differential and stability were shown to be key drivers in the development of NGV market.
- Lack of competition, low market volume and high US incentives led to high prices for NG vehicles which depresses market interest in Canada.
- New markets can be primed by well planned technology demonstrations with suppliers and users.
- Momentum takes time to build. Success is achieved by signing one customer (and other stakeholders) at a time.
- Transit markets are well suited for NGV, but rebuilding this market will take time and support from governments

More specific lessons learned by different stakeholders are summarized in sections 3.2.1 and 3.2.2 below.

### **3.2.1 Governments**

From the policies and programs that have been implemented domestically and globally, it can be concluded that governments' role can assist initial market development where there is an economic potential for NGV.

Key lessons are:

- Government should support industry's lead with programs that reduce (not eliminate) risk, including information programs
- Incentives and subsidies should be temporary, not built into the long term cost structure
- NGV programs work best in regions where federal support is provided along with strong provincial and utility support
- Vehicle grants are best provided at point of sale (e.g. by gas utility) or within 30 days by federal program
- Government fleet conversion provides an example for other fleets and supports fueling infrastructure
- It could be difficult to support NGV growth when oil prices drop to low levels or where there is uncertainty about gas supply and price
- Mandates used in some countries don't work well in absence of a business case
- Even though NGV technology is fairly mature, there is still a need for ongoing government R&D support

### 3.2.2 Others

#### *Fuel Providers*

A detailed review of the past activities by fuel suppliers including utility companies and their market partners shows that:

- Turnkey projects can ease market entry for fleets
- Visible marketing campaign and financing programs are required to overcome the lack of awareness of NGV opportunity
- LDV fleet growth must be supported by adequate public station availability which can be enhanced by means of (a) securing public access to private stations; and (b) a targeted home refueling strategy
- Provide NG fuel price can be stabilized by hedging, long term contracts and other strategies
- It is crucial to coordinate the rollout of fueling infrastructure with vehicle fleet growth
- Developing training for conversion and maintenance industry should be assisted.

#### *Technology Providers*

The NGV technology providers have also learned from their earlier phases of technology development. Some of this learning can be summarized below:

- NGV technologies need to perform seamlessly with current sophisticated automotive systems
- Challenge of scaling up production and geographical reach
- Component costs controlled by others have a large impact on economics of NGV, e.g. fibre-wound tanks, LNG tanks, dual fuel injectors
- Continuous R&D programs are required with focus on
  - Fuel injection and combustion
  - Emission control systems
  - Component and system integration
  - Tank material and fuel storage technologies

#### *NGV Champions*

The impact of the Pickens Plan in US is an example of how a business or political champion could have a significant impact on the development of NGV market.

After spending more than 35 years traveling to Washington asking presidents and legislators to formulate a comprehensive energy plan for America while U.S. oil imports climbed from 24 percent to almost 70 percent, in July 2008 Pickens decided to take his case to the American public. He bankrolled a national ad and media blitz campaign outlining how the United States was exporting an alarming portion of its wealth to pay for its addiction to foreign oil and detailing a Pickens Plan that offered alternative energy solutions. He conducted continuous town meetings<sup>11</sup> across the country and solicited millions of "soldiers" for his plan on a Pickens Plan website.

---

<sup>11</sup> <http://www.boonepickens.com/helping/default.asp>

## 4 Fuel Supply

This section provides an overview of current and projected market trends regarding natural gas as a commodity, as well as the fuel supply industry, including distribution infrastructure, as well components of pricing of natural gas fuels at the retail level.

### 4.1 Upstream Supply and Demand

Natural gas can be extracted from conventional reserves that in many cases are found together with oil. This type of natural gas is in widespread production worldwide today. There are other types of natural gas reserves that have been historically less attractive due to economic or technical difficulties. These include shale gas, tight gas and coal-bed methane.

#### 4.1.1 Current Outlook Reports

A variety of industry reports and forecasts indicate that conventional NG resources are in decline in North America. Currently available forecast reports from Canadian, US and international agencies charged with monitoring the supply and demand of energy commodities indicate that there will be a growing supply of unconventional gas in Canada, but not yet sufficient to offset the reduction in conventional supply.

The National Energy Board (NEB) in Canada reports the following in its Reference Case 2009:

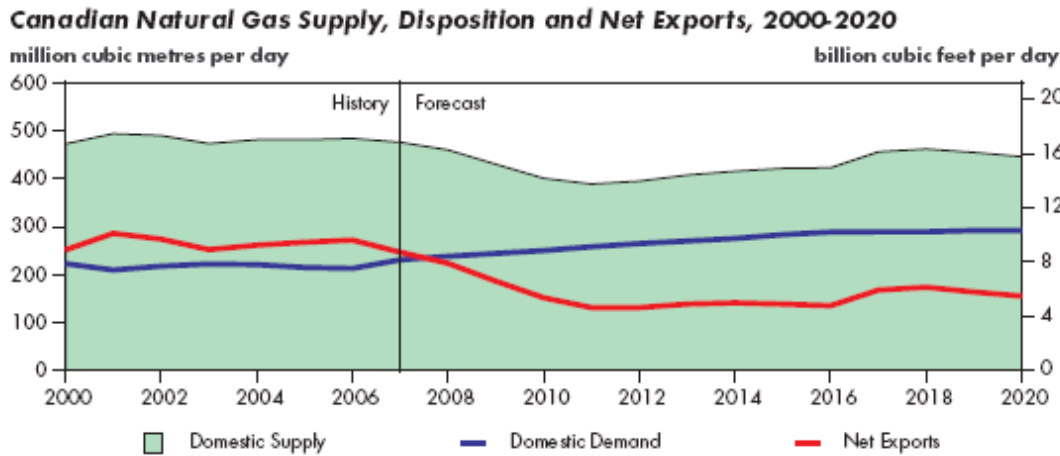
As of 2007, Canadian and US drilling continued to diverge: US recorded a 4% increase and is increasingly targeting unconventional gas plays, including shale gas in Texas, Arkansas, and Oklahoma, and coal bed methane in the US Rockies while Canada recorded a dramatic 25% decline. Historical trends show that NG production had been in decline up to 2008 but is now rising in the US. In Canada the production trend will bottom-out at 14.5 bcf/day in 2014, and then will begin to climb again to 16 bcf/day by 2020. The North American demand is expected to grow at approximately 1.5% per year. The average growth rate in Canada will be 2.3%. Overall, the North American supply is expected to increase by about 20% by 2020<sup>12</sup>.

The NEB reference case is shown in Exhibit 3.

---

<sup>12</sup> National Energy Board – Reference Case 2009

**Exhibit 3 Natural gas demand forecast in Canada (from National Energy Board 2009 Reference Case)**

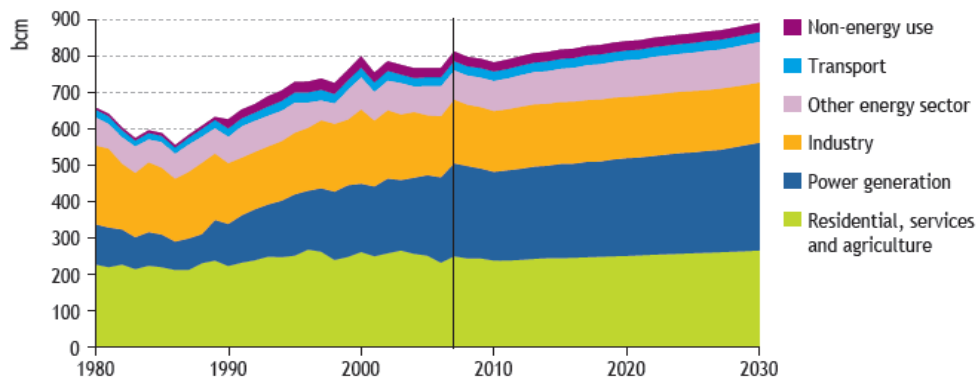


The World Energy Outlook (WEO) 2009 published by the International Energy Agency (IEA), natural gas production shows a significant increase in shale gas production in the US, but no significant overall increase in supply in North America.

The WEO 2009 also indicates that Canada has followed a very similar trend to that in the United States, with an increasing proportion of unconventional gas being developed as conventional basins mature. Several producing and service companies operate in both countries, using largely the same technologies, and knowledge is transferred rapidly from one market to the other. Production in Canada is projected to decline gradually, by 15 bcm between 2008 and 2030 in the Reference Scenario; it falls by a more marked 26 bcm in the 450 Scenario which assumes a coordinated global effort is in place to reduce GHG emissions.

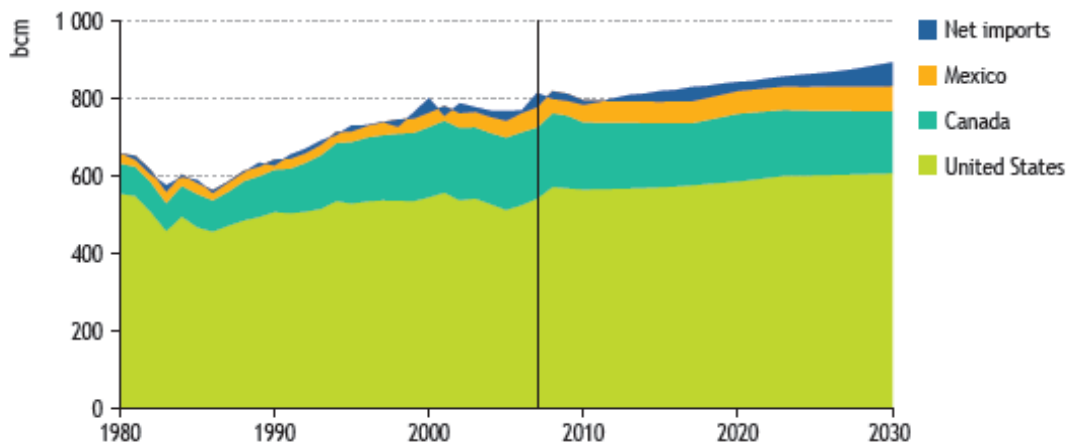
The IEA’s Natural Gas supply and demand outlook 2007-2030<sup>13</sup> for North America for total natural gas supplies including both conventional and unconventional (shale and tight gas, and coal bed methane) is illustrated in Exhibit 4 and Exhibit 5 respectively. The Canadian natural gas supply and demand forecast from WEO 2009 published data is presented in Exhibit 6.

**Exhibit 4 Natural gas demand forecast in North America (from World Energy Outlook 2009)**

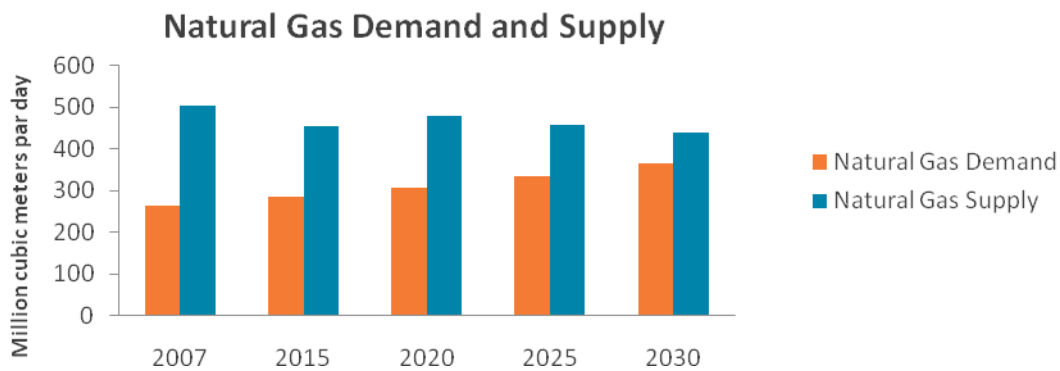


<sup>13</sup> Source: World Energy Outlook 2009, © OECD/ IEA 2009 – The graph corresponds to the OECD/IEA Reference Scenario (i.e. In the absence of drastic government action to reduce GHG emissions)

**Exhibit 5 Natural gas production forecast in North America (from World Energy Outlook 2009)**



**Exhibit 6 Natural gas demand forecast in Canada (from World Energy Outlook 2009)**



#### 4.1.2 Recent Events

##### *Development of Shale Gas Reserves*

Recent deployment of new technologies such as horizontal drilling and hydraulic fracturing to economically access unconventional gas resources, appear to be changing the market in a fundamental way. Among the various types of NG resources in North America, shale gas appears to be particularly promising. New discoveries and extraction activities related to shale gas plays are reported on a weekly, if not daily basis, indicating the fast growth dynamics in this NG segment.

Notwithstanding the official reports, the increasing pace of development of unconventional gas reserves (and shale gas in particular) is leading many industry observers to conclude that the natural gas market is no longer "supply-constrained". There is much optimism that North American reserves will be sufficient to meet the demand for 100 years or longer and expectations are that development of US supplies will reduce the level of Canadian exports, making more gas available in this country. Much of these dynamics are not yet well documented or reflected in the official (albeit recent) energy outlook reports.

Canadian shale gas plays that are being evaluated currently include:

- **Montney Formation** – The production of natural gas from horizontal shale gas wells in the Montney of northeast B.C. has risen from zero in 2005 to 10.7 10<sup>6</sup> cubic metres per day (376 million cubic feet per day) and is expected to continue rising. As of July 2009, 234 horizontal wells were producing from the Montney shale. Exploration companies have spent more than \$2 billion since 2005 to acquire rights in the Montney Formation from the B.C. government.
- **Horn River Basin** - Wells in this basin in northeast British Columbia are prolific and produce an average initial flow rate of 230,000 cubic metres per day (8 million cubic feet per day) with the top wells ranking amongst the most productive drilled in Western Canada last year. Exploration companies have spent over \$2 billion to acquire resource rights in this basin.
- **Colorado Group** - The Colorado Group of southern Alberta and Saskatchewan have been producing natural gas from shale for over 100 years. Because of poor rock conditions and the risk of caving in the wellbore, only vertical wells are planned in the Colorado shale.
- **Utica Group** - These shales, located between Montréal and Quebec City near the Appalachian Mountain front, have an increased potential for natural fractures. The potential for shale gas from the Utica Group is still in the early evaluation stages.
- **Horton Bluff Group** - While still in the early evaluation stage, two vertical wells drilled in New Brunswick have flowed 4,200 cubic metres per day (0.15 million cubic feet per day) after undergoing small fractures.

Mapping of shale plays is difficult due to the heterogeneity of the rock formations, their extremely low permeability and uncertainty as to the volume of reservoir that can be connected to a production well.

### *Environmental Considerations*

There are environmental issues with shale gas extraction that could affect the viability of recovery efforts. These include concerns about the effects that shale gas drilling has on the watershed, land-use footprint and a potential increase in lifecycle GHG emissions, among others.

Drilling and hydraulically fracturing wells can be water-intensive procedures. In the U.S., where water is extensively used in hydraulic fracturing, producers developing the Barnett Shale in Texas used one per cent of all the water consumed in the Fort Worth basin in 2007. Water that has been used to fracture a shale gas well can contain chemicals and additives so it is never allowed to enter the watershed. Typically, it is disposed of by injecting it deep below the earth's surface into rock formations, which is a common practice in Western Canada and strictly regulated by provincial authorities.

The land-use footprint of shale gas development is not expected to be much greater than conventional operations because advances in horizontal drilling allow for up to ten or more wells to be drilled from the same wellsite.

A number of factors can affect the relative GHG footprint of shale gas:

- **Leakage of methane.** Normally, field production, gathering and cleaning, separation of water or oil from associated gas, and the extraction of natural gas liquids reduce gross natural gas production by about 6 to 10 percent. There is no indication that this would be any different for shale gas.

- Fuel and energy use. The carbon footprint of a horizontal well exceeds that of a typical vertical well since the drilling process, the completion process, and the production stimulation process (hydraulic fracturing) require more carbon-based fuels, more drilling mud, and more water. Further, running the required equipment and pumps produces more emissions. On the other hand, developing equivalent amounts of natural gas resources requires two to three times more vertical wells than horizontals, for example, extracting 20,000 MMcf of natural gas may require 10 horizontal wells, but 25 to 30 verticals.<sup>14</sup>
- CO<sub>2</sub> releases. While not all shale gas contains significant amounts of CO<sub>2</sub>, the potential growth in carbon emissions from some shale gas is being addressed with proposals for carbon capture and sequestration.

On a per MMBtu basis, total GHG emissions from natural gas produced from shale formations are currently considered to be similar to those of natural gas from conventional sources. Still, it is very early to draw definitive conclusions regarding the potential impact of these developments on the environment.<sup>15</sup>

Movements opposing hydraulic fracturing are growing in NY State which is sitting at the edge of the enormous Marcellus shale play. The state has imposed a moratorium on drilling until it ensures the development won't threaten water sources. Also, a U.S. congressional committee is investigating drilling firms, including two Calgary companies, over concerns that their drilling for shale gas deposits may be contaminating water supplies.

Currently, shale gas producers have to comply with the same regulations as conventional natural gas producers, and provincial governments in Canada have well-established regulations in this area. This study did not examine whether provincial regulations in Canada regarding natural gas production are more stringent than those of the United States.

## 4.2 Fuel Delivery

In transportation applications, natural gas is used either as compressed natural gas (CNG) or liquefied natural gas (LNG).

- CNG is made by compressing natural gas to less than 1% of its volume at normal temperature and pressure. It is stored in steel or fibre-wound cylinders at high pressures (3000 psi) and used directly in spark-ignited or diesel engines.
- LNG is made by condensing natural gas at temperatures of approximately -162°C. The liquefaction reduces the volume by a factor of more than 2 compared to CNG and eliminates the need for high pressures. The LNG is stored on a vehicle in a double-walled stainless steel tank and it is vaporized before injection into the cylinders of a gasoline or diesel engine.

There is also potential to establish L-CNG stations that can dispense both LNG and CNG for a range of vehicles.

---

<sup>14</sup> Shale-Deposited Natural Gas: A Review of Potential, May 2009, California Energy Commission

<sup>15</sup> National Energy Board – Understanding Shale Gas, November 2009

### 4.2.1 Components and Players

Natural gas is typically piped from upstream supplies through standard transmission and distribution networks but may also be sourced from import terminals. Key components may include transmission pipelines, distribution networks, storage, and LNG import terminals.

- Transmission pipelines include pipelines and compressor stations to transport the gas across large distances from upstream supply areas to key market hubs.
- Distribution networks include the networks of piping, stations, services and meters to distribute the gas to end-users. These are owned and operated by Local Distribution Companies (LDCs) who are typically regulated as monopoly utilities.
- Storage includes depleted gas or oil reservoirs, or engineered storage caverns mined in salt formations. Being able to store gas gives market participants the ability to have a physical hedge (insurance) against price volatility and to store excess gas in the summer months for use during the winter heating season.
- LNG import terminals involve specially constructed vessels delivering imports of LNG from overseas LNG plants to shipping terminals and regasification plants in North America. The only operating terminal in Canada is the Canaport LNG Terminal in Saint John, NB.

LNG infrastructure includes liquefaction plants and stations.

- LNG Plants require special cooling systems and cryogenic tanks to maintain low temperatures. Plants range in size from 50,000 to 1 million litres/day, cost from \$5-50 million. LNG Plants could obtain gas from distribution networks, or directly from transmission pipelines or import terminals.
- LNG stations typically include storage containers, dispensers, control systems and meters. Some stations may also include CNG dispensers. The typical cost for an LNG station is about \$2.5 million.
- Plants and stations may or may not be co-located. In the latter case, tanker trucks are required to deliver the LNG to the stations.

CNG infrastructure includes a range of slow or fast fill station designs, typically consisting of compressor, storage and dispensing equipment.

- High pressure fast fill stations can supply up to 25-50 LDE per minute and meet the needs of up to 100 transit buses for a cost of \$2-3 million.
- Smaller units could supply a fleet of 10 MDVs for approximately \$250,000 with fast fill, or about \$150,000 for overnight slow fill.
- Vehicle Refuelling Appliances can be slow fill or fast fill. They range in price from \$35,000 for fast fill quad dispenser (for 10 LDV / forklifts) to \$6,000-7,000 for slow fill dispenser (for single LDV / ice resurfacer).

### 4.2.2 Current Fuel Supply

Currently, the only form of NG fuel used in Canada is CNG. CNG is available from approximately 72 public and 12 private stations. Public stations are typically operated by traditional fuel retailers (e.g. Shell). The gas is supplied by LDCs, and the compression, storage and dispensing equipment is either owned or provided by a service provider (e.g. Clean Energy). Fleets may or may not have private fuel supply (transit bus applications usually have a private supply).

LNG is not currently used for transportation in Canada, however Gaz Métropolitain, Union Gas and Terasen Gas have small LNG plants, with associated LNG storage facilities. Existing public stations can provide refuelling for heavy vehicles, but space and onsite compression capabilities

need to be considered. Similarly, the compatibility of dispenser designs may also be an issue, as there are different versions and not all pairs of vehicle fuel receptors – fuel dispensers are compatible.

### 4.2.3 *Future Fuel Supply*

Possible players include upstream companies (e.g. Encana), transmission companies (e.g. Transcanada), LDCs (e.g. Enbridge, Gaz Metro), service providers (e.g. Clean Energy, Gaz Metro), fuel retailers (e.g. Shell), or fleet owners (e.g. municipalities, trucking firms, large retailers).

So far, Terasen has obtained regulatory approval to sell excess LNG from its TGI Tilbury facility (located in Delta, BC) for transportation use as a five year pilot and Gaz Metro is looking to offer LNG or CNG for fleet, rail and marine applications<sup>16,17</sup>.

Encana has proposed the construction of several LNG plants and stations along the Quebec City – Windsor corridor and in Alberta and BC. However the business model for this initiative is not yet clear, nor is it clear who would build, own and operate the plants and the retail infrastructure.

For regulated transmission or distribution utilities, a key consideration is whether or not regulators (i.e. provincial energy/utility boards and commissions) would allow investments in fuelling infrastructure to be rate based. Ratebasing the investments would allow a predictable return and would mitigate key risks but, to be effective, it would likely depend on cross-subsidization from residential and commercial customers, which would be difficult for regulators to approve without strong signals from governments. If the business case were strong enough, some utilities might consider making the investments on the non-regulated sides of their business. This would likely require a higher level of confidence in the timing and scale of the transportation market.

### 4.2.4 *Pricing*

In general, the main factors that affect price volatility are:<sup>18</sup>

- Storage levels: high storage levels promote lower prices and vice versa (short term effect)
- Crude oil influence (longer term effect) due to fuel switching at industrial and power generation facilities
- Regional supply and demand: natural gas prices are the lowest in Alberta and the Rockies
- Limitations in distribution capacity
- Speculations based on economic forecasts of commodity prices.

#### *Commodity Prices*

The main factors responsible for recent (2007-2008) natural gas commodity prices were the dramatic increase in US natural gas production driving prices down and volatility in the price of crude oil driving prices both up and down. The average intra-Alberta NG price for 2000-2007

---

<sup>16</sup> British Columbia Utilities Commission – Order number G-65-09

<sup>17</sup> From consultations with Gaz Metropolitan, March 2010.

<sup>18</sup> “What Drives Natural Gas Prices?”, Stephen P. A. Brown and Mine K. Yücel (Research Department, Federal Reserve Bank of Dallas), The Energy Journal, Volume 29, Number 2, 2008, International Association for Energy Economics

period was \$6.07/GJ, with several peaks over \$10. Moving forward, prices expected to remain in the range of \$6/GJ.

### Retail Prices

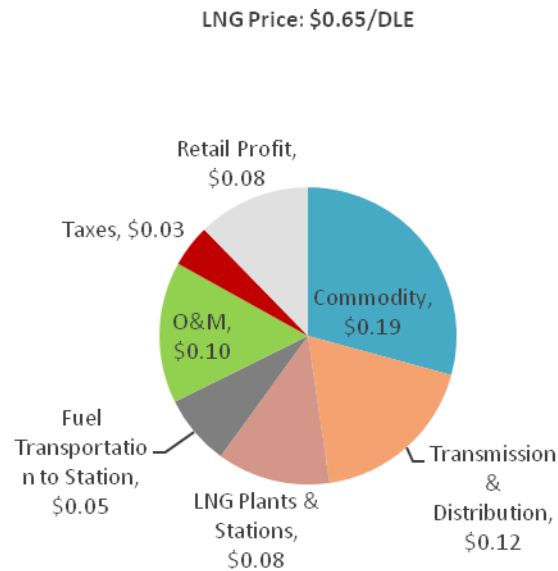
There is currently no market for transportation LNG in Canada and very small one for CNG. The lack of completion and the fact that fuel prices are tied to regulated quarterly price adjustments leads to higher prices than necessary.

- Current prices for CNG range from \$0.60 to \$0.80/litre of diesel equivalent (DLE). \$0.65/DLE is considered to be a representative price for initial stages of an expanding marketplace.
- Prices for LNG in California are in the range of C\$0.60/DLE. Canadian prices for LNG could be lower initially as suppliers make use of existing excess LNG capacity but would eventually also be expected to be in the neighbourhood of \$0.65/DLE

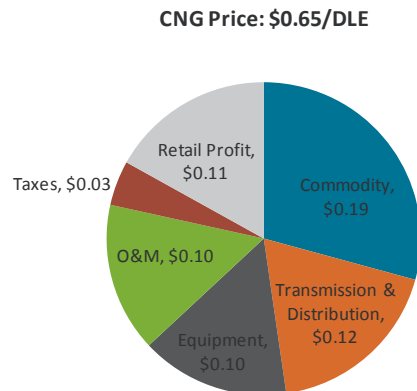
As noted in Exhibit 7 and Exhibit 8, at the expected prices, returns should be highly attractive for either public or private stations (these are based on a commodity price of \$5.50/GJ).

The financial analysis for NG vehicle purchases is presented separately in Section 7, followed by a discussion of non-financial barriers in Section 8.

### Exhibit 7 LNG Price Components



## Exhibit 8 CNG Price Components



### 4.3 Biogas

Renewable natural gas (RNG) or biogas as commonly referred to is another type of methane-based gas with similar properties to natural gas that can be used as transportation fuel.

Sources of biogas are mainly landfills, sewage and animal/agri-waste. Based on the process type, biogas can be divided into the following: Bio gas produced by anaerobic digestion, contains mainly CH<sub>4</sub> and CO<sub>2</sub>; Landfill gas collected from landfills, treated to remove trace contaminants, composition similar to biogas; and Synthetic Natural Gas (SNG), contains mainly CH<sub>4</sub>, produced via biomass gasification followed by methanation.

In addition to methane the following compounds might be present in biogas: water vapour, carbon dioxide, hydrogen sulphide, siloxane, aromatic compounds, air (oxygen, nitrogen), halogenic compounds (chlorides, fluorides).

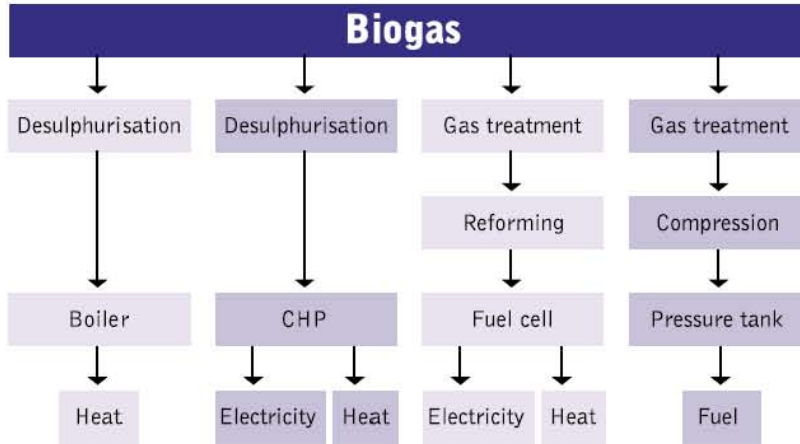
Cleaned biogas can be converted to CNG or LNG through similar processes, or can be introduced to utilities natural gas pipelines to serve distant clients, hence eliminating storage issues.

The cost of biogas depends of the level of processing. Use of biogas in transportation requires a much higher quality than biogas one used in boilers. Current costs are \$7-8 per GJ assuming the existing collection pipes are already in place.

The current costs of biogas are not competitive with natural gas but could be competitive with diesel/gasoline.

Biogas can be used in various end uses to produce heat and/or electricity. Cleaning, treatment and upgrading requirements depend on the type of end use.

### Exhibit 9 Different Processing Paths for Biogas<sup>19</sup>



<sup>19</sup> “Biogas Production and Utilisation”, International Energy Agency (IEA), 2005

## 5 Technology Trends

### 5.1 Heavy and Medium Duty Vehicles

Heavy and medium duty vehicles use two types of engine technologies: Spark Ignited (SI) engines and High Pressure Direct Injection (HPDI) engines. Both types are commercially available. HDVs are supplied with either LNG or CNG fuel tanks. LNG is more suitable for longer haul vehicles but lack of stations is the main impediment to general market growth.

#### *Spark Ignited Engines*

SI engines are used in return to base refuse trucks, transit and school buses. SI engines typically use CNG.

The main suppliers of SI engines are Cummins Westport, Doosan Infracore, Emissions Solutions (ESI), Iveco, Daimler, Volvo, MAN, Scania, Shanghai Diesel, Weichai Petersen and Hyundai.

Cummins Westport is based in Vancouver, BC. It produces heavy duty natural gas SI engines that are sold worldwide. Doosan Infracore and Emissions Solutions (ESI) produce spark ignited engines for North America. Iveco, Daimler, Volvo, MAN and Scania supply SI engines in Europe, Asia and South America, as does Doosan, Cummins Westport, Shanghai Diesel, Weichai Petersen, Hyundai. There is also dual fuel CNG/LNG but only as a non-certified aftermarket retrofit (by Hardstaff, Clean Air Power)<sup>20</sup>.

SI engines have a typical additional cost of \$50,000 compared to diesel heavy duty engines which consists of \$10,000 engine cost and \$40,000 integration costs, including tanks. A HDV using natural gas fuel is about 10% less efficient than one using diesel fuel.

The most recent ISL G engine manufactured by Cummins-Westport operates on either CNG or LNG. Rated at 320 hp and 1,000 lb-ft of torque, the ISL G is compliant with 2010 emission standards without the use of selective catalytic reduction (SCR) or a diesel particulate filter (DPF). CNG and LNG fuel tanks can be configured to suit customer applications and range requirements.<sup>21</sup>

#### *High Pressure Direct Injection Engines*

High Pressure Direct Injection (HPDI) engine technology is used in Class 8 trucks.

BC-based Westport Innovations adapts Cummins engines for HPDI, adding dual fuel injectors (diesel pilot and NG main fuel charge) and other equipment. Cummins –Westport has sold over 20,000 ISL G 8.9 Litre engines worldwide. Cummins – Westport and Westport Innovations supply about 15 OEMs worldwide. MAN and Iveco sell heavy duty natural gas engines in the European market.

HPDI engines have the same efficiency as diesel engines and can be driven up to 1000km on one fuel charge. The engines typically cost \$70,000 more than diesel engines and the LNG

<sup>20</sup> From consultations with Westport, March 2010.

<sup>21</sup> “Kenworth Expands Natural Gas Truck Line with T440 Powered by ISL G”, The Globe and Mail, March 24, 2010

tanks cost an additional \$10,000 each (line-Haul HDVs typically require 2 LNG tanks). Westport produces up to 2400 engines per year in Vancouver, mainly for export to the US and China.

## 5.2 Light Duty Vehicles

Natural gas Light Duty Vehicle (LDV) technology is commercially available but its availability in North America is extremely limited. Honda is the only OEM to offer a natural gas LDV in the North American market, with the CNG-driven Civic. It has limited sales (700 per year) in the US only.

In the absence of significant OEM offerings, another source of NG LDVs is the OEM-approved upfitting of NG technology. Fuel metering/injection technologies are well developed for low volume LDVs and there are many North American conversion suppliers, including BAF, IMPCO, Baytech, FuelTek, ECO Fuel Systems. Ford and GM are each planning to produce one natural gas ready engine for the North American upfitting market, but the timing and availability remains uncertain. Even in the upfitting market, the number of engine/vehicle combinations for light van and pickup truck markets is limited. Suppliers (non-OEM) have difficulty in introducing more makes/models due to technical, regulatory and financial barriers and lack of OEM support. Therefore, an increased market volume is difficult to support with current supplier industry. The lack of a sufficient number of Qualified Vehicle Modifiers (QVMs), has led to uncertified kits and installations sold sometime through Internet causing safety and quality concerns.

Storage tank cost, weight and size is a challenge for LDVs, especially as the vehicles are likely to get smaller over the next decade, in part to reduce GHG emissions. Thus low pressure storage technology will be needed, leading to conformable tanks. The NG technology will also need to adapt to smaller vehicle platforms, turbo-downsized engines, variable valve control, etc.

The price increment is typically around \$6,500 with respect to gasoline-driven models. Fiat and Volvo offer NG cars in Europe at much lower prices. In US, an EPA certified pick-up truck or panel van cost an additional \$14,000 to \$18,000 compared to a gasoline-driven truck. The lack of competition and the availability of generous US incentives are leading causes of excessive price mark-ups. The LDV market would benefit from increased competition, especially among the OEMs (Fiat, Volvo, etc.)

## 5.3 Marine

Natural gas marine technology is commercialized. Marine diesel engines are available that can burn NG with pilot diesel injection, with seamless fuel switching (NG/Diesel/HFO). Companies such as MAN and Wärtsilä manufacture large displacement HPDI engines for the large ship market.

The preferred NG fuel for marine application is LNG. LNG tanks need to be integrated into new vessel design; hence, additional design costs and construction cost increments are involved. These typically amount to approximately \$100,000 per vessel for design and \$5 million per vessel for construction.

Some ships may idle a long time during which they use diesel. Therefore, an anti-idle strategy is needed to avoid more diesel fuel being used at idle compared to cruise. The fuel consumption ratio is currently about 36% diesel-64% NG during idling and 4% diesel-96% gas NG during cruising.

## 5.4 Rail

Natural gas locomotive technology is NOT commercialized. However, it has been demonstrated that the common diesel or diesel-electric technology can be adapted to Westport's HPDI technology. Demonstrations have occurred in the US in the past that showed the feasibility of integrating NG to locomotive engines. There are additional design costs and construction cost increment to be borne in order to adapt and optimize NG technology in rail applications.

LNG is the preferred NG fuel for rail applications. It is especially well suited to high-load short-distance operations such as ore or coal hauling. Good examples of such applications are found in the Australian iron ore industry.

In order to provide enough fuel supply, LNG tanks need to be integrated into trains or railcars. LNG railcars are already available. In line haul trains, these railcars need to be hauled over large distance, causing feasibility issues with the LNG technology.

In rail applications, engine idling is very common. The current NGV technology uses diesel piloting during idling which reduces the benefits of NG fuel. The higher use of diesel at idle (36%) and low fuel use in rail yard operations require further technology improvements.

Even though the NG locomotive technology is not mature, in 2001, the Napa Valley Railroad and the Napa Valley Wine Train in California undertook the conversion of one locomotive to CNG, starting with 60 percent natural gas and 40 percent diesel fuel mixture. By early 2008, the conversion to compressed natural gas was 100 percent.<sup>22</sup>

There is a serious interest in NG for rail in Canada, but projects could take a long time to realize.<sup>23</sup>

## 5.5 Indoor Equipment

Indoor equipment suited to natural gas fuel includes forklifts and recreational equipment such as ice resurfacers. These vehicles run typically on propane or electricity. There is a growing trend in converting propane forklifts to natural gas using aftermarket conversion kits.

Among engine manufacturers, Westport has recently started to produce 2.4 litre and 2.0 litre LPG and CNG engines for forklifts through its joint venture partner Juniper Engines Inc.

Korean manufacturers are dominant in the global market for natural gas driven forklift engines. Toyota also offers a factory-direct natural gas forklift

Indoor equipment is usually serviced by private VRAs. FuelMaker manufactured VRAs in Canada until 2009. However, with the purchase of FuelMaker assets by Italian-based Fuel System Solutions (through its subsidiary IMPCO), Canadian manufacturing ceased and shortages of parts and services for existing VRA units in use in Canada have been a problem. This situation is expected to improve by Q3 2010<sup>24</sup>. The deployment of alternatives to the current VRA choice

---

<sup>22</sup> <http://winetrain.com/ontrack/news-rail-yard>

<sup>23</sup> Communications with Westport, March 2010.

<sup>24</sup> From consultations with Westport and CNGVA, March 2010.

would be helpful to ensure the continued development of the off-road market<sup>25</sup>. One option is higher cost refueling stations which may be affordable for larger forklift fleets.

The benefits of using natural gas to power indoor equipment include:

- Improved air quality resulting in better health and safety of employees;
- Safer than propane alternatives since the refueling process does not require lifting of heavy tanks;
- Ease of refueling using VRA overnight or between uses;
- Natural gas units are lighter than electric alternatives, which can require facility retrofits; and
- Lower cost of natural gas results in a good return on investment.

---

<sup>25</sup> From consultations with Westport, March 2010.

## 6 Environmental Analysis

### 6.1 Greenhouse Gas (GHG) Emissions

This section provides a comparison of GHG emissions for conventional vehicles and NGVs. Results are provided for heavy, medium and light duty, refuse trucks, marine and rail. GHGenius 3.16 was used for light duty vehicles. For HDV, MDV, marine and rail segments, the freight emission calculation capability in GHGenius version 3.17 was used. This version has the functional unit of tonne-km (i.e., the movement of one tonne of goods one kilometre) which is a better reference for transportation systems used to move goods.

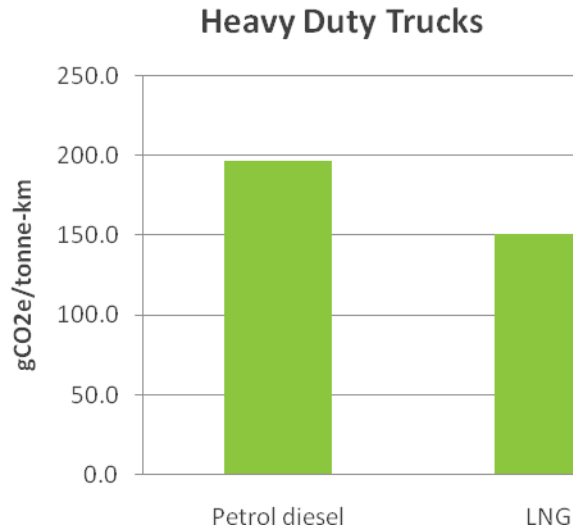
The following factors were included in the calculations of the lifecycle emissions:

- Vehicle operation
- Carbon in end-use fuel from CO<sub>2</sub> in air
- Net Vehicle Operation
- Fuel dispensing
- Fuel distribution and storage
- Fuel production
- Feedstock transmission
- Feedstock recovery
- Land-use changes, cultivation
- Fertilizer manufacture
- Gas leaks and flares
- CO<sub>2</sub>, H<sub>2</sub>S removed from NG
- Vehicle materials, assembly

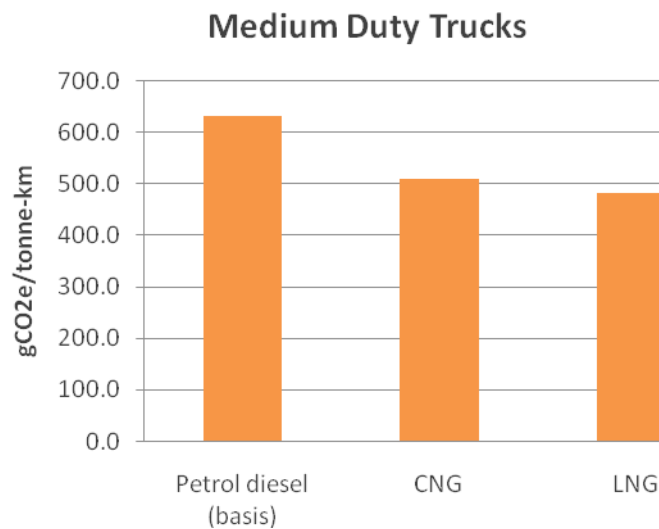
For each segment the results are illustrated in two forms. First, the emissions from the base fuel used in the vehicle are compared with the replacement NG fuel (CNG, LNG, or both, if applicable). Then, the percentage change by using the NG fuel compared with the base fuel is noted.

The results are shown in Exhibit 10 through to Exhibit 16. Overall, lifecycle GHG reductions of 15-25%, depending on the end use, are obtained for NG fuel. The most significant reductions are obtained in the HDV, MDV, and LDV segments, which show reductions above 20%. As noted in Exhibit 13, biogas as a renewable fuel, has the benefit of much lower GHG emissions than non-renewable natural gas.

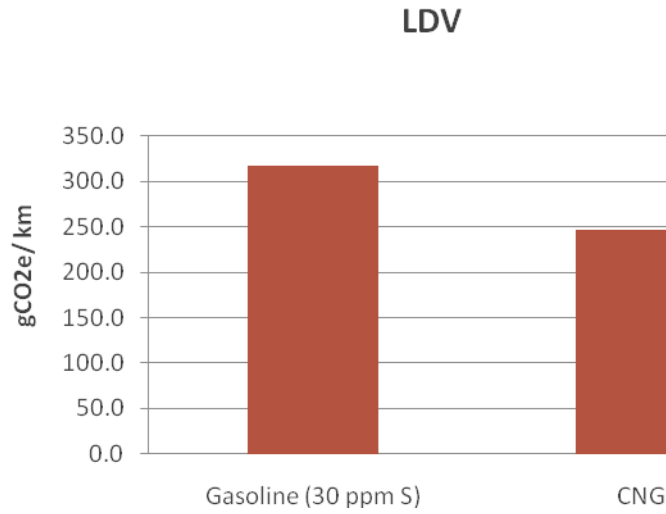
**Exhibit 10 GHG emissions calculated for heavy duty trucks (23% reduction for LNG in comparison with diesel)**



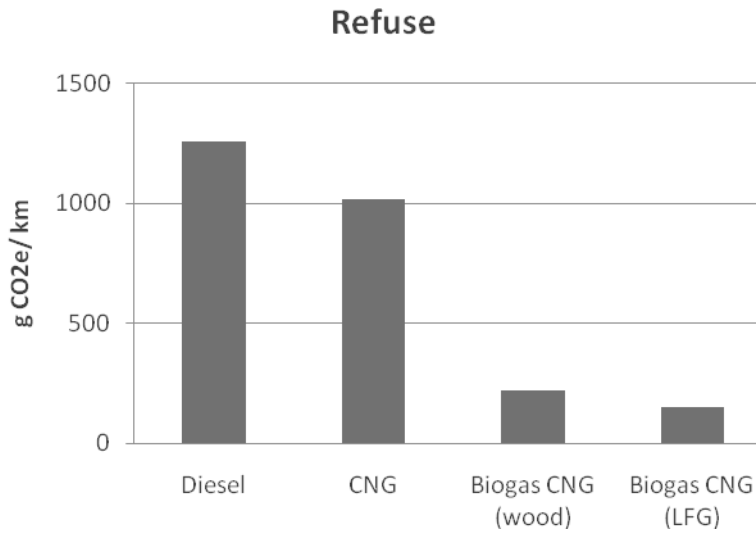
**Exhibit 11 GHG emissions calculated for medium duty trucks (19% decrease for CNG, 23% decrease for LNG in comparison with diesel)**



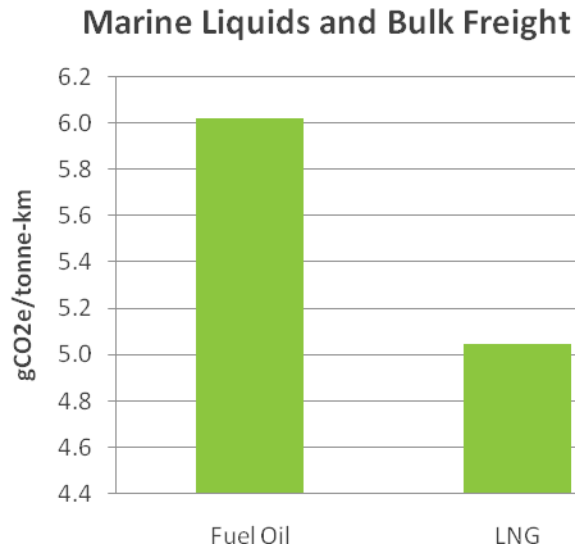
**Exhibit 12 GHG emissions calculated for light duty vehicles (23% decrease for CNG in comparison with gasoline)**



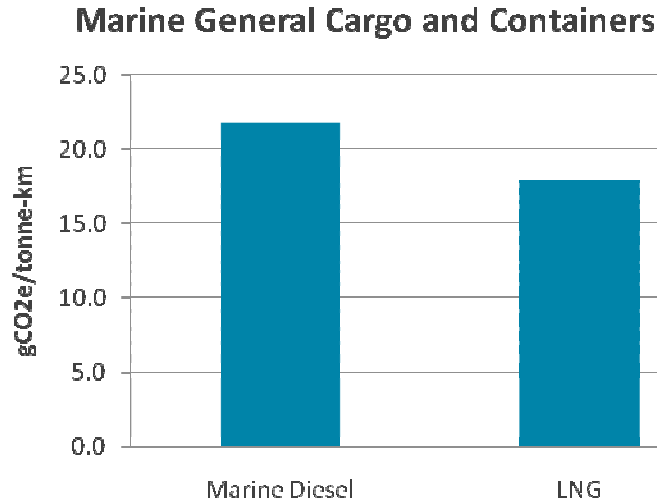
**Exhibit 13 GHG emissions calculated for refuse trucks (19% decrease for CNG, 82% decrease for wood-based biogas, 88% decrease for landfill gas in comparison with diesel)**



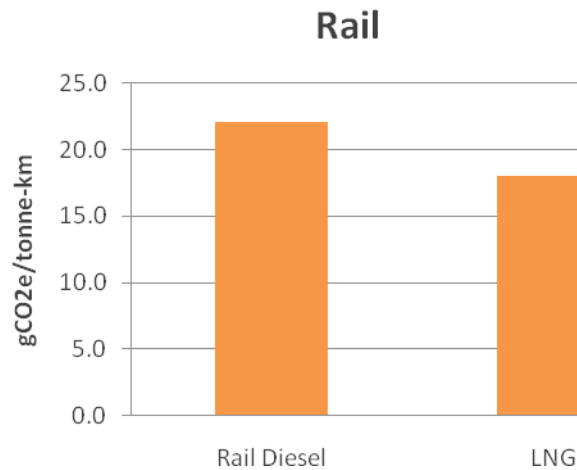
**Exhibit 14 GHG emissions calculated for marine – Liquids and bulk freight (16% decrease for LNG in comparison with heavy fuel oil)**



**Exhibit 15 GHG emissions calculated for marine – General cargo and containers (18% decrease for LNG in comparison with marine diesel)**



### Exhibit 16 GHG emissions calculated for rail freight (19% decrease for LNG in comparison with rail diesel)



### Criteria Air Contaminant (CAC) Emissions

The implications for CAC emissions vary by market segment:

- HDV/MDV. Natural gas has had a long-standing advantage in producing fewer emissions of a variety of CACs than diesel vehicles. Although HDV diesel exhaust will be cleaner because of 2010 standards, NG still has an advantage in Particulate Matter (PM) emissions over diesel as diesel particulate has more potentially carcinogenic content than NG. Tractors are able to meet 2010 CAC standards more easily than diesel vehicles, with less maintenance to emission control equipment due to lower engine-out PM and NO<sub>x</sub> emissions.
- Marine and Rail. NO<sub>x</sub> and PM emissions benefits from low sulphur gas displacing heavy fuel oil and marine diesel are likely to be particularly important for commuter trains and emission control areas in marine applications. For marine, conversion to NG would mean that the vessels could easily meet new CAC standards for environmentally sensitive regions around ports and Great Lakes. Significant fuel cost savings possible as low sulphur diesel would be largely replaced by NG.
- Indoor Equipment. Indoor air quality improves by using NG in forklifts and ice-resurfacers.

NG vehicles may have advantage over other technologies in meeting the fixed cap for tailpipe methane emissions.

New diesel emission control systems are costly (\$8-9K for SCR system plus operating costs). School bus operators in the US, having been subjected to DPF retrofit programs, are balking at further SCR additions to their vehicles, and are leaning to the idea of switching to simpler natural gas fuelling.

## 7 Financial Analysis

In this Section, the financial aspects of NGV purchase decisions are analyzed (note: the financial analysis of fuelling infrastructure investments was presented previously in Section 4). Financial viability is characterized in terms of simple payback, net present value (using a 10% discount rate), and internal rate of return. The NPV is based on the life of vehicle, engine or tanks, whichever is longest.

Viability is assessed for a variety of end-use natural gas vehicle fleet application, including several medium and heavy duty vehicles scenarios, light duty vehicles, marine vessels, and indoor equipment (note: viability is not assessed for rail because the technology is not commercially available).

Capital cost assumptions are based on the analyses provided in Section 5. Other assumptions are based on information collected from industry stakeholders and experts.<sup>26</sup> The following fuel prices assumptions are used (note that these are the same prices that were noted in our market assessment and used to calculate the viability of fuelling infrastructure investments):

- Diesel: \$0.95/L
- Gasoline: \$1.00/L
- LNG: \$0.65/DLE
- CNG: \$0.65/DLE
- Propane: \$0.70/L

For each application, a sensitivity analysis is performed. Multiple curves based on variations in fleet energy consumption (litres of fuel consumed) or capital cost increment are provided on the same graph. The cost curves are presented for each fleet application, showing capital investment payback based on fuel retail price differentials (natural gas/gasoline or diesel) (y-axis) and time (years) (x-axis).

It should be noted that GHG credits could add 1-3 cents incremental benefits/DLE but these credits were not included in the analysis.

### 7.1 Financial Scenarios

Eight Scenarios based on commercially available options were considered. These are described in Exhibit 17.

---

<sup>26</sup> Note: the analysis assumes that operating costs (other than fuel) are the same for NG and conventional vehicles. The new ISL G engine introduced by Cummins-Westport in March 2010 could add further NG savings by eliminating the need for the use of selective catalytic reduction (SCR) or diesel particulate filter (DPF).

## Exhibit 17 Financial Scenarios for NGV Segments

Scenario 1 – HDV line haul (e.g. Robert) using LNG fuel	<ul style="list-style-type: none"> <li>■ Capital Cost Increment \$90,000</li> <li>■ Life of engine: 5 years</li> <li>■ Life of tanks: 10 years</li> <li>■ Annual Fuel Consumption 95,000 litres</li> <li>■ Annual Fuel Savings: \$27,000</li> </ul>
Scenario 2 – HDV return to base truck (e.g. Molson) using LNG fuel	<ul style="list-style-type: none"> <li>■ Capital Cost Increment \$70,000</li> <li>■ Life of engine: 5 years</li> <li>■ Life of tanks: 10 years</li> <li>■ Annual Fuel Consumption 60,000 litres</li> <li>■ Annual Fuel Savings: \$17,550</li> </ul>
Scenario 3 – Transit bus using CNG	<ul style="list-style-type: none"> <li>■ Capital Cost Increment \$45,000</li> <li>■ Life: 10 years</li> <li>■ Annual Fuel Consumption 40,000 litres</li> <li>■ Annual Fuel Savings: \$10,800</li> </ul>
Scenario 4 – Refuse Truck using CNG	<ul style="list-style-type: none"> <li>■ Capital Cost Increment: \$50,000</li> <li>■ Life: 8 years</li> <li>■ Annual Fuel Consumption: 28,500 litres</li> <li>■ Annual Fuel Savings: \$7,700</li> </ul>
Scenario 5 – LDV using CNG	<ul style="list-style-type: none"> <li>■ Capital Cost Increment \$8,000</li> <li>■ Life: 8 years</li> <li>■ Annual Fuel Consumption: 5,000 litres</li> <li>■ Annual Fuel Savings: \$2,100</li> </ul>
Scenario 6 – Marine takers using LNG	<ul style="list-style-type: none"> <li>■ Capital Cost Increment: \$5.1m</li> <li>■ Life: 30 years</li> <li>■ Annual Fuel Consumption: 3.9m litres</li> <li>■ Annual Fuel Savings: \$1.1m</li> </ul>
Scenario 7 – Forklifts using CNG	<ul style="list-style-type: none"> <li>■ Capital Cost Increment: \$5,000</li> <li>■ Life: 8 years</li> <li>■ Annual Fuel Consumption: 7,200 litres</li> <li>■ Annual Fuel Savings: \$2,650</li> </ul>
Scenario 8 – Ice resurfacers using CNG	<ul style="list-style-type: none"> <li>■ Capital Cost Increment: \$7,000</li> <li>■ Life: 12 years</li> <li>■ Annual Fuel Consumption: 3,600 litres</li> <li>■ Annual Fuel Savings: \$1,325</li> </ul>

## 7.2 Results

Results are shown in Exhibit 18 through Exhibit 20.

**Exhibit 18 Financial Viability Results**

Market Segment / Scenario	Capital Investment	Payback (years)	NPV	IRR
HDV line Haul	\$90,000	3.3	\$48,140	22.4%
HDV RTB	\$70,000	4.0	\$9,613	13.5%
Transit Bus	\$45,000	4.2	\$37,146	22.9%
Refuse Truck	\$50,000	6.5	-\$8,948	4.9%
LDV	\$8,000	3.8	\$3,203	20.2%
Marine - Lakers	\$5,100,000	4.6	\$5,378,015	21.7%
Forklift	\$5,000	1.9	\$7,115	44.1%
Ice Resurfacer	\$7,000	5.3	\$503	11.5%

**Exhibit 19 Simple Payback Results**

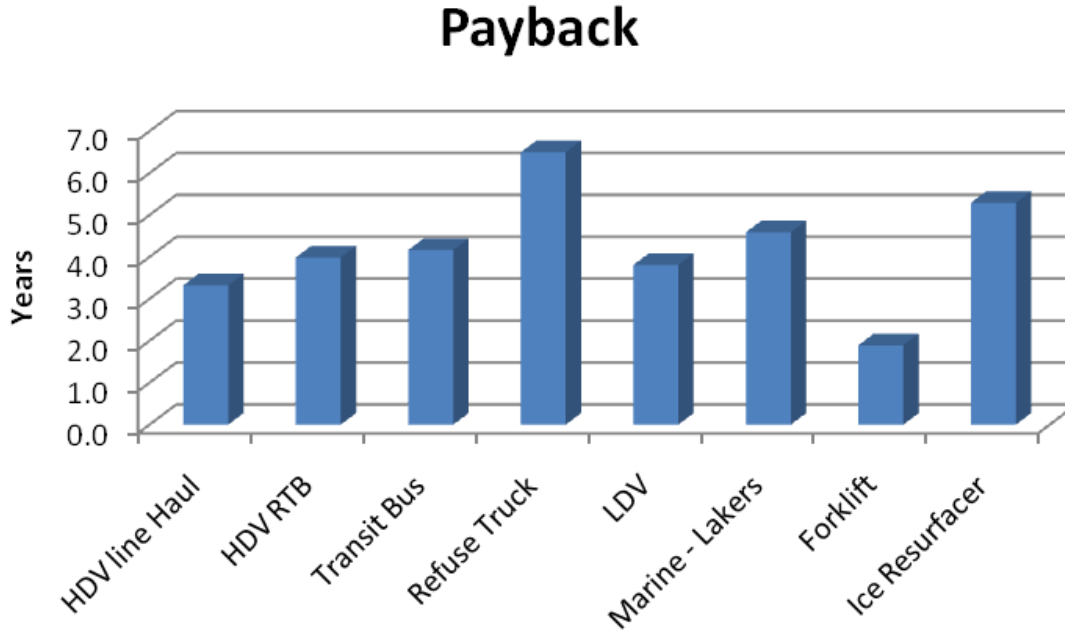
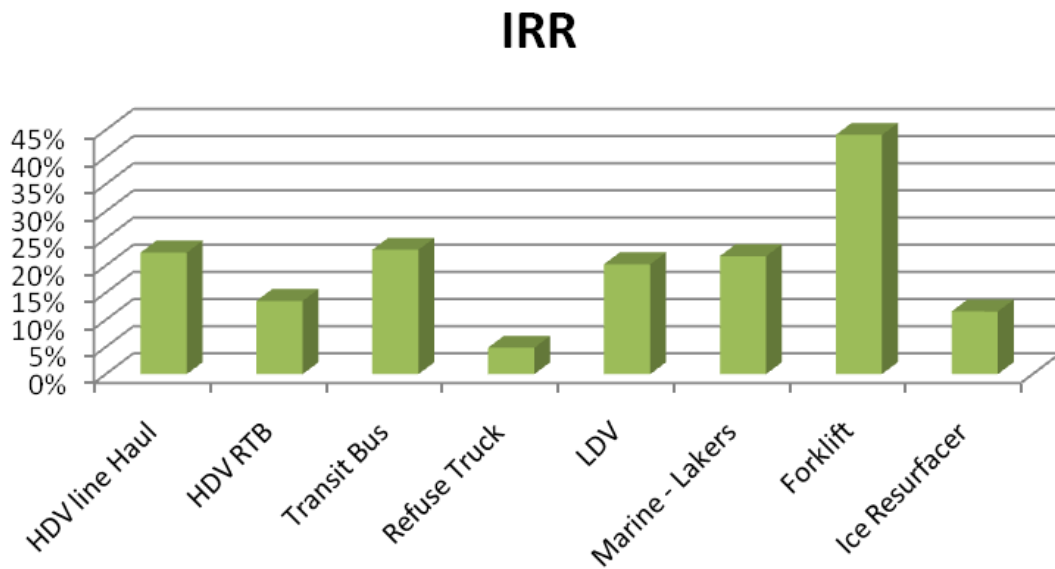


Exhibit 20 Internal Rate of Return Results



### 7.3 Sensitivity Analysis

Exhibit 21 through Exhibit 24 illustrates the variability of payback to various assumptions concerning capital cost increment, price differential and fuel consumption.

Exhibit 21 HDV/MDV Cost Curves

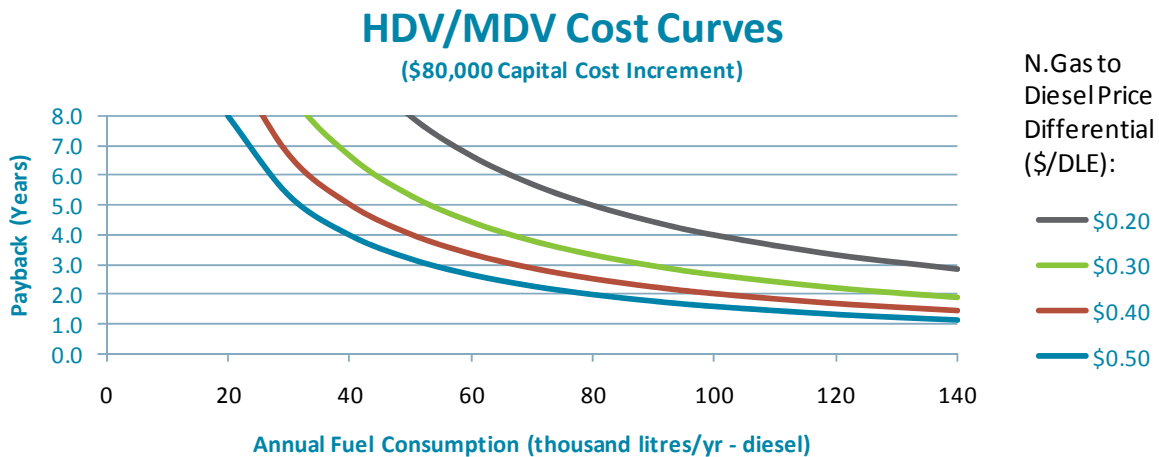


Exhibit 22 Refuse Truck Cost Curves

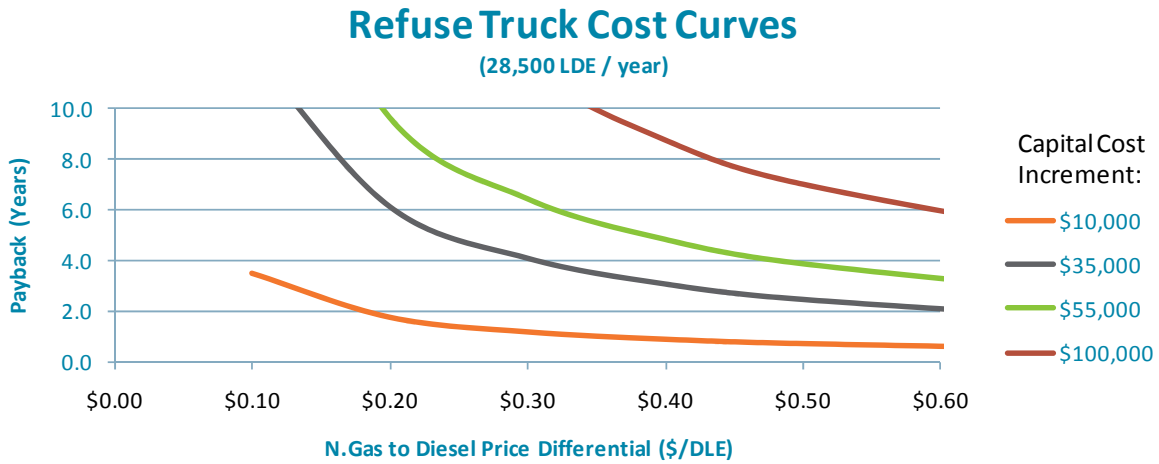


Exhibit 23 LDV

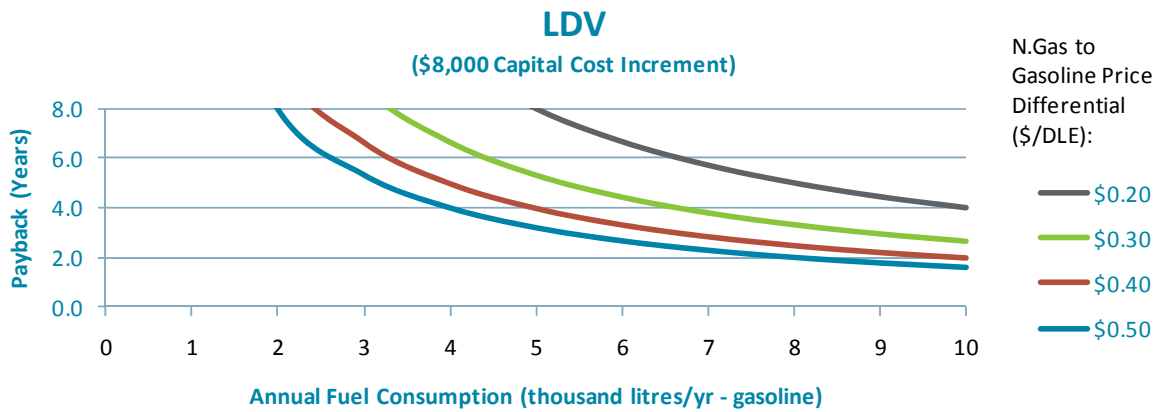
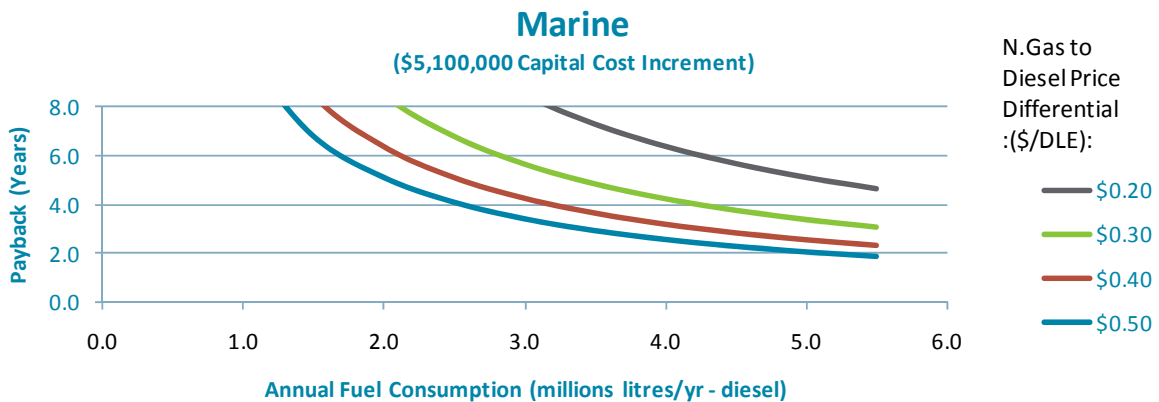


Exhibit 24 Marine



## 7.4 Implications

The financial analysis indicates that all segments except refuse truck are economically viable, provided that fuel is available at the assumed retail price. Other observations include:

- The forklift segment offers the best return, almost 45%.
- Line haul, transit bus, LDV and marine segments offer attractive returns, in the range of 20%. Because of the large sums involved, the marine scenario is particularly attractive in terms of the absolute dollars.
- The Return-to-Base HDV scenario and the ice resurfacers scenario are only marginally viable, in the range of 10-15% return.
- The refuse truck segment could be financially viable if capital cost increment could be reduced, say by \$15,000.

Although financial viability is an important determinant of the achievable potential, several of these segments/scenarios have other important advantages that could improve their prospects. For example, the environmental advantages of NGVs were noted in Section 6. In the context of indoor equipment, these environmental advantages translate into health advantages which can be overriding. In the case of refuse trucks, municipal interest in the GHG reduction advantages of biogas and the fact that refuse fleets are often under municipal control provides an attractive combination.<sup>27</sup>

---

<sup>27</sup> From consultations with Westport and CNGVA

## 8 Barriers and Solutions

The review of the history of NGV development in Canada and lessons learned from the current and existing programs in other jurisdictions reveal that several barriers have prevented the development of a sustainable NGV market. These are both market and non-market barriers. Before any policy and programs can be designed to support the NGV market, it is important to identify these barriers and ways of overcoming them.

In this study we have divided these barriers into general and segment-specific barriers. These are presented in Exhibit 25 through Exhibit 31.

### 8.1 General

Exhibit 25 lists general market barriers that apply to all segments, along with possible ways to overcome them. Overlaid on these barriers is a general lack of understanding and confidence among a variety of stakeholders. Overcoming this will require a comprehensive communications strategy – potential elements of which are presented in Exhibit 25.

**Exhibit 25 General Market Barriers for all NGV Segments**

Barrier Type	General Barriers for all End-Use Segments	Ways of Overcoming
Market	Chicken and egg dilemma (vehicles & stations)	Simultaneous development of end use technology and fuel distribution and retail infrastructure
Market	Concern about availability of fuel/refuelling stations	Large upstream NG suppliers entering early into retail market, fuel suppliers marketing directly to end-users
Market	Limited range (related to concern of insufficient/not optimally located refuelling stations)	Target return to base fleets
Market	Concern regarding price fluctuations of the fuel	Long term federal and provincial deals with NG suppliers
Market	Limited choice of vehicles and engines for CNG and LNG	Facilitating vehicle imports, business incentives for the development of new NG vehicle plants
Market	Lengthy delivery times for vehicles (and parts)	Increase number of suppliers (competition)
Market	Increased maintenance costs for vehicles (Need for training mechanics and periodic high-pressure storage tank testing)	Financial support to cover the cost of training mechanics and acquiring tools. Some cost reductions come from possible longer oil change cycle with NG and extended engine rebuild intervals (engine rebuild does not apply to LDV or Indoor).
Market	Insufficient manufacturing and aftermarket conversion capacity, non-certified converters	Negotiate supply arrangements
Market	Defuelling systems (for maintenance work)	Training programs specifically offered /run/ subsidized by government, technical improvements

The markets where there has been negative experience with either technology and/or payback with NGVs could benefit from the following communications strategies:

**Transit market.** Transit managers and provincial departments of transportation could be made aware of the following:

- greatly improved Canadian technologies that are assembled by Canadian bus manufacturers and used successfully in the US;
- Improved economics of NG buses as gas prices remain low and oil prices are stabilizing above \$80/bbl.

The communications strategy should be coordinated with engine manufacturers, bus manufacturers and gas utilities. Venues include the Canadian Urban Transit Association (CUTA) annual conference (speakers, exhibits, articles) as well as visits to bus operations. Demonstration buses could be loaned to selected fleets (successful method in the past) and maintenance and operation data from successful operations in US should be provided to confirm economics.

**Indoor forklift market.** This market is at some risk with the previous experience on the only refueling equipment manufacturer (FuelMaker) being interrupted due to bankruptcy and new management. Discussions should occur with new owners of the technology to determine availability in Canadian market. Also, alternative low-cost refueling packages should be investigated with other suppliers so their availability can be communicated to forklift fleet users through articles and visits by participating gas utilities. Initiative should be led by gas utilities.

**LNG trucking.** This is an important new market which needs to be supported by a communications strategy in Ontario-Quebec and Alberta-BC. The initial objective is to increase awareness of the option and the economics for certain types of operation. The communications strategy should be coordinated with engine manufacturers and gas utilities/suppliers. Possible avenues include: using truck exhibitions and rodeos, articles in fleet management media, etc. The GHG reduction opportunity should be highlighted for larger fleets and shippers who have a growing interest in this topic.

Exhibit 26 lists general non-market barriers that apply to all segments, along with possible ways to overcome them.

**Exhibit 26 General Non-market Barriers for all NGV Segments**

Barrier Type	General Barriers for all End-Use Segments - Continued	Ways of Overcoming
Non-Market	Lack of interest/commitment from retailers – in terms of ability to outfit and fuel NGVs	Vehicle orders and incentives. Financing plans
Non-Market	Planning, zoning, code enforcement, permitting, and start-up issues with the installation of new LNG/LCNG fuelling stations	Facilitating permitting procedure, expediting the permitting process, training programs specifically offered /run/ subsidized by government
Non-Market	Lingering perceptions of early technology performance (e.g. buses)	Marketing to public, educating end-users , low cost NG fuel, early adoption by government fleets, public transit and other public end-uses to demonstrate that the technology works
Non-Market	Lack of interest/commitment from some utilities – in terms of lack of marketing resources (including staff), no financing or incentives, etc.	Large upstream NG suppliers entering early into retail market to create competition, stable NG prices and reliable technology
Non-Market	Increased training requirements for mechanics – cost/time barrier to fleets that would have to train mechanics in multiple technologies/systems	Training programs specifically offered /run/ subsidized by government
Non-Market	Different regulations/requirements (permits) for the garages (e.g., venting and sensors)	Provision of technical information and turnkey solutions

## 8.2 Heavy and Medium Duty Vehicles

Exhibit 27 lists barriers that apply to the heavy and medium duty segments, along with possible ways to overcome them.

**Exhibit 27 Barriers in the Heavy and Medium Duty Segment**

End-Use Segment	Sub-Segment	Barrier Type	Barriers	Ways of Overcoming
HDV / MDV	All	Market	High cost of LNG tanks (although the financial analysis incorporates this incremental cost, it does not consider/deal with the initial barrier of up-front capital financing)	R&D investments on advanced materials and tank manufacturing technology for NG tanks
		Market	Limited choice of engines and suppliers	Increase NGV uptake to level that attracts larger suppliers. Facilitating vehicle imports, business incentives for the development of new NG vehicle plants
		Market	Limited range (therefore limited routes)	Return to base options (route redesign)
		Non-Market	If vehicles have weight restrictions – would have to decrease cargo, passengers, etc. because of weight of cylinders	R&D investments on advanced material technology for NG tanks, return to base options

## 8.3 Light Duty Vehicles

Exhibit 28 lists barriers that apply to the light duty segment, along with possible ways to overcome them.

**Exhibit 28 Barriers in the Light Duty Segment**

End-Use Segment	Sub-Segment	Barrier Type	Barriers	Ways of Overcoming
LDV	Fleets	Market	Availability of vehicles (OEM) / choice of models – with respect to fleets, smaller vehicles would not be available	Vehicle imports
		Non-Market	Perceived risk of vehicle reliability	Public education, availability of subsidized training programs for mechanics, Manufacturers directly marketing to public, early adoption of NG vehicles in government fleets
		Market	Additional cost of vehicle (capital and maintenance)	GHG regulations, purchase incentives
		Market	Payback improves with more mileage	Focus on fleets in the short term that have significantly greater annual mileage than personal vehicles
		Market	Tank location and size – the tanks tend to use up valuable trunk space – furthermore, the trend for taxi vehicles is toward smaller cars (e.g., Camry size) and there would not be as much room on them for the tanks	R&D investments on advanced material technology for NG tanks to increase the capacity, thus reducing size, use of multiple tanks

## 8.4 Marine

Exhibit 29 lists barriers that apply to the marine segment, along with possible ways to overcome them.

**Exhibit 29 Barriers in the Marine Segment**

End-Use Segment	Sub-Segment	Type of Barrier	Barriers	Ways of Overcoming
Marine		Market	Big investment to change ships and/or propulsion systems – would need a ~ 20 year LNG supply guarantee	NG price stability, reliable storage technology
		Market	Storage / limited range? Space limitations on board (particularly relevant for retrofit).	Use of multiple tanks

## 8.5 Rail

Exhibit 30 lists barriers that apply to the rail segment, along with possible ways to overcome them.

**Exhibit 30 Barriers in the Rail Segment**

End-Use Segment	Sub-Segment	Type of Barrier	Barriers	Ways of Overcoming
Rail		Market	No OEM offerings for powertrains	
		Market	Traditionally use dual fuel engines already (run on NG or diesel with diesel injection for both)	Novel NG fuel delivery system to reduce or eliminate diesel
		Market	Some trains do a lot of idling and use more diesel when idling – currently this is a technical barrier	Novel NG fuel delivery system to reduce diesel at idle

## 8.6 Indoor

Exhibit 31 lists barriers that apply to the indoor segment, along with possible ways to overcome them.

**Exhibit 31 Barriers in the Indoor Segment**

End-Use Segment	Sub-Segment	Type of Barrier	Barriers	Ways of Overcoming
All	Market	Market constrained with one supplier only	Facilitate partnership between potential suppliers and end users to increase competition in the VRA market	

## 9 Achievable Potential

Determining the achievable potential involves consideration of the technical potential and financial assessment, as well as the barriers and potential solutions. Scenarios must consider practical limitations on how quickly the market can change, as well as limits to what governments and other players can do to overcome non-market barriers. At the same time, it is important not to let scenarios be constrained by an artificial attachment to a business as usual approach and consider how effective policy instruments might unleash the technical, environmental and economic potential revealed in our analysis.

The process involved three concurrent activities:

- **Consideration of Policy Options and Development of Strategy.** We examined the non-market barriers to the achievement of the technical and economic potential and the potential policy instruments available for governments to help overcome these barriers. We considered alternative strategies for development of a portfolio of instruments. We selected instruments taking into consideration these strategies, as well as key public policy objectives (e.g. environmental objectives, economic objectives, fiscal responsibility, fairness, etc.) and the lessons learned from Section 3.
- **Achievable Scenarios.** We constructed a realistic but relatively ambitious achievable scenario for each market segment. Where applicable, this was done on a bottom-up basis looking at individual market segments and regions, which were then extrapolated to the rest of Canada. Scenarios were adjusted to take into account the recommended portfolio of policy instruments. Conversely, where possible and realistic, the portfolios of policy instruments were adjusted to take maximum advantage of what was considered achievable.
- **BAU Scenarios.** In parallel with the development of the achievable scenario, we also developed business as usual scenarios, in order to be able to assess the incremental impact of the proposed initiatives.

Given the nature of the exercise, and the time and resource limitations, the application of the analysis was relatively subjective, relying primarily on the judgment and experience of team members. Notwithstanding the many years of experience and the expertise of our team members, these should be considered illustrative scenarios only.

### 9.1 Policy Options

Governments have a number of instruments that are, or could be, used to assist NGVs in overcoming non-market barriers, including:

- Financial Incentives (e.g. grants, rebates, tax incentives)
- Regulations (e.g. vehicle or fuel standards)
- Support for Innovation (e.g. financial support for R,D&D and/or early commercialization)
- Information and Suasion (e.g. social marketing)
- Government Procurement (e.g. fleet targets).

In selecting from this menu, there are some important observations drawn from our previous analysis of lessons learned and from the consultations with stakeholders:

- Fuel Tax policy is a visible and powerful instrument in providing a long term price signal to the industry and potential users of natural gas. Thus maintenance of current tax exemptions is an important part of the policy mix.
  - Federal Excise Tax is not assessed on natural gas - cf. Gasoline (10c/L), Diesel (4c/L). All provinces have zero motor fuel tax for natural gas - cf. 14.7c/L on gasoline and 14.3 c/L on diesel in Ontario
- Vehicle incentives (e.g. grants, rebates or tax incentives on vehicles) are needed to overcome the first cost barrier (even though the investments are financially sound, the initial capital requirement acts as a barrier – particularly when combined with the risk inherent in moving to new technology):
  - Incentives have been used successfully in the past. Their impact depends on oil prices and natural gas price differential, and the availability of stations (especially for LDVs).
  - OEMs should be involved in rebuilding LDV opportunity before incentives are offered - may take 2-3 years at best. For a self-sustaining LDV market, OEMs must support upfitting industry with technical information or develop Qualified Vehicle Modifiers (QVMs). The goal should be a much lower cost increment for LDVs than that in the US market now.
  - Competition is a good way to control cost increment. Encouraging new market entrants from Europe is a feasible strategy (Fiat, Volvo, etc), although market would initially be limited to where there are public stations.
- Refuelling infrastructure incentives (e.g. grants to assist the construction of new stations and LNG facilities) are needed in parallel with vehicle incentives to overcome initial risk and small market size. Both are necessary to avoid the “chicken and egg” dilemma.
- Fiscal measures including accelerated depreciation and tax credits applicable to vehicles, stations, and liquefaction facilities could be an alternative to grants and rebates.
- Information/promotion programs:
  - These programs are needed to compliment incentive and research programs. They could range from small programs to provide technical information, to large programs such as the US DOE’s Clean Cities.
  - Government does not have to run information programs – this could be delivered by CNGVA or similar organizations.
  - Information programs should be targeted to specific markets being supported.

## 9.2 Recommended Strategy

Two potential strategies were considered:

- **Strategy 1: Gradual Development of NGV Markets.** This would be an industry-led approach, with Governments offering modest support, in the form of information, R&D and limited incentives, including maintenance of current tax advantages. Governments would work with provinces, the industry and other stakeholders to further understand the context, the barriers and the opportunities and to identify initiatives for all parties. For example, this could include actions for provinces and municipalities to provide incentives for in the transit market; industry coordination mechanisms to take advantage of HDV opportunities, etc.
- **Strategy 2: Aggressive Development of Selected Markets.** This would be led by both governments and industry in partnerships. Using this study as a starting point, the main market opportunities would be identified and targeted for concerted action by all players. For example, this could involve working with HDV suppliers, fuel suppliers and fleets, offering incentives to start the market for LNG.

Given the barriers identified, and the lessons learned from past program experience, our view is that meaningful development of the market beyond the BAU depends on a more aggressive approach. The achievable scenarios described below are based on this strategy.

## 9.3 Results - Heavy and Medium Duty Vehicles

### 9.3.1 *Rationale for the scenario*

Key considerations are:

#### *Medium and Heavy Duty Trucks*

- HD and MD in fleet applications constitute a limited sized market. Fleets are typically risk-averse, and are careful with capital outlays.
- Fleet market uptake will be incremental, based on experience from other fleets, demonstrations and secure payback.
- Incremental cost of LNG package is a major obstacle - cost must be reduced before a significant market share can be reached.
- As with energy efficiency, fleets are becoming more sensitive to demands from the clients of trucking services for greener transportation services and lower emissions.
- The best payback can be achieved for long-distance LNG tractor-trailer units, followed by return to base units with benefits from easier refuelling.
- MD trucks in urban and regional delivery and medium size buses (airport shuttles, door-to-door shuttles for the handicapped) are favourable options for the use of CNG.
- Investment by utility companies or other is needed in the manufacturing of LNG plant. The development of such plants can be stepwise, as fleet market will not fully utilize LNG capacity for several years.

#### *Transit Buses*

- Growth in transit use of NG is likely to be very slow:
  - Negative attitude from the past NG experience of several transit properties will take time to turn around.
  - Funding support from provinces and municipalities will be needed for bus acquisition - this will take time, especially as Ontario (largest transit market) is working on debt reduction.

#### *Refuse Trucks*

- Refuse trucks are suited to NG use because of regular suburban routes and return to base, but current high installation cost makes economics marginal and thus growth is likely to be slow without sustained measures to encourage adoptions. Market could be encouraged by municipal contract policy requiring some level of NG truck use.  
(Suggestion by Westport: requiring lower emission truck technologies including natural gas.)
- Use of renewable biomethane is particularly strategic in the refuse truck segment as many public and private sector players have existing landfill assets that could be leveraged.

### **9.3.2 Possible Government Support and Rationale**

#### *Medium and Heavy Duty Trucks*

The proposed portfolio would include modest federal government support, primarily in the form of vehicle grants and station incentives to reduce the risk of initial capital outlays for fleets and fuel providers. This would support reductions in GHG emissions from the HDV sector, which has few other options. Examples of specific measures could include:

- Vehicle grant of 1/3 of incremental vehicle cost, declining to 20% by year 5
- CCA incentive on stations, or grants of \$50K-100K for in-yard tank and dispenser depending on size, grants for limited number of LNG multi-fleet stations
- Additional incentives from provinces.

#### *Transit Buses*

Transit use of NGV has potential to reduce transit operating costs, reduce urban noise and particulate pollution. Large use of gas per bus and centrally fuelled fleets makes transit one of the best NG opportunities. Examples of specific measures could include:

- Demonstrations of current NG bus technology
- Partial financial support for bus cost increment and fuel station installation

CNGVA suggestion: New bus garages should be built to be fuel flexible, supporting NG and even hydrogen. Bus garages are typically built to last 40-50 years.

#### *Refuse Trucks*

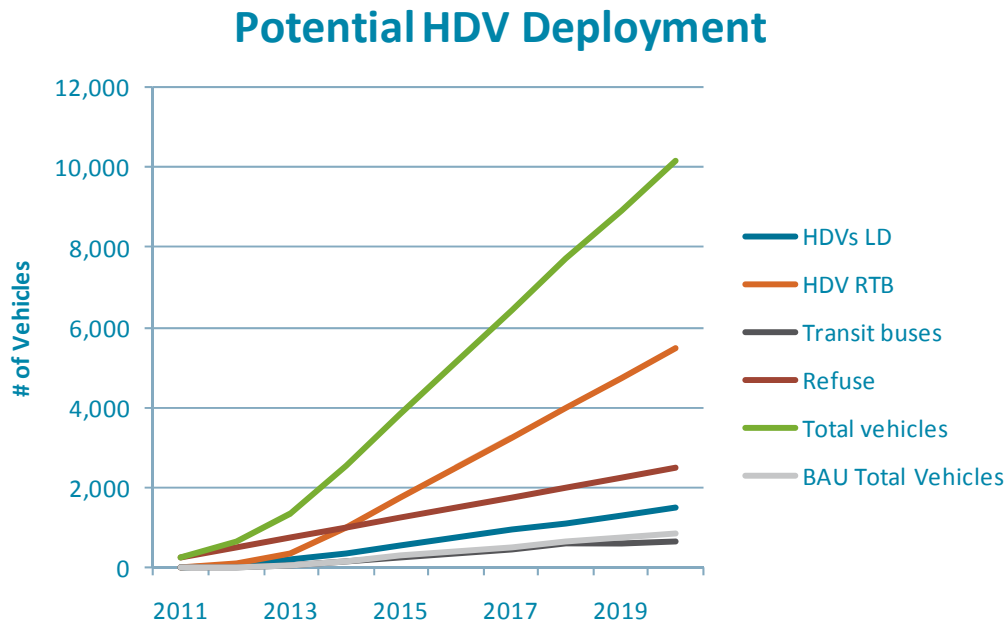
Grants will make the economics more attractive while progress is made to reduce installation costs. Examples of specific measures could include:

- Grants to offset part of cost of vehicle installation and refuelling station

### **9.3.3 Results**

Results are shown in Exhibit 32. These are based on a bottom-up assessment of the potential within the Québec City – Windsor corridor and extrapolation to rest of Canada using a factor of 1.25 for trucks and 1.5 for transit.

Exhibit 32 Achievable potential for the medium and heavy duty NG vehicles



## 9.4 Results - Light Duty Vehicles

### 9.4.1 Rationale for the scenario

Rebuilding NGV supply industry in Canada will take some years, so growth will likely be delayed until the second half of the decade and will be slow - a few thousand vehicles per year.

### 9.4.2 Possible Government Support and Rationale

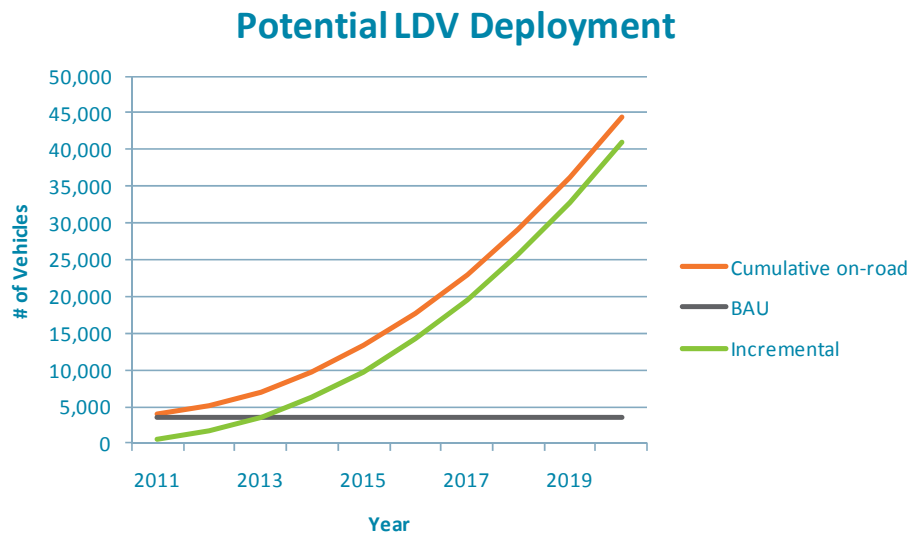
Past experience has shown that government cannot push the LDV market to success, even with strong incentives. Mandates are used in some developing countries, but this would not be justified in Canada. Examples of specific measures could include:

- Work with industry and partners to rebuild this market if there is an interest
- Work with industry and partners to overcome unreasonably high mark-ups on incremental conversion costs.

### 9.4.3 Results

Results are shown in Exhibit 33. These are based on a bottom-up assessment of the potential in each region of Canada.

Exhibit 33 Achievable potential for the light duty NG vehicles



## 9.5 Results - Marine

Although the technology is commercially available and is financially viable, the large investments involved in building LNG fuelling facilities for this sector require thorough analysis and relatively long lead times. As the purchase of new vessels occurs infrequently, it would be important to capture such opportunities when they occur. Unfortunately it appears that one of the best opportunities (i.e. purchase of a large fleet of lakers by Algoma) has come too soon to be realized. Although, other opportunities may arise, the uncertainty is too high to include a marine segment in the achievable scenario.

## 9.6 Results - Rail

Given that the technology for the use of NG in the rail segment is not yet commercial, we do not believe there is a significant achievable potential for this segment within the period to 2020.

## 9.7 Results – Indoor Equipment

### 9.7.1 *Rationale for the scenario*

The potential for NG use indoor is established and will need to be developed through steady marketing efforts by the NG utilities and forklift suppliers. The competition in VRA manufacturing must be increased by utilities working with suppliers to offer an economic refuelling package.

### 9.7.2 *Possible Government Support and Rationale*

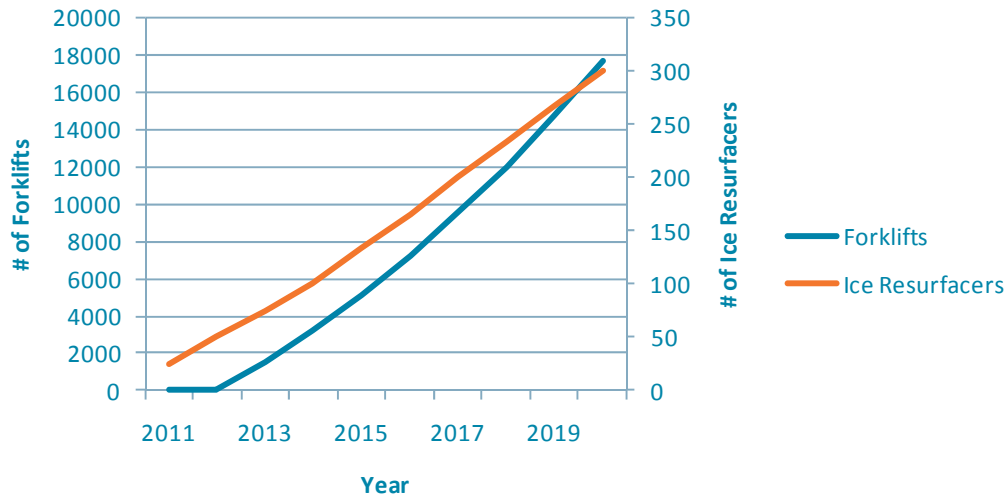
The proposed portfolio is to partially offset the initial cost of refueling and grow this market. grants for refueling stations would be a possibility.

### 9.7.3 Results

Results are shown in Exhibit 34. These are based on an overall assessment of the national potential for each segment, based on conversations with stakeholders and experts.

Exhibit 34 Achievable potential for indoor NG vehicles

### Potential Indoor Equipment Deployment (incremental)

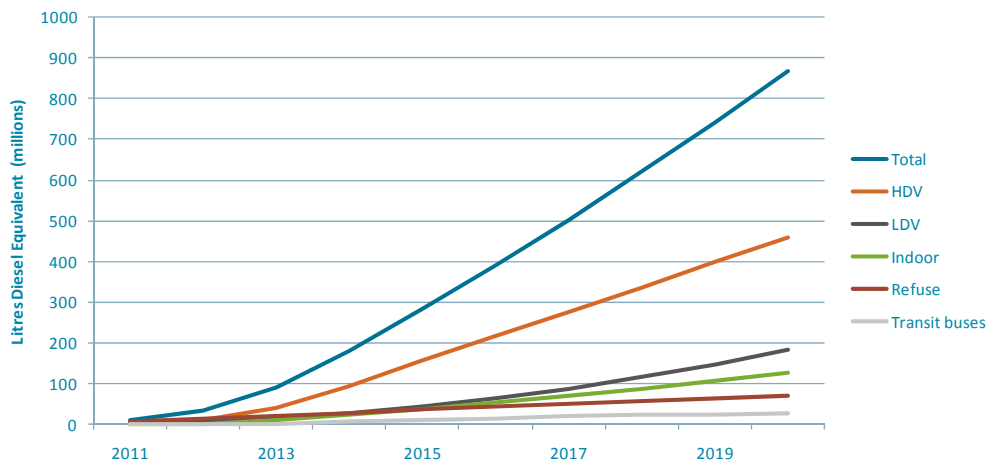


## 9.8 Fuel Displacement and GHG Emission Reductions

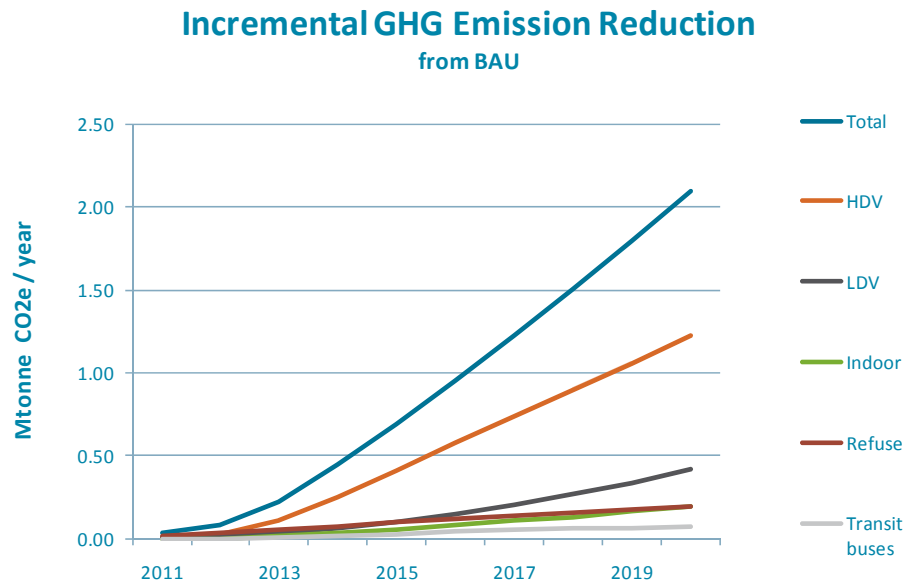
The incremental fuel displacement for all NGV segments included in the achievable analysis is calculated and given in Exhibit 35. The corresponding GHG emissions reduction is given in Exhibit 36.

Exhibit 35 Incremental fuel displacement for all NGV segments based on the achievable potential

### Incremental Fuel Displacement from BAU



### Exhibit 36 Incremental GHG emissions reduction for all NGV segments based on the achievable potential



## 10 Conclusions

### *Current Market*

The Canadian market for NGVs has stagnated and is lagging far behind other countries. This is due to a variety of factors, including past price volatility and problems with NGV technologies in some sectors. The concurrent lack of availability of vehicles and of fuel continues to act as a “chicken and egg” barrier to further development.

### *Lessons Learned from Previous Programs*

A variety of programs and policies to encourage the development of NGVs have been implemented in Canada and around the world, with varying levels of success. Key lessons include:

- Need for a stable and predictable price advantage for natural gas – mechanisms to manage risk are needed
- Technologies need to be commercially and financially viable on their own – government support should help overcome barriers but should be temporary
- Programs are more likely to be successful if federal, provincial and municipal governments cooperate
- Support is needed both for vehicles and for fuelling infrastructure.

## *Fuel Supply*

The increased access to unconventional gas (in particular to shale gas) appears likely to lead to a surplus in North America by 2020. This surplus is not yet reflected in official forecasts and is subject to some uncertainty, including potential environmental concerns that could constrain the potential.

Current retail fuel supply is characterized by a lack of availability and a lack of competition. As a result, prices are higher than they need to be.

The analysis indicates that investments in fuelling infrastructure could be financially attractive even with somewhat lower prices. However, the business case depends on access to a sufficient market. Thus, potential investors may require assistance to deal with risk and to overcome the initial period of market development.

## *Technology Trends*

The study indicates that NGV technologies are proven and commercially available for all market segments, except rail. In all cases, there remain incremental costs, but opportunities to reduce these costs are being pursued.

Emerging technologies, particularly in the HDV/MDV sector are particularly promising, with new developments signaling that tailpipe emissions are being reduced to a level that could eliminate the need for some of the costly exhaust after treatment components used by conventional fuel vehicles.

## *Environmental Analysis*

The environmental analysis showed that GHG emissions can be reduced by 15-25% depending of the vehicle segment (greater reductions of up to 88% are possible by using biogas). The greatest reductions occur in medium and heavy duty, light duty and refuse truck segments.

It was also noted that NGVs offer other environmental advantages in several segments. In particular the reduction of CACs is important for indoor equipment.

The use of biogas is attractive for municipal fleets that are seeking to drastically reduce GHG emissions while using a locally available fuel source.

## *Financial Analysis*

The financial analysis showed that all NGV segments could potentially be viable without incentives, except the refuse truck segment.

- The forklift segment offers the best return, almost 45%.
- Line haul, transit bus, LDV and marine segments offer attractive returns, in the range of 20%. Because of the large sums involved, the marine scenario is particularly attractive in terms of the absolute dollars.
- The Return-to-Base HDV scenario and the ice resurfacer scenario are only marginally viable, in the range of 10-15% return.
- The refuse truck segment could be financially viable if capital cost increment could be reduced, say by \$15,000.

Several of the segments/scenarios (e.g. refuse, ice resurfacer) have important non-financial advantages that could improve their prospects.

### *Barriers and Solutions*

Despite their technical, financial and environmental benefits, NGVs still face formidable market and non-market barriers. Each of these barriers can be overcome but this will require concerted action by all stakeholders, including governments and industry. In particular a comprehensive communications strategy will be needed to overcome a lack of awareness, understanding and confidence on the part of stakeholders.

### *Achievable Potential*

A number of segments of the market have the potential to see modest NGV penetration, notably the HDV segment.

Achieving this potential will require governments to play an active role, taking the lead in coordinating the actions of other players and providing targeted incentives for both vehicles and fuelling infrastructure.

If realized, this potential increase in NGV penetration would displace up to 850 million litres of conventional fuels per year and reduce GHG emissions by more than 2 megatonnes per year, by 2020.



**Appendix A**

**International NGV Programs**

# USA - Federal Programs

## History

NGV strategy in the US has generally focused on high-fuel-use, urban fleets that refuel in a central or constant location (e.g., transit buses, refuse trucks, taxis, and shuttle, delivery, port, and airport vehicles). A variety of programs and initiatives have been implemented over the years.

As in Canada, the various initiatives have had limited success in fostering a sustainable NGV market.

An example of an ineffective federal mandate was the US Federal Energy Policy Act (EPACT 1992), which required certain fleets to purchase a percentage of alternative fuel LDVs. For example, federal LDV fleets had to purchase 75% AFVs. The initiative was meant to stimulate demand and encourage manufacturers to provide more choice. However, a number of Agencies did not meet this requirement and environmental groups have resorted to court action to have the rules enforced.

The Clean Fuels Grant Program was established (year) under the US DoT Federal Transit Administration (not specific to NGVs) program with the purpose of assisting nonattainment and maintenance areas in achieving or maintaining the National Ambient Air Quality Standards for ozone and CO, and supporting emerging clean fuel and advanced propulsion technologies for transit buses and markets for those technologies.

## Current Situation

A variety of incentives are available for NG fuel, vehicles, and infrastructure are in place.<sup>28</sup> Federal income tax credits are also available to offset the cost of each of these options. In addition, many states and air quality districts offer incentives, and some utilities offer preferential gas rates to customers with a small home refueling appliance sold under the name “Phill”.

Clean Cities is a government-industry partnership sponsored by the US DOE Office of Energy Efficiency and Renewable Energy’s Vehicle Technology Program, which strives to advance economic, environmental, and energy security through support for practices that contribute to reduction of petroleum consumption.

---

28 [http://www1.eere.energy.gov/cleancities/pdfs/clean\\_cities\\_workshop\\_natural\\_gas.pdf](http://www1.eere.energy.gov/cleancities/pdfs/clean_cities_workshop_natural_gas.pdf)  
<http://www.iangv.org/policy.html>  
<http://www1.eere.energy.gov/cleancities/index.html>  
<http://www.energy.gov/recovery/cleancities.htm>  
<http://www.ngvglobal.com/us-department-of-energy-allocates-300m-for-alternative-fuel-projects-0826>  
<http://www.epa.gov/otaq/cff.htm>  
[http://www.fta.dot.gov/funding/grants/grants\\_financing\\_3560.html](http://www.fta.dot.gov/funding/grants/grants_financing_3560.html)  
[http://www.afdc.energy.gov/afdc/progs/fed\\_summary.php/afdc/US/0](http://www.afdc.energy.gov/afdc/progs/fed_summary.php/afdc/US/0)  
<http://www.aga.org/Legislative/issuesummaries/NaturalGasVehicles.htm>

NGV projects feature in 19 of 25 cost-share projects announced in 2009 under the Clean Cities program that will be funded with ~ \$300 million from American Recovery and Reinvestment Act (ARRA).

In addition, Clean Cities allocates annual funding for grants for vehicles, infrastructure, and education. In 2009, it announced 23 cost-shared grants (10 relating to NG) for the Transportation Sector, which totaled approximately \$13.6 million.

In addition to Clean Cities, the American Recovery and Reinvestment Act of 2009 provided new funding to other programs that may benefit NGVs. These are as follows:

- EPA Diesel Emission Reduction Program - \$300 million to be allocated as follows: (1) \$156 million for the National Clean Diesel Program; (2) \$30 million for the SmartWay Finance Program; (3) \$20 million for “emerging technologies”; (4) \$88 million to states to administer programs; and, (5) \$6 million to EPA to administer programs.
- Federal Transit Administration Capital Expenditures - \$8.4 billion for transit capital improvements.
- Energy Efficiency and Conservation Block Grants (EECBG) - \$3.2 billion for the US DOE for energy efficiency and conservation programs including those involving transportation.
- US General Services Administration Federal Fleet Acquisitions - \$300 million in new funding to help federal agencies acquire motor vehicles with higher fuel efficiency.

## USA - States Level Programs

State tax credits for fuel, vehicles, infrastructure, and business development exist in 25 states. In this report, programs in California, New York, Utah, Colorado and Texas are summarized.

### California

California has multiple incentives and programs for alternative fuel vehicles.

State Laws and Regulations examples<sup>29</sup>:

- Alternative Fuel Tax - excise tax imposed on CNG, LNG, paid through an annual flat-fee rate sticker tax, based on weight of the vehicle (e.g., LDV \$36; more than 12,001 lbs \$168). Alternatively, may pay an excise tax on CNG of \$0.07 per 100 cubic feet, \$0.06 per gallon of LNG.
- Public Agency Fleet Emissions Reduction Requirements - South Coast Air Quality Management District (SCAQMD) requires government fleets and private contractors under contract with public entities to purchase cleaner, AFVs. It applies to transit buses, school buses, refuse trucks, etc. and has set purchasing requirements for public and commercial fleets.
- Mobile Source Emissions Reduction Requirements – includes rules for different types of vehicles (e.g., port trucks, transit buses, refuse trucks, fleets for public agencies and utilities) to reduce emissions, including the option to use alternative fuels
- Vehicle Acquisition and Petroleum Reduction Requirements - California Department of General Services is responsible for maintaining specifications and standards for passenger

---

<sup>29</sup> [http://www.afdc.energy.gov/afdc/progs/state\\_summary.php/CA](http://www.afdc.energy.gov/afdc/progs/state_summary.php/CA)

cars and light-duty trucks purchased or leased for use by state offices, agencies, and departments. Specifications include minimum vehicle emission standards and encourage the purchase or lease of fuel-efficient and AFVs, including a rule that vehicles capable of operating on alternative fuel must operate on that fuel unless the alternative fuel is not available.

- Fleet Vehicle Procurement Requirements - Every city, county, and special district, including school and community college districts, is authorized to require that 75% of the passenger cars and/or light-duty trucks acquired be energy-efficient vehicles, including AFVs that meet California's advanced technology partial zero emission vehicle (AT PZEV) standards.
- Compressed Natural Gas (CNG) Tax Exemption for Transit Use - CNG used by local agencies or public transit operators in the operation of public transit services is exempt from any applicable fuel taxes.
- Alternative Fuel Vehicle Retrofit Regulations – AFV retrofit systems have to be evaluated and certified by the California Air Resources Board (ARB).

Examples of State Incentives follow:

- Alternative Fuel and Vehicle Research and Development Incentives - Administered by the California Energy Commission, it aims to increase the use of alternative and renewable fuels and innovative technologies by providing grants and loans for projects that: develop/improve alternative low-carbon fuels ; expand fuel infrastructure; improve technologies; establish workforce training programs; etc.
- Alternative Fuel Vehicle (AFV) and Fueling Infrastructure Grants – AB 2766 Motor Vehicle Registration Fee Program provides funding for projects that reduce air pollution from on- and off-road vehicles. Eligible projects include purchasing AFVs and developing alternative fueling infrastructure.
- Emissions Reductions Grants - Carl Moyer Memorial Air Quality Standards Attainment Program provides incentive-based funding for the incremental cost of purchasing cleaner than required engines and equipment. Eligible projects include heavy-duty fleet modernization, LDV replacements and retrofits, idle reduction, and the purchase of cleaner off-road vehicles and equipment.
- Lower-Emission School Bus Grants - Provides grant funding for the replacement of older school buses with new buses fueled by diesel or an alternative fuel, provided that the required emissions standards specified in the current Lower-Emissions School Bus Program Guidelines are met.
- Alternative Fuel and Advanced Technology Research and Development - Innovative Clean Air Technologies (ICAT) Program, which is currently on hold, was developed by ARB and co-funds demonstration projects of innovative technologies that will improve emission prevention or control while promoting new industries and jobs in California. Developing alternatives to diesel fuel and diesel engines are of particular interest.
- Technology Advancement Funding - South Coast - South Coast Air Quality Management District's Clean Fuels Program provides funding for R,D,D&D projects that are expected to help accelerate the commercialization of advanced low-emission transportation technologies. Eligible projects have included implementation of clean fuels (e.g. natural gas), including their infrastructures. Approximately \$10 million in funding is available annually with expected cost-share from other project partners and stakeholders.
- Low-Emission Vehicle Incentives and Technical Training - San Joaquin Valley - REMOVE II Program, administered by the San Joaquin Valley Air Pollution Control District (APCD), provides incentives for the purchase of low-emission (e.g., alternative fuel) passenger vehicles, light-duty trucks, small buses, and trucks with Gross Vehicle Weight Ratings of 14,000 pounds or less. It offers between \$1,000 and \$3,000 per vehicle and varies according to the emission certification level and size of the vehicle. Program also includes an AFV

Mechanic Training Component providing incentives for education on the mechanics, operation safety, and maintenance of AFVs, fueling stations, and tools involved in the implementation of the technologies.

There are also Utilities and Private Company incentives in California. For example:

- Alternative Fuel Vehicle (AFV) and Hybrid Electric Vehicle (AFV) Insurance Discount Farmers - Insurance provides a discount of up to 10% on all major insurance coverage for HEV and AFV owners.
- Low-Emission Vehicle Electricity Rate Reduction - PG&E - Pacific Gas & Electric (PG&E) offers a discounted rate for electricity used to charge battery electric vehicles, plug-in hybrid electric vehicles, and natural gas vehicle home fueling appliances.
- Natural Gas Vehicle Home Fueling Infrastructure Incentive - South Coast - Residents of the South Coast Air Quality Management District may be eligible for an incentive of up to \$2,000 toward the purchase of a qualified natural gas vehicle home fueling appliance.
- Low-Emission Taxi Incentives - San Francisco - San Francisco Taxicab Commission committed to reduce GHG emissions from the taxi fleet by 20% by 2012 (compared to 1990 levels). Under the Clean Taxi Program, companies apply for a surcharge of up to \$7.50 on gate fee charged for the use of certain low-emission vehicles. Additionally, grants of up to \$2,000 may be available from San Francisco County Transportation Authority toward the purchase of light-duty hybrid electric and CNG taxis.
- Employee Vehicle Purchase Incentives – Riverside - City of Riverside employees are eligible to receive a rebate toward the purchase of qualified NG vehicle that are purchased from a City of Riverside automobile dealership. The rebate for a new qualified vehicle is worth up to \$2,000, or \$1,000 for a qualified used vehicle.
- South Coast Air Quality Management District’s (SCAQMD) Heavy-Duty Natural Gas Drayage Truck Replacement Initiative - The project will replace 180 diesel drayage trucks at the Ports of Los Angeles and Long Beach with LNG trucks. Workshops will be made available to truck operators and technicians. There is also an education/outreach component for alternative fuelled vehicles that will be deployed by the Southern California Association of Governments Clean Cities Coalition and the SCAQMD. (Total DOE award: \$9,408,389)
- South Coast Air Quality Management District’s UPS Ontario-Las Vegas LNG Corridor Expansion Project - Project will complete a regional LNG fuelling corridor (700 miles along heavily traveled truck routes) across the southwestern US, making the final connection between the existing public access LNG fuel infrastructure in Southern California and the LNG fuel stations being developed in Utah. UPS will construct a publicly-accessible LNG fuel station and deploy 48 heavy-duty LNG vehicles. The new LNG station will support these 48 trucks, an additional 161 LNG trucks in UPS’ fleet, and other LNG fleet operators in the region. (Total DOE award: \$5,591,611)

## New York

New York has multiple incentives and programs for alternative fuel vehicles.<sup>30</sup>

- Alternative Fuel Tax Exemption – CNG is exempt from state sales and use taxes.
- Alternative Fuel Vehicle (AFV) Acquisition Requirements - State agencies and other affected entities must procure increasing percentages of AFVs as part of their annual vehicle acquisition plans. By 2010, 100% of all new LDVs must be AFVs, with the exception of designated specialty, police, or emergency vehicles. State agencies and other affected

---

<sup>30</sup> [http://www.afdc.energy.gov/afdc/progs/state\\_summary.php/NY](http://www.afdc.energy.gov/afdc/progs/state_summary.php/NY)

entities that operate medium- and heavy-duty vehicles must implement strategies to reduce petroleum consumption and emissions by using alternative fuels and improving vehicle fleet fuel efficiency.

- Low Emission Vehicle (LEV) Standards – Each OEM sales fleet of passenger cars and light-duty trucks produced and delivered for sale in New York must follow the requirements in Title 13 of California Code of Regulations, Section 1962. Under this program, OEMs must make the following commitments: 7% of vehicles must be partial (PZEV), 2% advanced technology PZEV, and 1% ZEV; any ZEV or PZEV models available in California must also be made available in New York. New light-duty passenger car, light-duty truck, or medium-duty passenger vehicles must be certified to the California emission standards. OEMs must also meet a fleet average GHG emissions standard.
- Alternative Fuel Vehicle (AFV) Acquisition Requirements - New York City - At least 80% of the New York City light-duty, non-emergency fleet, and 20% of bus fleets operated in New York City are required to be AFVs.
- Alternative Fuel Use Requirement - New York City - Any bi-fuel motor vehicle owned or operated by the city must use the specified alternative fuel to operate the vehicle.
- Compressed Natural Gas (CNG) Use Requirement – Smithtown - The town of Smithtown requires all contracted residential refuse collection operators to switch from diesel vehicles to vehicles that operate exclusively on CNG.
- Fuel Exclusivity Contract Regulation - Motor fuel franchise dealers are permitted to obtain alternative fuels from a supplier other than a franchise distributor, if the distributor does not supply or offer to supply the dealer with the alternative fuel. Distributors who violate the law by entering into exclusivity contracts will be subject to a fine of \$1000. If the distributor does offer renewable fuels, they are allowed to require the station to use their brands.

Examples of Incentives follow<sup>31</sup>:

- Alternative Fueling Infrastructure Tax Credit - Tax credit available for installation of AFV fueling infrastructure. The tax credit is equal to 50% of the cost of the infrastructure. This includes infrastructure for storing or dispensing an alternative fuel into the fuel tank of a motor vehicle powered by that fuel, including natural gas. The credit expires after December 31, 2010.
- Alternative Fuel Bus and Infrastructure Funding - The Clean Fueled Bus Program, administered by the New York State Energy Research and Development Authority (NYSERDA), provides funds to state and local transit agencies, municipalities, and schools for up to 100% of the incremental cost of purchasing new alternative fuel buses and infrastructure. Eligible buses include those powered by CNG (including dual-fuel technology that is factory built and certified or a new diesel engine with a minimum of 75% use of CNG during typical operation). Eligible infrastructure includes construction and installation of equipment to fuel or recharge alternative fuel buses. Funding for this program is provided by the Clean Water/Clean Air Bond Act.
- AFV and Fueling Infrastructure Funding - The New York State Clean Cities Challenge, administered by NYSERDA, awards funds to members of New York's Clean Cities Coalitions that acquire AFVs or install AFV fueling or recharging infrastructure. Funds can be used to cost-share up to 75% of the proposed project, including the incremental cost of purchasing AFVs, the cost of installing fueling and recharging equipment, and the incremental costs associated with bulk alternative fuel purchases.

---

<sup>31</sup> <http://www.ogs.state.ny.us/supportServices/vehicles/defaultCFV.html>  
<http://www.nyserda.org/default.asp>

- AFV Technical Assistance - The New York State Clean Cities Sharing Network, providing technical, policy, and program information about AFVs, is managed by NYSERDA. Membership is open to all organizations, businesses, and individuals interested in AFVs. Other than publishing information about tax incentives, fueling stations, etc., the Network organizes and sponsors technical workshops.
- AFV and Fueling Infrastructure Technical Assistance – NYSERDA’s Flexible Technical (Flex-Tech) Assistance Program provides assistance to fleet managers who want to evaluate the feasibility and cost of adding AFVs and fueling facilities to their operations. Low-cost training for vehicle mechanics is also available through certified institutions.
- Alternative Fuel Product Development Funding - NYSERDA Transportation Research Program sponsors a wide variety of product development efforts aimed at improving efficiency and increasing the use of alternative fuels.
- Alternative Fuel and Advanced Technology Vehicle Funding - New York City - The New York City (NYC) Private Fleet Alternative Fuel/Electric Vehicle Program, administered by the NYSERDA in cooperation with NYC Department of Transportation, helps private companies and non-profit organizations to acquire alternative fuel and advanced technology vehicles. Funds awarded for up to 50% of the incremental cost of purchasing new light-duty NGVs, and up to 80% of the incremental cost for purchasing new or converting medium- and heavy-duty NGVs (dedicated and bi-fuel). In addition, up to 50% of the costs for alternative fueling equipment and installation may be eligible.
- CNG Taxi Funding - New York City - The NYC Clean Fuel Taxi Program provides funding towards the purchase of new CNG taxis cabs or the conversion of gasoline powered taxi cabs to operate on CNG.
- NGV and Infrastructure Rebates and Technical Assistance - National Grid offers a NGV incentive program that provides rebates for NGVs and special rates for CNG fueling. It will also help secure CNG fueling station financing, and provide technical assistance and other services to NGV fleets. Financial awards are made depending on the fleet size, amount of fuel used, and vehicle type.
- Greater Long Island Clean Cities Coalition’s Long Island Regional Energy Collaborative Promoting a Green Economy through Clean Alternatives. The project will deploy five CNG stations and 87 heavy-duty trucks throughout Nassau and Suffolk counties. The alternative fuel stations will be accessible to the public and include the installation of five new CNG fueling stations. The proposed 87 alternative fuel vehicles include: 44 CNG refuse trucks, 40 heavy-duty CNG dump trucks, and three heavy-duty CNG trucks. (Total DOE award: \$14,994,183)
- NYSERDA’s Statewide Alternative Fuel Vehicle Program for CNG, LPG, EV, and HEV Vehicles and Fueling Stations Initiative. The project will utilize multiple alternative fuels and technologies in multiple sectors across the state. Alternative fuel and/or hybrid school buses, municipal vehicles, urban delivery, and utility vehicles will be deployed throughout the state. The fleets include two utility fleets, five cities and towns, three counties, ten private companies, two state fleets, ten school districts, and two universities. The accurate and reliable data collected from the use of these vehicles will provide NYSERDA and DOE insight on how these alternative technologies operate in diverse conditions. (Total DOE award: \$13,299,101)

## Utah

Utah has multiple incentives and programs for alternative fuel vehicles<sup>32</sup>.

---

<sup>32</sup> [http://www.afdc.energy.gov/afdc/progs/state\\_summary.php/UT](http://www.afdc.energy.gov/afdc/progs/state_summary.php/UT)

- Natural Gas Vehicle Conversion Promotion – The state recommends that EPA revise certification requirements for small volume conversion manufacturers, provide guidance to those manufacturers regarding the conversion of older vehicle models, and continue a NGV R&D funding program. The state also encourages the formation of public and private partnerships to increase the states' vehicle fueling infrastructure.
- Natural Gas Rate Authorization - The Public Service Commission is authorized to find that a gas corporation's request for a NGV rate that is less than full cost of service may be just and reasonable in the interest of the public. If the commission approves such a request, the remaining costs may be spread to other customers of the gas corporation.
- Alternative Fuels Tax - The tax on CNG is \$0.085 per gasoline gallon equivalent; this rate will be modified proportionally with any changes to the traditional motor fuel rate.
- Public Access to State Compressed Natural Gas (CNG) Fueling Stations - The Utah Department of Administrative Services Division of Fleet Services may allow a private individual or entity to purchase CNG from the state's fueling network if there is no commercial fuel site that meets the geographical CNG distribution needs of the individual or entity, and there is no emergency that requires CNG to be reserved for use by state or emergency vehicles. They also provide information on obtaining a GasCard for fueling as well as state fueling network stations that are available to private individuals and entities.
- Provision for Establishment of Alternative Fuel Use Mandate - The Utah Air Quality Board is authorized to mandate fleet vehicles to use clean fuels, if such a mandate is necessary in order to meet national air quality standards.
- Alternative Fuel Vehicle (AFV) and Fueling Infrastructure Grants and Loans – The Utah Clean Fuels and Vehicle Technology Grant and Loan Program, funded through the Clean Fuels and Vehicle Technology Fund, provides grants and loans to assist businesses and government entities in covering: cost of converting a vehicle to operate on clean fuels; incremental cost of purchasing an OEM clean fuel vehicles. The Program also provides loans for the purchase of fueling equipment for public/private sector business and government vehicles. The program can provide grants and loans to serve as matching funds for federal and non-federal grants for vehicles to operate on a clean fuel, purchasing OEM clean fuel vehicles.
- Clean Fuel Vehicle Tax Credit – Income tax credit for 50% of the incremental cost (up to \$3,000 maximum) of a clean fuel vehicle built by an OEM and/or an income tax credit for 50% of the cost (up to \$2,500 maximum) of converting the vehicle to operate on an alternative fuel for vehicles purchased between January 1, 2001 and January 1, 2009. If not previously used, the tax credit may be claimed on used vehicles. Tax credits are available for businesses and individuals. For vehicles purchased after January 1, 2009, the credit amount for OEM CNG vehicles is 35% of the vehicle purchase price or \$2,500, whichever is less; other new clean fuel vehicles may be eligible for a credit of up to \$750. This incentive expires December 31, 2013.
- Incentive for Airport Alternative Fuels Use - The Salt Lake City Department of Airports provides incentives to commercial ground transportation providers who purchase and operate clean fuel vehicles that exclusively operate on approved clean fuels (as designated by Utah code 59-13-102). CNG vehicles are eligible. The incentives are in the form of a credit against ground transportation fees. Incentive credit amounts are \$2,500 for each OEM vehicle or certified vehicle converted to operate on an alternative fuel.
- Natural Gas Technical Assistance - Questar Gas offers technical assistance to customers interested in converting their vehicles to operate on CNG. The company provides financial analysis and fleet consulting services for alternative fuel comparisons.
- Utah Clean Cities (partnered with Questar Gas) was selected for negotiation of an award of up to \$150,000 to install four CNG dispensing units.

- Utah Clean Cities Coalition’s Clean Cities Transportation Sector Petroleum Reduction Technologies Program - The initiative includes 16 new CNG public fuelling facilities, upgrades to 24 CNG public fuelling facilities, three new liquid/compressed NG facilities, three new biodiesel public refuelling stations, and increases the number of NGVs operating in Utah by 678. (Total DOE award: \$14,908,648)

In addition to the State programs, one utility offers the following:

- Natural Gas Technical Assistance - Questar Gas offers technical assistance to customers interested in converting their vehicles to operate on CNG. The company provides financial analysis and fleet consulting services for alternative fuel comparisons.
- Additionally, one Utah based project received a grant from the Clean Cities annual funds and one of the Clean Cities ARRA funded projects will take place in Utah:
- Utah Clean Cities (partnered with Questar Gas) was selected for negotiation of an award of up to \$150,000 to install four CNG dispensing units.
- Utah Clean Cities Coalition’s Clean Cities Transportation Sector Petroleum Reduction Technologies Program - The initiative includes 16 new CNG public fuelling facilities, upgrades to 24 CNG public fuelling facilities, three new liquid/compressed NG facilities, three new biodiesel public refuelling stations, and increases the number of NGVs operating in Utah by 678. (Total DOE award: \$14,908,648)

## Colorado

Colorado has multiple incentives and programs for alternative fuel vehicles<sup>33</sup>.

State Laws and Regulations examples follow:

- Alternative Fuel Use and Vehicle Acquisition Requirement – The Executive Director of the Colorado Department of Personnel has adopted a policy beginning on January 1, 2010, motor vehicles that operate on CNG must be purchased, subject to the availability of vehicles and adequate fueling infrastructure. If purchases of CNG vehicles are not possible due to the incremental cost being more than 10%, the Executive Director must purchase another type of flexible fuel or hybrid electric vehicle, again subject to availability and incremental costs.
- AFV Weight Limit Exemption – GVWR limits for AFVs are 1,000 lbs greater than those for comparable conventional vehicles, as long as the AFVs operate using an alternative fuel or both alternative and conventional fuel, when operating on a highway that is not part of the interstate system.
- Alternative Fuels Tax and Vehicle Decal - Fuel tax exemptions are granted for CNG and LPG vehicle owners. Owners of CNG and LPG fueled vehicles are required to purchase an annual tax decal from the Colorado Department of Revenue. All CNG and LPG vehicles must display a current fuel tax decal. Non-profit transit agencies are exempt from the fuel tax.

Examples of State Incentives follow:

- AFV and Hybrid Electric Vehicle (HEV) Tax Credit – An income tax credit is available from the Colorado Department of Revenue for a vehicle that uses or is converted to use an alternative fuel. Beginning January 1, 2010, tax credits are based on specified state-defined vehicle categories, including: Light-duty passenger vehicle, light-duty truck, or medium-duty truck natural gas conversions. The percentage of the actual or incremental cost that may be claimed as a credit for NGVs is 75% until January 2012, and decreases to 25% by January 2016. There is no cap on NGV conversions. For credits claimed in 2010 and 2011, for NGVs

<sup>33</sup> [http://www.afdc.energy.gov/afdc/progs/state\\_summary.php/CO](http://www.afdc.energy.gov/afdc/progs/state_summary.php/CO)

that permanently displace vehicles or power sources at least 12 years old are eligible for 1.25 times the credit percentages, up to 100%.

- AFV and Hybrid Electric Vehicle (HEV) Rebate – The Colorado Department of Revenue offers a rebate for the purchase of an AFV, HEV, or for the conversion of a vehicle to operate using an alternative fuel. Vehicles must be owned by the State of Colorado, a political subdivision of the state, or a tax-exempt organization, and be used in connection with the official activities of the entity. The rebate is a percentage of the incremental cost if used toward purchasing a new vehicle, or is a percentage of the conversion cost. For costs incurred between July 1, 2009, and July 1, 2015, the rebate percentages are based on specified vehicle categories, including: Light-duty passenger vehicle, light-duty truck, or medium-duty truck natural gas conversions. The percentage that may be claimed as a credit for NGVs is 75% until July 2010, and decreases to 25% by July 2015. Each qualified entity is limited to \$350,000 per state fiscal year in total rebates paid.
- Alternative Fuel Infrastructure Tax Credit – For tax years beginning prior to January 1, 2011, the Colorado Department of Revenue offers an income tax credit for the cost of construction, reconstruction, or acquisition of an alternative fueling facility that is directly attributable to the storage, compression, charging, or dispensing of alternative fuels to motor vehicles. The credit value was 35% of the cost if claimed during the 2009 tax year, and 20% of the cost if claimed during the 2010 or 2011 tax year. For an alternative fueling facility that will be generally accessible for use by the public, in addition to the person claiming the credit, the percentages specified above will be multiplied by 1.25. The credit has a maximum value of \$400,000 in any consecutive five-year period for each fueling facility.

In addition to the State programs, two utilities offers the following:

- Natural Gas Fuel Rate Reduction and Infrastructure Maintenance - Clean Energy Fuels offers services to the NGV industry that include CNG fueling station equipment maintenance, competitive fuel pricing for larger fleet customers, and alternative fuel vehicle financing. Clean Energy also operates public CNG fueling stations in Colorado.
- Natural Gas Infrastructure Technical Assistance - Atmos Energy offers preliminary feasibility studies for CNG fueling stations and will assist with vendor selection.

## Texas

Texas has multiple incentives and programs for alternative fuel vehicles<sup>34</sup>.

State Laws and Regulations examples follow:

- Alternative Fuel Use Required in State Fleets – State fleets with more than 15 vehicles, excluding emergency and law enforcement vehicles, may not purchase or lease a motor vehicle unless the vehicle uses CNG, LNG, LPG, methanol or methanol-gasoline blends of 85% or greater (M85), ethanol or E85, biodiesel or B20 and higher blends, or electricity including plug-in hybrid electric vehicles. Waivers may be granted for some fleets (e.g., neither the state agency nor a supplier can reasonably be expected to establish adequate fueling for these fuels; unable to obtain equipment or fueling facilities at a cost that is no greater than the net costs of using conventional fuels). By September 30, 2010, state agency

---

<sup>34</sup> [http://www.afdc.energy.gov/afdc/progs/state\\_summary.php/TX](http://www.afdc.energy.gov/afdc/progs/state_summary.php/TX)  
<http://www.glo.state.tx.us/altfuels/NGIPG.html>  
<http://www.tceq.state.tx.us/implementation/air/terp/ntrd.html>  
<http://www.glo.state.tx.us/energy/in-kind/index.html>

fleets must consist of at least 50% AFVs and use these fuels not less than 80% of the time the vehicle is driven. Covered state agencies may meet these requirements through the purchase of new vehicles or the conversion of existing vehicles.

Examples of State Incentives follow:

- Heavy-Duty Natural Gas Vehicle (NGV) Grants – Texas General Land Office (GLO) has an NGV Initiative Grant Program available for public-sector partners in certain Texas counties. Private fleets also may be eligible particularly those that operate directly under contract for government work or do other government business. The program is funded with a Texas Emissions Reduction Plan grant through the Texas Commission on Environmental Quality. A variety of vehicles, including street sweepers, forklifts, buses, and garbage trucks, are eligible for grants to help cover the cost of replacing diesel vehicles with NGVs.
- Alternative Fuel Grants - The Texas Emissions Reduction Plan (TERP) provides grants for alternative fuel and advanced technology demonstration and infrastructure projects under the New Technology Research and Development (NTRD) Program, which provides incentives to encourage and support research, development, and commercialization of technologies that reduce pollution. NTRD Program is administered by the Texas Environmental Research Consortium, with support from the Houston Advanced Research Center from 2006 to 2009.
- Texas Clean Fleet Program - Beginning in 2010, the Texas Commission on Environmental Quality (TCEQ) will administer the Texas Clean Fleet Program (Program), which encourages owners of fleets containing diesel vehicles to permanently remove the vehicles from the road and replace them with alternative fuel or hybrid electric vehicles. Grants will be available to fleets to offset the incremental costs. An entity that operates a fleet of at least 100 vehicles and places 25 or more qualifying vehicles in service for use entirely in Texas during a given calendar year is eligible to participate in the Program. This Program expires August 31, 2017.
- Natural Gas Fuel Rates and Alternative Fuel Promotion – Through its Natural Gas Program, the Texas General Land Office (GLO) makes competitively-priced NG available to school districts, state and local public entities for use in NGVs. The GLO has also established an alternative fuels program to aggressively promote the use of alternative energy sources, especially for those fuels abundant in Texas. The GLO alternative fuels program serves as a liaison between government and industry.
- Clean Taxi Replacement Grants - Dallas-Fort Worth - The North Central Texas Council of Governments partnered with the US EPA and the City of Dallas to develop the North Texas Green & Go Clean Taxi Partnership as part of Dallas Sustainable Skylines Initiative. This program facilitates the replacement of existing taxis with low emission vehicles. A grant program to offset incremental costs was developed and other non-financial incentives implemented for the purchase of cleaner vehicles.
- Alternative Fuel Vehicle (AFV) Grants - Houston-Galveston - Congestion Mitigation and Air Quality (CMAQ) Program Grants are available through the Houston-Galveston Area Council, via the Greater Houston Clean Cities Coalition, for up to 75% of the incremental cost of purchasing new OEM clean fuel vehicles, clean fuel vehicle conversions/repowers, or establishing publicly accessible alternative fueling infrastructure. This grant is for government and private entities.

Further state level programs exist through the Texas Public Fleet Project

In addition to the State programs, two utilities offer the following:

- Natural Gas Vehicle (NGV) and Fueling Infrastructure Rebates - The Texas Gas Service Conservation Program offers a \$2,000 rebate for the purchase of an NGV or \$3,000 for the conversion of a gasoline powered vehicle to operate on NG. The rebate is available for up to five vehicles per customer; conversions must be performed by a center that is certified by the Railroad Commission of Texas. A \$1,000 rebate is also available for a NG forklift. Additionally, qualified residential and commercial NGV fueling infrastructure may be eligible for a \$2,000 rebate. These incentives are available to commercial and residential customers with specific gas rate codes.
- Natural Gas Infrastructure Technical Assistance - Atmos Energy offers preliminary feasibility studies for CNG fueling stations and may assist with vendor selection.
- Additionally, a couple of Texas based projects received grants from the Clean Cities annual funds and one of the Clean Cities ARRA funded projects will take place in Texas:
- North Central Texas Council of Governments' North Central Texas Alternative Fuel and Advanced Technology - The project will deploy refuelling stations and AFVs in the Dallas-Fort Worth area. The project includes a portfolio of different technologies and fuels, including CNG (three stations and 97 vehicles). In addition to the city fleets, high mileage and high visibility fleets are included, such as Coca-Cola, Sysco, Frito Lay, school districts, and taxis. (Total DOE award: \$13,181,171)

## Other International Programs

The NGV programs in the countries listed in Exhibit 1 are summarized.

### *Pakistan*

Pakistan has the largest total number of NGV fleets in circulation for public transportation. In the National Environment Policy of Pakistan issued by Pakistan Ministry of Environment, development and implementation of a plan for conversion of public transport to CNG is included under Energy Efficiency and Renewables section.

Among NGV policies in Pakistan, strong government commitment, liberal licenses for CNG retailing, free market consumer price of CNG, Natural gas tariff for CNG linked to petrol, priority of natural gas connection for CNG, and exemption of import duty and sales tax on import of machinery and kits can be enumerated.<sup>35</sup>

Toyota Pakistan and Suzuki Pakistan, among others, are quickly producing new models to meet the rising national demand for both public transportation and consumer vehicles.

### *Argentina*

Argentina is second only to Pakistan in the number of NGVs (Argentina 1,745,677; Pakistan 2,000,000 – IANGV 2008) and for number of fuelling stations (Argentina 1,801; Pakistan 2,600). The Government decided in the early 1980s to keep the price of natural gas artificially low (there was a push in favour of natural gas because Argentina had an abundance while diesel supplies were declining).

The Government facilitated the installation of the equipment needed for service stations and created a program for several hundred taxis in Buenos Aires to convert to natural gas.

---

<sup>35</sup> DEVELOPMENT OF CNG AS TRANSPORT FUEL IN PAKISTAN, By S. Naushab Sarwar, General Manager, Karachi Ops. Hydrocarbon Development Institute of Pakistan

The savings realized by the Buenos Aires taxi drivers was enough to convince car owners to convert their vehicles, which in turn prompted more service stations to offer natural gas. With the fuel price differential (between gasoline and CNG), Argentina drivers of CNG vehicles could achieve a quick payback (even within months, depending on distance travelled), and taxation and purchase of CNG engines is also favourable.

A large portion of their public transportation system has also been converted to CNG, encouraged by government-enforced financial incentives.

Local industry is making an effort now, to gradually replace diesel in the HDV fleets. A 3 year plan to convert 1000 HDVs is underway (spurred on by the possible elimination of current diesel subsidies to transportation companies).

Another project being developed in the south cone of South America are the 'Blue Corridors' that will interconnect some cities such as Buenos Aires with Rio de Janeiro and Sao Paulo (Brazil), Montevideo (Uruguay), and Santiago (Chile). These are routes where natural gas is (or would be available) for NGVs and will enhance existing conditions to improve export-import transactions and political integration among the countries<sup>36</sup>.

## **Brazil**

Brazil ranks third in the world for number of NGVs (1,588,331 – IANGV 2008) and for number of refuelling stations (1,688).

NG was first used in LDVs in 1996, after a law extended the use of NG as a fuel to all types of vehicles (previously allowed only for city buses). Most of the NGVs now are aftermarket converted taxis or commercial MDVs.

In some large cities (e.g., Sao Paulo, Rio de Janeiro), the government is planning to promote programs to displace diesel with natural gas in the city buses.

Strategies are also being developed to make natural gas attractive to fleet operators by resolving issues such as technology, price differentials to diesel engines and fuel, taxation, and operating and maintenance practices. OEMs are increasing their participation in the NGV market, as quality, safety and fuel availability are key issues and this favours OEM products.

The 'Blue Corridors' will also have an impact on the NGV market in Brazil.

The Gas Company Sulgás developed a new short term initiative, GNV: Sinal Verde para a Economia (CNG: Green Sign for the Economy), to expand sales. It was a collaborative effort with a network of fuelling stations, vehicle converters and distributors of NGV equipment and had government support. It was divided into two parts: conversion incentives for new users (bonus of 400 m<sup>3</sup> of fuel from Sulgás and a 10% discount on conversion); and fuel discounts for the 37,000 already-converted users.

---

<sup>36</sup> <http://www.guardian.co.uk/world/2008/sep/10/environment.carbonemissions>  
<http://www.cngnow.com/EN-US/Vehicles/AroundTheWorld/Pages/default.aspx>  
[http://www.cleanairnet.org/caiasia/1412/articles-35275\\_recurso\\_1.pdf](http://www.cleanairnet.org/caiasia/1412/articles-35275_recurso_1.pdf)  
<http://www.iangv.org/tools-resources/ngvs-by-country/brazil.html>  
<http://www.ngvglobal.com/latin-america-ngvs-an-update-report-0820>

Success factors in the growth of the NGV market have included: government incentives; sound regulation, standards and certification; good distribution infrastructure; competitive price of fuel; environmental performance<sup>37</sup>.

## India

Mandates are an effective measure if monitored correctly by authorities. They can apply to vehicle owners (e.g., mandate a percentage of NGVs in a fleet), or they can apply to energy suppliers (e.g., mandate to provide alternative fuel stations).

India provides a well known example of a mandate – the public bus system in Delhi, which is required to use CNG. In July 1998, the Supreme Court of India ordered the CNG program for Delhi, which included the following:

- No buses over 8 years old after 4/1/2000 except on CNG
- All buses on CNG or other clean fuel by 3/31/2001
- Financial incentives for CNG in taxis, three-wheelers etc.
- Increase number of buses to at least 10,000
- Automated I/M (inspection/maintenance) program for commercial vehicles; Strengthen I/M for all vehicles

Government support was provided through further measures, such as:

- Sales tax exemption on conversion kits
- Concessional custom duty on CNG conversion kits
- Allotment of land for CNG stations and pipelines on priority basis
- Banned old vehicles from registering in Delhi

Despite the Supreme Court order, there was resistance. For example, making the order for the CNG bus, but not accepting delivery. Another Supreme Court order of April 5, 2002 fined the Union government for wasting court's time by repeatedly appealing for dilution of the CNG order. The Court imposed fines on diesel bus operators (Rs 500/day (about US\$11), to Rs 1000/day in 30 days). As a result, operators had to take delivery of new buses ordered<sup>38</sup>.

The Delhi Govt. was directed to phase out 800 diesel buses/month. The National Govt. was to report on measures for extending CNG to other polluted cities.

---

<sup>37</sup> <http://www.iangv.org/tools-resources/ngvs-by-country/brazil.html>

<http://www.ngvglobal.com/brazils-sulgas-offers-incentives-to-boost-natural-gas-conversions-0629>

R.Fernandes, IBP NGV Committee, Brazil NGVs: Beyond a million, NGV-2006, November 7 –9 Cairo, Egypt

<sup>38</sup> Anumita Roychowdhury, Centre for Science and Environment, *The Leapfrog Factor - Clearing the air in Asian cities: The Delhi experience*, presented at National Urban Air Quality Workshop, Karachi, September 13-14, 2006

Christopher S. Weaver, Engine, Fuel, and Emissions Engineering Inc., *Challenges and Success of Delhi's CNG Program: Lessons for Other Cities*, presented at The Leapfrog Factor: Towards Clean Air in Asian Cities, New Delhi, March 30 – April 4, 2004 (<http://www.cseindia.org/campaign/apc/pdf/Christopher.PDF>)

<http://www.cleanairnet.org/infopool/1411/propertyvalue-19513.html>

A K Purwaha, NGVAI, *CNG Developments – An Indian Experience*, presented at NGV 2004, Argentina, 26 – 28 October, 2004 (<http://www.iangv.org/tools-resources/reports.html?func=select&id=9>)

A D Chowdhury, Ahok Leyland Ltd., *CNG Programme for Commercial Vehicles in India*, presented at ANGVA 2005, Kuala Lumpur, Malaysia, 26 – 28 July, 2005 (<http://www.iangv.org/tools-resources/reports.html?func=select&id=8&orderby=2&page=1>)

Rajeev Sharma, Indraprastha Gas Ltd., *Compressed Natural Gas Program (CNG) in Delhi – India*, Country Reports Asia-Pacific, presented at NGV 2000, Yokohama, Japan, 17 – 19 October, 2000 (<http://www.iangv.org/tools-resources/reports.html?func=select&id=11>)

The mandate resulted in more than 10,000 CNG buses on Delhi's roads and has been credited with making significant improvements to Delhi's air quality.

Further results included establishing Euro II emission standards in 2000 and Euro III in 2005; implementing more than 100,000 CNG vehicles in one city within a span of 5 years (over 10,000 of which were the bus fleet); and 124 CNG stations were set up in the first 3 years.

Other cross cutting policy measures that resulted from this mandate included improved air quality monitoring, and strengthening the vehicle inspection programmes.

This mandate is unusual, in the sense that it has been imposed by the Supreme Court of India, rather than as a result of Government policy. The decision arose from civil suits that were brought in relation to the right of citizens to breathe clean air.

In 2003, another Supreme Court Order acknowledged the success of the Delhi CNG Project and issued a directive to the Union of India and the state governments to draw plans to introduce clean fuels in 11 polluted cities across India.

## **Europe**

Gasoline in Europe sells for about €1.3/L (about \$1.80/L or \$6.80/gallon), therefore a government mandate to motivate conversion to alternative fuels is unnecessary. Nonetheless, financial incentives from the government to pay for as much as 75% of conversion costs, and environmental concerns provide further incentives among the European community.

While many European countries are developing the CNG vehicle market, Italy, Russia and Germany are currently dominating the agenda. Italy has the largest number of CNG vehicles in Europe and is the 4th largest country in the world for CNG vehicles on the road.

Germany, Poland and France are rapidly working to catch up with Italy. Germany plans to expand their numbers to include 2 million CNG vehicles in circulation by 2020, facilitated by an aggressive program to decrease carbon emissions, and increasing the number of CNG fueling stations from 700 to 1,000 by the end of 2008.<sup>39</sup>

---

<sup>39</sup> <http://www.cngnow.com/EN-US/Vehicles/AroundTheWorld/Pages/default.aspx>



222 Somerset Street West, Suite 300  
Ottawa, Ontario, Canada K2P 2G3  
Tel: +1 613 523-0784  
Fax: +1 613 523-0717  
[info@marbek.ca](mailto:info@marbek.ca)  
[www.marbek.ca](http://www.marbek.ca)



We encourage you to print on recycled paper.  
Marbek prints only on EcoLogo-certified paper.

Project ID: 29064