Halifax Regional Municipality Exploratory Study: Municipal Fleet Conversion to Compressed Natural Gas

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Executive Summary

The Halifax Regional Municipality (HRM) is currently exploring the conversion of all or part of their municipal fleet to natural gas. Stantec Consulting Ltd. was retained to give an overview of available technologies for converting part or all of the municipal fleet from conventional fuels to natural gas, and provide a high-level cost-benefit analysis (CBA) of such a conversion. Natural gas is a cheaper fuel per unit energy than either gasoline or diesel, and a relatively large domestic reserve of natural gas implies a higher degree of fuel security in the long run. Natural gas has also been shown to emit fewer greenhouse gases and air contaminants than gasoline and diesel per unit energy, and could therefore assist HRM in attaining greenhouse gas mitigation goals set out in their municipal climate change action plan.

A review of the current fleet operated by HRM suggested that the municipal support fleet, Metro Transit fleet, and residential municipal solid waste fleets warranted additional analysis to determine the costs and benefits associated with conversion to compressed natural gas (CNG). Other fleets operated by HRM, such as emergency services, had special operational requirements making a conversion from conventional fuels unsuitable at this time. Additionally, fleets would generally not be converting entirely to natural gas, but would become hybrid fleets composed of some mix of CNG vehicles and conventional fuel vehicles. An exception might be the residential municipal solid waste fleet, as vehicles are bought at the start of a contract with the municipality, and could conceivably convert their entire fleet if the supporting infrastructure was available.

Based on a combination of fleet data provided by HRM, pricing information available through the Energy Information Administration, Natural Resource Canada, and Heritage Gas, infrastructure costs, and capital costs based on interviews with vehicle manufacturers, a high-level CBA was completed for the municipal support fleet, Metro Transit Fleet, and residential solid waste fleet.

The results confirm previously published literature showing that CNG conversion is most favourable for fleets with high fuel consumption rates. The municipal support fleet showed that CNG conversion of roughly half of the fleet by 2018 would incur a net cost to HRM of between $700,000 and $2.5 million over six years. Potential savings are only predicted to occur through an aggressive replacement scenario with an additional 20% increase in diesel prices through to 2018.

The Metro Transit fleet shows a more positive response to CNG conversion. Depending on the replacement strategy, conversion of the Metro Transit fleet by 2018 could save HRM between $500,000 and $1.4 million over six years. The savings are relatively insensitive to sourcing fuel through a compressor station, or purchasing CNG from the Stanfield Airport Mother Station, but are more sensitive to future prices of diesel and natural gas.

CNG conversion of the residential solid waste fleet showed the most positive response. The contract structure of residential solid waste collection implies that a substantial part of the fleet would be replaced at once. Our assumption that the fleet is 100% composed of CNG vehicles leads to cost savings of roughly $3.3 million – or higher if coinciding with rising diesel prices. Savings on fuel prices is predicted to translate into operational cost savings by 2016, and produce a total savings of over $2.6 million through 2018.

For all fleets, the feasibility of converting to natural gas appears to be much more sensitive to changes to conventional (diesel or gasoline) fuel prices than changes to natural gas prices. The change was most pronounced for the Metro Transit and solid waste fleets, which showed potential savings of up to $2.8 and nearly $6 million over six years, respectively.

The CBA analysis presented here offers the results from a few select scenarios based on capital replacement planning provided by HRM. Results have indicated that the Metro Transit fleet and the residential solid waste fleet are both possible candidates for CNG conversion given their high fuel consumption rates and their operational requirements.

1.0 Compressed Natural Gas Conversions for Municipal Fleets

The Halifax Regional Municipality (HRM) is currently exploring the conversion of all or part of their municipal fleet to natural gas. Fuel diversification in the transportation sector can provide access to cheaper fuels, and provide some security against short-term regional supply shortages. Roughly 99% of transportation demands in North America are met using crude oil and its derivatives (Natural Gas Use in Transportation Roundtable, 2010). Municipalities are more aware than ever of rising transportation costs, and the associated effects of transportation on climate change and local air quality.

Natural gas has been a relatively common transportation fuel worldwide, but only a small fraction of the 11 million natural gas powered vehicles are found in North America. The lack of natural gas vehicles in Canada in particular is surprising given the relative abundance of natural gas within our borders. Domestically, Canada is both a major producer of natural gas and a major contributor to research and development for natural gas-powered vehicles. Canada also maintains one of the world‘s most extensive natural gas pipeline distribution networks.

As traditional fossil fuel prices rise, converting municipal fleets to natural gas is an attractive means of reducing costs. Recent reports suggest that natural gas costs up to 50% less than conventional fuels (*e.g.*, diesel, gasoline) per energy unit (Natural Gas Use in Transportation Roundtable, 2010; Marbek, 2010). Current and future reserves of natural gas in North America suggest that the current price differential is likely to exist in the long-term.

Converting to natural gas for transportation fuel is also likely to reduce greenhouse gas (GHG) and air pollution emissions due to the relatively lower carbon content and the reduced level of impurities in the fuel (Marbek, 2010). A conversion to CNG would therefore be consistent with HRM’s commitment to reducing GHG emissions as part of their municipal climate change action plan, and consistent with Environment Canada policies on continually improving air quality across the country.

The current limitation to natural gas powered vehicles in Canada is related to the conversion of fleets from conventional diesel or gasoline engines to natural gas-compatible engines. The relatively low density of natural gas requires it to be converted into a compressed form (Compressed Natural Gas, or CNG), or into its liquefied form (Liquefied Natural Gas, or LNG) when used for transportation. The compression introduces additional costs to provide natural gas as a fuel. Additionally, the market share gap between natural gas vehicles and vehicle powered by conventional fuels has led to higher purchasing costs for natural gas vehicles of all types. In particular, vehicles using LNG technology are rarely used beyond a demonstrational capacity due to the limited fueling infrastructure availability and lack of investment by vehicle manufacturers.

While movement to natural gas-powered vehicles has been slow in North America, there are still many examples of municipal fleet conversions to CNG technology, and enough case studies which exist to suggest it to be a viable option for HRM. It is estimated that 20% of transit buses in the United States currently run on natural gas. Conversion to natural gas vehicles has been mostly positive in the US. For example, the city of Tucson converted half of their 200-bus fleet to CNG, and realized annual savings of over $1 million per year in fuel costs, with no significant change in maintenance costs for natural gas vehicles. The switch to natural gas also improved air quality in the city. The town of Smithtown converted a significant portion of their solid waste management fleet, and instantly realized a savings of $3 per home per year in operating costs (Barnett, ND). While most municipalities in the US do acknowledge fuel cost savings, many others – including Los Angeles County, New York City, and Cleveland – have found increased costs associated with maintenance, and were also concerned about the potential liability issues associated with on-site natural gas compression (Watt, ND).

Several examples of transit fleet conversion also exist in Canada. The Municipality of Ottawa recently converted a large portion of its municipal fleet to compressed natural gas. Hamilton, Ontario was the first city to employ CNG powered buses, and currently employs a CNG fleet of roughly 100 buses. Toronto, Vancouver, London, Mississauga, and Kitchener-Waterloo also employ CNG transit buses in their fleets, with Edmonton also researching a potential conversion (McIntyre, 2012). While Coast Mountain Bus in Vancouver found that the initial decrease in fuel costs did not outweigh the increase in maintenance costs in 1997, the continual improvements to natural gas combustion technology was reducing that price gap (Watt, ND).

Municipalities consistently find lower fuel costs by converting to natural gas compared to conventional fossil fuels. Despite those savings, the increased maintenance, capital, and/or infrastructure costs of conversion often significantly reduce, or in some cases, eliminate those savings. Fuel prices are also subject to global supply and demand, which typically exerts more volatility on the natural gas sector globally than crude oil derivatives. As CNG combustion technology continues to improve, however, negative experiences reported by fleet managers appear to diminish with time.

This report examines the feasibility of CNG conversion for HRM fleet vehicles by first summarizing the current and planned fleet composition, and detailing current and planned natural gas distribution within HRM. These factors are combined with expected capital upgrade costs to provide HRM into a cost-benefit feasibility analysis.

2.0 HRM Municipal Fleet Asset Inventory

Converting all or part of the HRM fleet will require vehicle replacement or conversion as well as making upgrades to existing fueling facility or finding alternative locations. Typical CNG fueling facilities involve the compression of natural gas from existing or planned distribution lines (or storage vessels), compressing the gas to required vehicle specifications (3600 psig), and distribution via dispensers or fill posts Vehicles require an internal combustion engine specifically designed for natural gas. Due to the lower energy level per unit volume of natural gas compared to conventional fuels, CNG vehicles may also require additional on-board storage capabilities. Conversion kits are available for some vehicles.

2.1 MUNICIPAL FLEET INVENTORY

Converting the municipal fleet from a gasoline or diesel engine to CNG technology depends on the availability of suitable engines for a particular class. Some vehicles require extended range for a single tank of fuel, while some require accessibility to fueling stations in more remote areas. The municipal fleet is responsible for a wide variety of services which can be generally groups as follows:

- Municipal Infrastructure Support
- Metro Transit
- Municipal Solid Waste
- Emergency Services (Police and Fire)

Each service type requires differing levels of fueling infrastructure support, range capabilities, and accessibility. Replacement, retrofitting, and fuel station conversion costs will also vary from service to service. The overlap of available CNG stations and vehicle suitability for conversion will greatly determine the level of CNG conversion viable for HRM municipal fleets.

2.1.1 Municipal Support Fleet

The municipal support fleet includes street and road servicing, general infrastructure maintenance (*e.g.*, traffic lighting), and snow removal. The requirements for the municipal support fleet are largely seasonal. Summer and fall operations (nominally April to November) require less vehicle support, with little to no snow removal support. Municipal support vehicles are typically used in eight-hour shifts, six hours of which are actually spent on the road. Other vehicles with more specialized equipment or services (*e.g.*, road repair vehicles) could see even more use throughout the summer and fall. During the winter and spring, vehicle use increases, especially during and following snowfall events. Fuel consumption during April 2010 compared to February 2011 (38,915 litres and 164,250 litres, respectively) illustrates the enhanced support requirements required by the municipal fleet due to winter weather events.

Municipal support vehicles offer the widest variety of vehicles compared to any other fleet service. Vehicle types range from passenger vehicles and light trucks, to medium and heavy duty hauling trucks (Table 2.1).

Table 2.1 Municipal Support Fleet Vehicle Inventory

Class	Quantity	Average Daily Use (hours/day)	Average Fuel Consumption (litres/day)*	Average Distance Travelled (km/day)*
Passenger	92	6.5	9	55
Truck Light	150	7	19	238
Truck Medium	55	7	18	60
Truck Heavy	64	9.5	85	119
Total	**361**			

* Daily average values are based on usage occurring 260 days per year (5 days per week)

The scope of this study is limited to light, medium, heavy trucks, and passenger vehicles within the municipal support fleet. Other transportation equipment not listed above (*e.g.*, self-propelled equipment and off-highway vehicles) were excluded from this study as they represent a variety of specialized equipment which are of intermittent use, and have significant range and fuel station accessibility requirements.

2.1.2 Transit Fleet

The HRM Metro Transit fleet is comprised of 339 vehicles operating on a 365-day schedule (Table 2.2). Vehicle classes range from the converted cutaway van chassis variety for accessibility services (Access-A-Bus), to 40-foot low-floor buses comprising over half of the fleet, to 60-foot articulating buses deployed for high-volume routes throughout HRM. On average, buses are in active use for 10 to 11 hours per day; however, some buses are required for up to 20 hours of service. In all cases, transit buses have been designed to operate on a single tank of fuel per day. Over 80% of the transit fleet is required to be operational daily.

Fuel consumption is generally correlated to average distance travelled. The bulk of metro transit's service is handled by both 40-foot and 60-foot buses, both of which consume the most fuel per day. While average vehicle distances range from 90 to 375 km/day, some buses are required to travel over 450 km/day.

Table 2.2 Metro Transit Fleet Vehicle Inventory

Class	Quantity	Average Daily Use (hours/day)	Average Fuel Consumption (litres/day)*	Average Distance Travelled (km/day)*
Light Truck	4	9.5	19	90
40-Foot High Floor Bus	38	10	127	203
40-Foot Low Floor Bus	173	10	155	239
60-Foot Hybrid Bus	2	10	123	162
60-Foot Articulated Bus	45	11	157	203
Access-A-Bus	35	9	48	183
Community Transit	3	9	135	375
MetroX	19	10	82	208
Rapid Transit Buses (MetroLink)	20	7.5	102	173
Total	**339**			

* Daily average values are based on usage occurring 260 days per year (5 days per week). Grey highlights are used for portions of the fleet which was not considered in the cost-benefit analysis due to infrequent or irregular usage patterns.

The Access-A-Bus fleet operates on a by-request basis, typically picking up and dropping off individuals to and from their destinations to their homes. Community transit buses are likewise unique, by providing service to outlying areas. These buses were therefore excluded from our study since they require intermittent use, variable routing, and access to fueling in remote areas, and are therefore considered to be poor candidates for CNG conversion.

2.1.3 Solid Waste Fleet

2.1.3.1 Residential Solid Waste

HRM contracts qualified collection companies for the residential curbside collection of garbage, organics and recyclables. Eight collection zones are served by four collection companies (Table 2.3) within HRM. Garbage and organics are collected bi-weekly on alternating weeks, typically with rear load packers. Roughly two thirds of HRM is serviced by weekly recycling collections, with the other third being serviced on a bi-weekly basis.

The estimated residential solid waste collection fleet includes over 100 rear- and side-loading haulers (Table 2.4). Most of the collections take place in relatively urban environments, with vehicles operating on 9 hour days and travelling roughly 75 to 100 km per day. A small proportion (roughly 10%) of the collections occurs in rural areas, and can travel distances of 200 to 300 km per day.

Table 2.3 Residential Collection Zones and Management Companies in HRM

Area	Region	Management Company
1	Former City of Halifax	Waste Management
2	Former City of Dartmouth	Waste Management
3	Bedford, Hammond Plains, Pockwock & area	Miller Waste
4	Beechville, Lakeside, Timberlea, Prospect & area	Waste Management
5	Sackville, Fall River, Dutch Settlement & area	Miller Waste
6	Cole Harbour, Westphal, Eastern Passage & area	Waste Management
7	Porter's Lake, Chezzetcook, Preston & area	Leo J. Beazley Ltd.
8	Elderbank, Musquodoboit & Eastern Shore	Eastern Shore Cartage

2.1.3.2 Commercial Solid Waste

Estimates of the corporate collection fleet size and distribution was not available. Corporate (*i.e.*, industrial and commercial) waste is estimated to be responsible for over 60% of solid waste generation in HRM, and include over a dozen private entities of various fleet sizes. Corporate collection is not part of the HRM tendering process for solid waste and was excluded from this study, despite the relatively large share of solid waste occurring for corporate sources in HRM.

Table 2.4 Residential Solid Waste Management Fleet Inventory

<table>
<tr><th>Class</th><th>Quantity</th><th>Average Daily Use (hours/day)*</th><th>Average Fuel Consumption (litres/day)*</th><th>Average Distance Travelled (km/day)*</th></tr>
<tr><td>Rear Loader (Refuse/Organics)</td><td>59</td><td rowspan="5">9</td><td>90</td><td rowspan="5">75 - 100 (urban); 250 (rural)</td></tr>
<tr><td>Side Loader (Recylcing)</td><td>40</td><td rowspan="4">70</td></tr>
<tr><td>Side Loader (Refuse/Organics)</td><td>8</td></tr>
<tr><td>Side Loader (Refuse/Organics/Recycle)</td><td>2</td></tr>
<tr><td>Cube Van (Refuse/Organics/Recycle)</td><td>1</td></tr>
<tr><td>Total</td><td>110</td><td colspan="3"></td></tr>
</table>

* Daily average values are based on usage occurring 260 days per year (5 days per week)

2.1.4 Emergency Vehicle Fleet

Regional fire services include over 250 vehicles distributed throughout the entire HRM region, with stations in both rural and urban areas (Table 2.5). HRM regional fire services provides firefighting services as well as training and education in fire prevention and fire inspection services. There are over 40 fire stations within HRM.

Table 2.5 Fire Services Vehicle Fleet Inventory

Class	Quantity
Passenger	22
Truck Light	58
Truck Medium	38
Truck Heavy	7
Fire Truck	117
Self-Propelled Equipment	3
Bus	1
Off Highway	7
Total	**253**

HRM Police service includes nearly 350 vehicles primarily in the core of HRM, while the RCMP mainly patrols more rural areas (Table 2.6). There are three main Police Headquarters: East Division (Dartmouth), Central Division (Peninsular Halifax) and West Division (West). The

Regional Police Services provide training, education and community outreach programs as well as policing services.

Table 2.6 Police Services Vehicle Fleet Inventory

Class	Quantity
Passenger	196
Motorcycle	18
Truck Light	28
Truck Medium	3
Total	**348**

Emergency services require specialized access characteristics which are usually incompatible with CNG conversions. In particular, emergency vehicles typically require the ability to idle for extended periods of time. The on-board storage capabilities combined with the current lack of existing CNG infrastructure is not conducive to the extended range emergency vehicles require. Since existing services must rely on the extended private distribution of gasoline and diesel fuels throughout HRM, the conversion to CNG is not viewed as cost effective or efficient. Therefore, emergency vehicles were not further assessed for CNG conversion viability in this study.

2.2 HRM FUELING SITES INVENTORY

Private sector installations of diesel and gasoline fuels exist throughout HRM, and provide a large share of fuel to the municipal fleet. Centrally-oriented services such as Metro Transit also enjoy dedicated fueling stations within their existing facilities due to their outstanding fuel requirements. Solid waste contractors make their own fueling arrangements, either within their own facilities or throughout contracts with fuel companies.

The quantity and location of CNG refueling sites throughout HRM is a significant potential barrier to converting fleet vehicles of all types and services. Heritage Gas is the sole distributor of natural gas in Nova Scotia, and has developed a conservative distribution methodology to provide customers with an attractive price for fuel while still covering infrastructure costs. As a consequence to such an approach, the distribution grid is potentially beyond the reach of some potential fueling locations for the HRM fleet. The primary reason why many municipal fleets were ignored by this study is their inherent need for fueling stations distributed throughout HRM and the up-front costs of installing so-called Mother Stations. Emergency and other municipal vehicles typically rely on commercial fueling stations, none of which currently provide natural gas fueling options.

Table 2.7 Current HRM-operated Fueling Locations

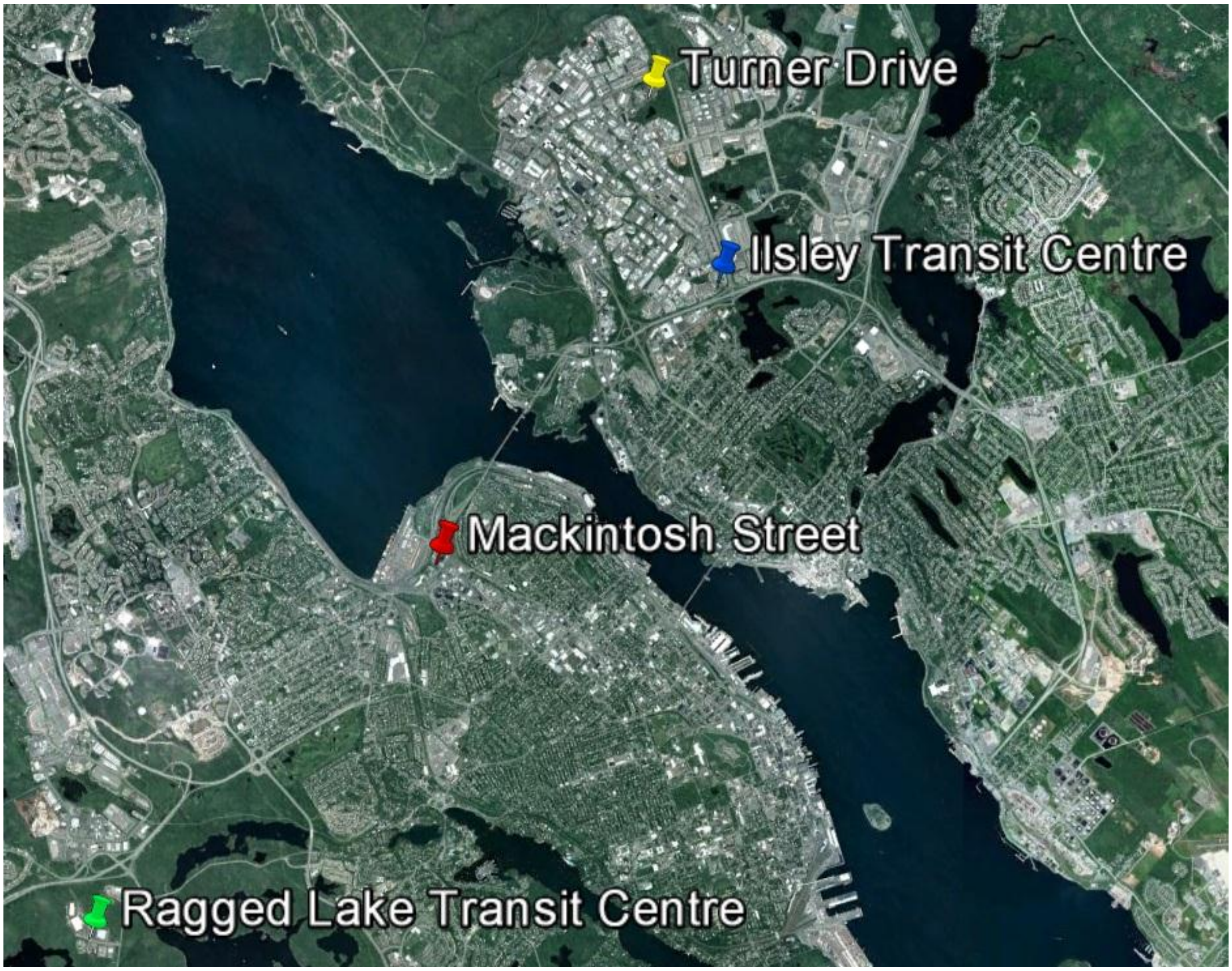
Facility	Address	Vehicle Storage	Fueling Capability	Maintenance Capability	Vehicle Category Serviced
Ilsley	200 Ilsley Ave. Dartmouth	Yes	Yes	Yes	Buses
Ragged Lake	80 Grassy Lake	Yes	Yes	Yes	Buses
Bedford	1 Mann Street Bedford	Yes	Yes	No	General Fleet
Turner Drive	11 Turner Drive Dartmouth	Yes	Yes	Yes – Minor Repairs	General Fleet
Bissett Road	215 Bissett Road – Cole Harbour	Yes	Yes	No	General Fleet
Police Station Gottingen St	1975 Gottingen Street Halifax	Yes	Yes	Yes	Emergency
Cowie Hill	375 Cowie Hill Road Halifax	Yes	Yes	No	General Fleet
MacKintosh Street	3825 MacKintosh Street	Yes	Yes	No	General Fleet
Knightsridge Fire Station	45 Knightsridge Drive Halifax	Yes	Yes	No	Emergency
West Street	5663 West Street	Yes	Yes	No	Emergency

* Colours indicate locations with possible connections to existing natural gas distribution lines shown in Figure 2.1.

Refueling for municipal larger fleet vehicles (*e.g.*, snow removal and transit) currently occurs at 10 locations throughout HRM (Table 2.7). It is possible that all of these locations could be potentially upgraded to allow CNG fueling. Three existing HRM locations are found near existing distribution lines, and could potentially be linked depending on Heritage Gas feasibility tests (Figure 2.1). Heritage Gas has also indicated that the potential consumption rate of natural gas would make Ragged Lake a viable service option.

This analysis confirms that, should HRM decide to pursue CNG vehicles, there are many suitable locations near existing municipal vehicle storage and repair sites. It is anticipated that building a compressor station by HRM would not require securing new property.

Figure 2.1 HRM Fueling Locations with Potential Access to Natural Gas Distribution Lines



3.0 CNG Fleet Requirements and Characteristics

3.1 CNG REGULATORY REVIEW

There are a variety of national and international codes and standards applying to CNG vehicles, refueling infrastructure, and fuel quality (Table 3.1). A myriad of standards exist for every phase of CNG development, from on-board pressure vessels, fueling connections, and system integrity, to hoses, temperature controls, valve controls on fueling systems, to fuel quality. Despite the number of standards and codes available, relatively few have been enshrined into provincial or federal regulations (Table 3.1).

Table 3.1 Applicable Standards for CNG Distribution and Consumption

Standard	Referenced in Regulations			
	NS	Atlantic	Other Province	Federally
Vehicles				
AGA NGV 3.1 /CGA 12.3- Fuel System Components for Natural Gas Powered Vehicles				
NGV1 /CSA NGV1 - CNG fuelling connection devices				
ANSI PRD 1 - Pressure Relief Devices for Natural Gas Vehicle (NGV) Fuel Containers				
CSA B51-03- Boiler, Pressure Vessel, and Pressure Piping code	x	x	x	x
CSA B51-09- Boiler, Pressure Vessel, and Pressure Piping code			x	x
ANSI NGV 2- CNG Vehicle Fuel Containers				x
CSA B109- Natural Gas for Vehicles Installation Codes		x	x	x
CGA-B149.4-M91 (superseded by CSA B109)			x	
CSA B149.5-05 Installation Code for Propane Fuel Systems and Tanks on Highway Vehicles		x	x	x
Test Method 301.2- CNG Fuel System Integrity (developed by Transport Canada)				
Refueling				
CSA B51-Boiler, Pressure Vessel, and Pressure Piping code	x	x	x	x
ANSI NGV1-2006/CSA NGV1-2006- Compressed Natural Gas Vehicle (NGV) Fuelling Connection Devices				
CSA 12.6- Vehicle Refuelling Appliances				
ANSI NGV 4.1 /CSA 12.5- NGV Dispensing Systems				
ANSI NGV 4.2 /CSA 12.52- Hoses for Natural Gas Vehicles and Dispensing Systems				
CSA America NGV 4.3 (draft)-Temperature Compensation Devices for Natural Gas Dispensing Systems				
ANSI NGV 4.4/ CSA 12.54- Breakaway Devices for Natural Gas Dispensing Hoses and Systems				
CSA America NGV 4.5 (draft) Priority and Sequencing Equipment for Natural Gas Dispensing Systems				
ANSI NGV 4.6 /CSA 12.56- Manually Operated Valves for Natural Gas Dispensing Systems				
CSA America NGV 4.7 (draft) Automatic Valves for Use in Natural Gas Vehicle Fuelling Stations				
ANSI NGV4.8 /CSA 12.8- Natural Gas Fuelling Station Reciprocating Compressor Guidelines				
CAN/CSA B108 Natural Gas Fuelling Stations Installation Code	x	x	x	
CAN/CSA B149.1 Natural Gas and Propane Installation code	x	x	x	
CAN/CSA B149.2 Propane Storage and Handling code	x	x	x	x
CAN/CSA B149.3 Code for the field approval of fuel-related components on appliances and Equipment	x	x	x	
NFPA 52 Vehicular Gaseous Fuel Systems Code			x	x
Fuel Quality				
CAN/CGA B105-M93: Code for Digester Gas and Landfill Gas Installations	x	x	x	
B105S1-07 Supplement No. 1 to CAN/CGA B105-M93		x		

Table 3.1 Applicable Standards for CNG Distribution and Consumption

Standard	Referenced in Regulations			
	NS	Atlantic	Other Province	Federally
CAN/CGSB-3.14-2006 Liquefied Petroleum Gas (Propane) for Fuel Purposes				x
ASTM D 1945 Test Method for Analysis of Natural Gas by Gas Chromatography				
ASTM D 1946 Practice for Analysis of Reformed Gas by Gas Chromatography				
ASTM D3246 Test method for Sulfur in Petroleum Gas by Oxidative Microcoulometry				

Regulations pertaining to the suitable pressure of storage tanks and refueling stations tend to vary between jurisdictions (SCC, 2012). Those provinces with existing refueling infrastructure tend to refer to national building codes for CNG refueling (CSA B108 – Natural Gas Fueling Stations Installation Code), where a maximum pressure for public refueling stations is set to 3,600 pounds per square inch (psi).

The lack of harmonization within Canada is relevant to consumers travelling between jurisdictions. While it will be important to align with the most prevalent technology in use nationally, fleet conversion will largely involve private refueling stations, and will therefore require little compatibility with other jurisdictions. Future standards are expected to more generally endorse tanks at higher pressures (*i.e.*, 3,600 psi), as they will allow for more on-board fuel storage, and therefore improve vehicle range.

The lack of regulations and standards existing provincially is largely associated with the lack of facilities and infrastructure currently accessible in Nova Scotia. It is likely that any future regulations enacted in Nova Scotia will be guided by existing regulations in other provincial jurisdictions with more mature fueling and vehicle infrastructure (*e.g.*, Ontario, Alberta and New Brunswick). Pursuing conversion of the municipal fleet will therefore require attention to available codes for CNG distribution and on-board storage and combustion in lieu of provincial or federal regulations except for certain circumstances (*i.e.*, specific codes adopted in the Occupational Health and Safety Regulations (Federal and Nova Scotia), the Motor Vehicle Safety Regulations (Federal) or Fuel Safety Regulations (Nova Scotia).

3.2 CNG FUEL CHARACTERISTICS

3.2.1 Energy Content and Fuel Efficiency

A significant drawback to CNG technology as a motive fuel is the lower heating value on a per unit volume compared to traditional combustion fuels such as gasoline and diesel. Heating value is important as it is the characteristic of the fuel that enables it to do work. While the heating value per unit mass for natural gas is superior to diesel, gasoline, or propane, the heating value per unit volume of natural gas is significantly lower due to its lower density at standard temperature and pressure (Table 3.2) Natural gas typically contains 900 BTU/ft^3 (260 kJ/L at STP), whereas gasoline and diesel generally rate much higher, at between 120,000 -

135,000 BTU/US gallon. In addition to the significant additional natural gas required on a per unit volume basis, conventional fossil fuels used in modern motive power units are typically 10-20% more fuel efficient than the newer CNG internal combustion engines.

Table 3.2 Higher Heating Values for Common Combustion Fuels

Combustion Fuel	Heating Value (at STP)	
	kJ/L	kJ/kg
Natural Gas	260	55,500
Gasoline	35,500	47,300
Diesel	39,200	44,800
Propane	26,100	50,350

Source: Alternative Fuels Data Center (2013)

3.2.2 Fuel Costs

A principal benefit of CNG technology is the fuel cost savings compared to conventional oil-based fossil fuels such as diesel and gasoline. The United States Energy Information Administration (US EIA) regularly tracks monthly retail prices for gasoline, diesel, and natural gas. As of February 2013, retail fuel prices for gasoline and diesel are nearly 10 times higher than natural gas on a per unit energy basis (typically evaluated in Diesel-Litre Equivalents, or DLEs) (EIA, 2013).

In Canada, Natural Resources Canada (NRCan) tracks retail gasoline diesel prices throughout Canada on a weekly basis (available at http://www2.nrcan.gc.ca/eneene/sources/pripri/prices_bycity_e.cfm). However, natural gas is typically not sold on the retail market for transportation, and is only distributed through regulated monopolies such as Alta Gas in Alberta, or Heritage Gas in Nova Scotia. While some fueling prices exist in Alberta, they are not likely representative of the costs likely incurred in Nova Scotia by HRM. The retail price for natural gas in Nova Scotia has been on average 25% more than prices in Alberta since 2008. Estimating fuel prices based on fixed prices provided by Heritage Gas does reveal a probable cost to HRM for natural gas on a DLE basis. Using Heritage Gas Tier 3 prices for customers using over 50,000 GJ annually (available at http://www.heritagegas.com/historical-rates.html), CNG is still a comparatively cheap transportation fuel for HRM, costing roughly 25% of fuel prices for diesel and gasoline in Nova Scotia (Table 4.1). Future forecasts for fuels continue to show a favourable price point for CNG relative to traditional fossil fuels over the next 10 years, according the EIA (EIA, 2013). By extrapolating forecasts in the US market based on the current ratio of prices between Canada and the US, prices for natural gas also appears to be favourable compared to traditional fossil fuels in Nova Scotia (Table 4.1).

Future fuel prices must be qualified by their relative uncertainty in the global markets. It is generally acknowledged that the price for natural gas is considerably more volatile than either gasoline or diesel prices (Alterman, 2012). The uncertainty is worldwide, but affects different regions for different reasons. In the Canadian context, the relatively tight supply of natural gas from a small number of sources, plus the associated vulnerability to risk from extreme weather events off the Nova Scotia coast, create additional risk that will have to be added to the actual cost of fuel in order to develop realistic annual budgets for fuel consumption. For example, Dalhousie University recently converted to natural gas for heating. Due to a decrease in supply from local natural gas sources, the price of natural gas climbed from $3.43 per GJ to $11.99 per GJ over two months, and severely affected the University's bottom line (CBC News, 2013). The future pursuit of shale gas plays in the Maritimes could reduce future market volatility in Nova Scotia, as has been recently experienced in the United States (Alterman, 2012).

3.2.3 Criteria Air Contaminant (CAC) and Greenhouse Gas (GHG) Emissions

The combustion of fossil fuels leads to the release of several greenhouse gases (GHGs) and criteria air contaminants (CACs) in amounts which depend on the fuel itself and its formulation during refinement. The release of GHGs is of primary concern for HRM in reducing municipal emissions and aligning itself with provincial objectives set out in the Environmental Goals and Sustainable Prosperity Act (2007) to reduce emissions by 10% of 1990 emissions by 2020. It also would assist in meeting objective outlined in the HRM municipal climate change action plan. Emissions of CACs are also a health concern, and are secondary benefits to health and well-being in the municipality, even without specific municipal or provincial targets for such emissions.

Natural gas has an improved emissions profile for GHGs and CACs when compared to conventional fossil fuels. Carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions from natural gas are considerably less than traditional fossil fuels due to the reduced carbon content of the fuel. On the other hand, natural gas tends to release significantly higher quantities of methane (CH_4) as a result of incomplete combustion. Natural gas also has a positive impact on ambient air quality by emitting fewer CAC emissions due to significantly less impurities (*e.g.*, sulfur, particulates) in the raw fuel compared to gasoline or diesel.

3.3 FUELING INFRASTRUCTURE

Significant changes and upgrades at existing facilities would be required to facilitate compressed natural gas fueling for the HRM vehicle fleets. The proximity of several existing HRM vehicle fueling locations to existing distribution lines indicates that the fleets considered for analysis in the current report would be able to install fueling infrastructure for CNG fleet conversion. Ragged Lake was also indicated by Heritage Gas to be a location that could be serviced due to the expected natural gas load such a facility would require.

Compressed natural gas fueling facilities would incur installation costs associated with the design (consulting) and physical of support infrastructure (*e.g.*, concrete, additional security fencing). There are also costs associated with the on-site compression to 3,600 psi, and the additional electrical requirements for the pumps. A full cost for a generic refueling station capable of meeting the demands of any one of the municipal fleets considered in this report is estimated to cost roughly $1.5 million (Table 3.2).

Table 3.3 Estimated Generic Combined Fast Fill/Slow Fill CNG Fueling Station

Description	Cost
Direct Costs (*e.g.*, Design, Excavation, Engineering)	$580,000
Indirect Costs (*e.g.*, permitting, construction management)	$110,000
CNG Equipment	$707,000
Contingencies	$16,000
TOTAL	**$1,413,000**

Another option to having natural gas delivered directly on-site, and compressed is having CNG delivered from Heritage Gas' Mother Station under construction at Stanfield Airport. By trucking in compressed vessels to a given HRM site, additional costs would be borne on a per unit energy basis. However, HRM would not be responsible for the planning, permitting, construction, and management of the compressor station. HRM would be required to install a decanting station on-site, which is a fraction of the cost of a full compressor station. A detailed feasibility study commissioned by QUEST Nova Scotia showed that a decanting station would cost roughly $144,000, or 10% of the cost of the compressor station (Jenmar Concepts, 2012).

While the decanting station would decrease immediate capital costs significantly, it would also lead to an increase in fuel costs over the lifetime of the conversion. Delivery cost estimates for such a scenario have been found to be roughly $3.50/GJ (Jenmar Concepts, 2012). Assuming a conservative $0.50 markup, that leads to an additional fuel cost of roughly $0.14/DLE for the HRM fleet. Assuming the trucks must travel 100 km per day to deliver CNG, there would be a negligible (< 1%) impact on GHG and CAC emissions.

4.0 HRM CNG Fleet Conversion High-Level Cost-Benefit Analysis

Several case studies have established that converting all or portions of municipal fleets to CNG is not only a viable approach to reducing GHGs and air pollution in urban areas, but is also more cost-effective. There is no denying the financial superiority of natural gas for almost any transportation economy. However, the infrastructure and vehicles powered by natural gas suffer from being a less mature technology and require more up-front costs. While access to the fuel is an important first step, access to reliable and efficient technologies confound the total benefits of switching technologies.

A cost-benefit analysis (CBA) is a powerful tool to weigh the appropriateness of converting HRM's fleet to CNG. The high-level feasibility CBA presented here is informed by operations and planning data provided by HRM as well as market prices available from the US EIA and NRCan. Current and historical natural gas prices to develop an estimate future cost of natural gas were retrieved from Heritage Gas, NRCan and the US EIA. Future fuel prices for gasoline and diesel were marked down according to current discounts received by HRM on fuel purchases (Larry Hilton, Pers. Comm.). Incremental vehicle replacement costs to switch from diesel to CNG engines were based on diesel and CNG vehicle quotes from industry for several vehicle classes, or from literature (Johnson, 2010). Costs of fueling station capital costs were estimated based on a preliminary engineering feasibility study to fulfill a fleet size of roughly 80 vehicles. The new CNG fuel stations are assumed to be built at existing fueling locations, and include retrofitting, employee training, and additional safety features for the site. For each scenario, it was either assumed that HRM would truck CNG from the Stanfield Airport Mother station, or would build one compressor station for the given fleet.

Several assumptions based on current literature and fuel price modeling were incorporated into the CBA. Future fuel prices were determined by correlating past and future gasoline, diesel, and natural gas price forecasts published by the US EIA to markets in Nova Scotia, as no published data extending beyond 2014 was available for markets in Nova Scotia. Incremental facility maintenance costs of $0.08/DLE were applied to CNG conversion for scenarios where a full compressor station was assumed to be built (Johnson, 2010). For scenarios where CNG is trucked from Stanfield Airport, a maintenance cost of 0.15 cents/DLE was used (Jenmar Concepts, 2012). There is some disagreement in the literature as to whether vehicle maintenance is more or less expensive for CNG vehicles compared to maintenance for conventionally fueled vehicles (Johnson, 2010). To be conservative, vehicle maintenance costs of $0.015/km above maintenance costs for conventional fuel vehicles were used in the CBA analysis (Samara, 2012). Diesel vehicles were assumed to operate 20% more efficiently than CNG vehicles (*i.e.*, CNG vehicles were assumed to consume 20% more fuel to achieve the same distance travelled) (Watt, ND).

Municipal support, transit, and solid waste fleets were treated independently as each sector has many inherent differences in planning and usage. Future fuel prices were common for all sectors and for all scenarios, unless otherwise specified (Table 4.1). The CBA extended to 2018, which matched the replacement strategy plan for HRM transit vehicles, and also roughly matches the length of the residential sold waste contracts. The CBA was evaluated on a net present value (NPV) approach, whereby the total future costs of each scenario are normalized to 2012 dollars using a discount rate of 5%.

Table 4.1 Summary of Predicted Fuel Prices Used for CBA

Year	$ Per Litre						
	Gasoline	Municipal Gasoline	Transit Diesel	Municipal Diesel	Retail Diesel	Heritage Gas Tier 2	Heritage Gas Tier 3
2012	1.46	0.93	0.90	0.92	1.31	0.25	0.16
2013	1.32	0.84	0.82	0.84	1.20	0.26	0.17
2014	1.39	0.88	0.87	0.90	1.28	0.27	0.18
2015	1.43	0.91	0.90	0.92	1.32	0.28	0.18
2016	1.44	0.91	0.91	0.94	1.34	0.28	0.19
2017	1.46	0.93	0.93	0.95	1.36	0.29	0.19
2018	1.47	0.93	0.94	0.96	1.37	0.30	0.19

* Natural gas price in Diesel Litre Equivalents (DLEs)

In addition to potentially reducing costs, GHG and CAC emissions are another important reason to convert fleets to CNG. Changes to air emissions were calculated based on emission factors calculated by GHGenius, a GHG lifecycle analysis model endorsed by Natural Resources Canada (Table 4.2) ($(S\&T)^2$ Consultants, 2012). GHGenius is regionally specific, computes total GHG and CAC emissions created by the extraction, refinement, distribution, and combustion of several fuels, including gasoline, diesel, and CNG, and is consistently updated as new research is produced. The lifecycle analysis from GHGenius indicates that CNG vehicles produce fewer GHG and CAC emissions than gasoline or diesel per kilometre driven (Table 4.2). An exception is CH_4, which is emitted in greater quantities in from CNG vehicles due to incomplete combustion of the gas.

Table 4.2 Predicted GHG and CAC Emission Factors for Diesel and CNG Vehicles

Vehicle Type	Fuel	GHG (grams/km)				CAC (grams/km)				
		CO_2	CH_4	N_2O	CO_{2eq}	CO	NOx	VOC	SOx	PM
LDV	Gasoline	288.7	0.217	0.001	302	10.93	0.51	0.38	0.25	0.06
	CNG	223	1	0.008	250	2.97	0.55	0.07	0.1	0.05
HDV	Diesel	1361	0.885	0.059	1400	0.54	1.54	0.26	0.78	0.15
	CNG	1062	3.61	0.051	1167	0.24	0.93	0.21	0.28	0.07

4.1 MUNICIPAL SUPPORT FLEET

A business-as-usual (BAU) case was constructed to determine the expected future fleet costs until 2018, and represents a fleet replacement of roughly 8 passenger vehicles, 17 light trucks, and 4 medium-duty trucks per year, as estimated by actual fleet replacement plans. No heavy-duty trucks were replaced in the BAU scenario, as internal projections do not indicate significant replacements over the next five to six years. The total NPV for the BAU case is $52,421,000 (Table 4.3).

When vehicles slated for replacement are instead converted to CNG fuel, the NPV cost for the fleet and the compressor station is predicted to be $54,912,000 by 2018, or roughly $2.5 million more costly than continuing with gasoline and diesel for replacement (Table 4.3). Under the planned scenario, roughly 50% of the fleet would be converted to CNG. In a hypothetical scenario in which 10 heavy-duty trucks are replaced annually in addition to the vehicles already on the replacement plan, the total NPV cost of the fleet drops to $54,199,000, roughly $1.8 million more than the BAU case, but would require almost 80% of the fleet to be converted to natural gas by 2018. A substantial improvement in the cost occurs since, by 2016, the support fleet consumed over 50,000 GJ and qualifies for the Heritage Gas Tier 3 rate (Table 4.7).

Table 4.3 CBA Scenarios for Municipal Support Fleet Including a Compressor Station (NPV 2012 $)

Year	BAU	Fleet Replacement Scenario		
		Planned	Enhanced	Double NG Price
2012	$8,666,000	$10,162,000	$10,162,000	$10,162,000
2013	$8,050,000	$8,354,000	$8,587,000	$8,388,000
2014	$7,776,000	$8,018,000	$8,128,000	$8,086,000

Table 4.3 CBA Scenarios for Municipal Support Fleet Including a Compressor Station (NPV 2012 $)

Year	BAU	Fleet Replacement Scenario		
		Planned	Enhanced	Double NG Price
2015	$7,466,000	$7,651,000	$7,649,000	$7,753,000
2016	$7,133,000	$7,267,000	$7,033,000	$7,397,000
2017	$6,819,000	$6,904,000	$6,548,000	$7,063,000
2018	$6,512,000	$6,556,000	$6,090,000	$6,742,000
TOTAL	**$52,421,000**	**$54,912,000**	**$54,199,000**	**$55,591,000**
Difference	**-**	**-$2,491,000**	**-$1,778,000**	**-$3,170,000**

Table 4.4 CBA Scenarios for Municipal Support Fleet Using Stanfield Airport Mother Station (NPV 2012 $)

Year	BAU	Fleet Replacement		
		Planned	Enhanced	Double NG Price
2012	$8,666,000	$8,816,000	$8,816,000	$8,816,000
2013	$8,050,000	$8,287,000	$8,545,000	$8,370,000
2014	$7,776,000	$7,966,000	$8,124,000	$8,134,000
2015	$7,466,000	$7,614,000	$7,680,000	$7,858,000
2016	$7,133,000	$7,243,000	$7,096,000	$7,555,000
2017	$6,819,000	$6,892,000	$6,641,000	$7,269,000
2018	$6,512,000	$6,555,000	$6,210,000	$6,985,000
TOTAL	**$52,421,000**	**$53,372,000**	**$53,112,000**	**$54,988,000**
Difference	**-**	**-$951,000**	**-$691,000**	**-$2,567,000**

A theoretical increase in natural gas prices over the whole six years would push the total cost value further negative, to $3.17 million. A 20% increase in diesel and gasoline prices over the same time period does change the overall costs of CNG conversion for the municipal support fleet, however the conversion cost is still greater than the BAU case (Table 4.4).

The CBA results improve noticeably when the fleet conversion instead takes advantage of the Stanfield Airport Mother Station (Tables 4.5 and 4.6). While CNG conversion is generally more costly than the BAU case, the sensitivity analysis shows that an aggressive fleet conversion and higher than predicted diesel prices would actually produce a net-positive savings to HRM by 2018 (Table 4.6, column 4).

Still, most predictions do indicate that HRM would not save money by 2018 by converting their fleet to CNG vehicles (Figure 4.1). The results from the sensitivity analysis confirm previous studies into CNG fleet conversion; the capital overhead associated with CNG suits fleets with high daily fuel consumption loads.

Table 4.5 CBA Scenarios for Municipal Support Fleet Compared to BAU Case and a 20% Increase in Diesel and Gasoline Prices and a Compressor Station (NPV 2012 $)

Year	BAU	Fleet Replacement		
		Planned	Enhanced	Double NG Price
2012	$9,145,000	$10,641,000	$10,641,000	$10,641,000
2013	$8,465,000	$8,750,000	$8,949,000	$8,785,000
2014	$8,193,000	$8,398,000	$8,437,000	$8,466,000
2015	$7,875,000	$8,006,000	$7,898,000	$8,107,000
2016	$7,528,000	$7,591,000	$7,221,000	$7,722,000
2017	$7,200,000	$7,201,000	$6,680,000	$7,359,000
2018	$6,878,000	$6,825,000	$6,169,000	$7,011,000
TOTAL	**$55,284,000**	**$57,412,000**	**$55,995,000**	**$58,091,000**
Difference	**-**	**-$2,128,000**	**-$711,000**	**-$2,807,000**

Table 4.6 CBA Scenarios for Municipal Support Fleet Compared to BAU Case and a 20% Increase in Diesel and Gasoline Prices and Using the Stanfield Airport Mother Station (NPV 2012 $)

Year	BAU (Conventional Fuels + 20%)	Fleet Replacement		
		Planned	Enhanced	Double NG Price
2012	$9,145,000	$9,295,000	$9,295,000	$9,295,000
2013	$8,465,000	$8,683,000	$8,906,000	$8,767,000
2014	$8,193,000	$8,346,000	$8,433,000	$8,514,000
2015	$7,875,000	$7,969,000	$7,929,000	$8,213,000
2016	$7,528,000	$7,567,000	$7,284,000	$7,880,000
2017	$7,200,000	$7,189,000	$6,773,000	$7,565,000
2018	$6,878,000	$6,824,000	$6,288,000	$7,254,000
TOTAL	**$55,284,000**	**$55,873,000**	**$54,908,000**	**$57,488,000**
Difference	**-**	**-$589,000**	**$376,000**	**-$2,204,000**

Figure 4.1 Cumulative Cost of the CNG Planned Replacement Scenario Relative to BAU for Municipal Support Fleet ($ 2012)

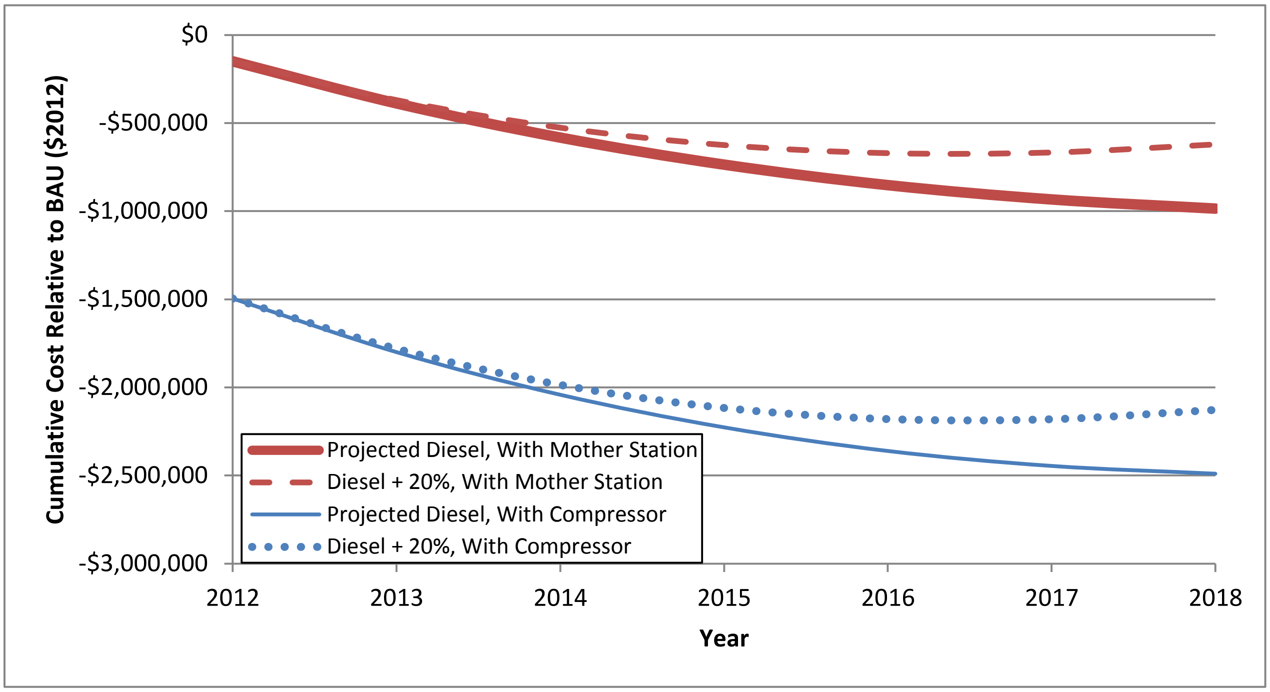


Table 4.7 Annual Predicted Natural Gas Demand by Support Fleet (GJ)

Year	Support Fleet		Metro Transit Fleet		Residential Solid Waste
	Planned	Aggressive	Planned	Aggressive	
2012	0	0	0	0	101,500
2013	5,200	15,000	44,900	54,000	101,500
2014	10,400	29,900	66,400	84,400	101,500
2015	15,500	44,900	82,400	109,600	101,500
2016	20,700	59,900	141,900	178,000	101,500
2017	25,900	74,900	165,100	210,300	101,500
2018	31,100	89,800	165,100	210,300	101,500

Vehicle emissions improve under both CNG-replacement strategies (Table 4.8). Despite a doubling of CH_4 emissions, GHG emissions on a CO_{2eq} basis decrease by roughly 10% by 2018. All CAC emissions decrease, with the most dramatic reductions occurring for CO, NOx, and SOx.

Table 4.8 Estimated Change in GHG and CAC emissions from Municipal Support Fleet

Scenario		Emissions (tonnes/year)								
		CO_2	CH_4	N_2O	CO_{2eq}	CO	NOx	VOC	SOx	PM
BAU		25,671	17	1	26,406	10	29	5	15	3
Replacement	Planned	22,576	45	1	23,995	7	23	4	10	2
	Aggressive	21,797	52	1	23,388	6	21	4	8	2

4.2 TRANSIT FLEET

The transit fleet is generally a superior fit to converting to CNG technology than the municipal support fleet due to the large number of diesel buses requiring large amounts of fuel and travelling long distances on a daily basis. Converting a significant portion of the municipal fleet appears to lead to noticeable savings to HRM in most scenarios.

Table 4.9 CBA Scenarios for Metro Transit Fleet Including a Compressor Station ($2012)

Year	BAU	Transit Replacement		
		Planned	Aggressive	Doubling NG Cost
2012	$25,652,000	$27,149,000	$27,149,000	$27,149,000
2013	$24,770,000	$25,914,000	$26,090,000	$26,110,000
2014	$24,538,000	$24,452,000	$24,498,000	$24,738,000
2015	$24,061,000	$23,603,000	$23,529,000	$23,957,000
2016	$23,414,000	$23,696,000	$23,510,000	$24,284,000
2017	$22,788,000	$21,594,000	$21,305,000	$22,259,000
2018	$21,799,000	$20,068,000	$19,566,000	$20,719,000
TOTAL	**$167,023,000**	**$166,476,000**	**$165,648,000**	**$169,216,000**
Difference	**-**	**$547,000**	**$1,375,000**	**-$2,193,000**

Table 4.10 CBA Scenarios for Metro Transit Fleet Using the Stanfield Airport Mother Station ($2012)

Year	BAU	Transit Replacement		
		Planned	Aggressive	Doubling NG Cost
2012	$25,652,000	$25,802,000	$25,802,000	$25,802,000
2013	$24,770,000	$25,965,000	$26,168,000	$26,161,000
2014	$24,538,000	$24,561,000	$24,660,000	$24,847,000
2015	$24,061,000	$23,751,000	$23,752,000	$24,105,000
2016	$23,414,000	$23,996,000	$23,909,000	$24,584,000
2017	$22,788,000	$21,940,000	$21,771,000	$22,604,000
2018	$21,799,000	$20,398,000	$20,010,000	$21,048,000
TOTAL	**$167,023,000**	**$166,412,000**	**$166,072,000**	**$169,152,000**
Difference	**-**	**$611,000**	**$951,000**	**-$2,129,000**

The BAU case for transit is a fleet entirely composed of diesel vehicles, with vehicles being replaced according to a replacement and expansion plan provided by HRM. The expansion plan proposes five new 40-foot buses per year for the next five years. The replacement plan proposes roughly 5 to 10 40-foot buses replaced annually. The total NPV cost to 2018 is $167,022,687 (Table 4.9). By introducing CNG buses via the replacement and expansion plan, the NPV cost for Metro Transit decreases to 166,475,967, or a savings of roughly $500,000 over six years (Table 4.9). By 2018, the fleet would be composed of 100 CNG buses, all of the 40-foot variety. A more aggressive approach by converting an additional five articulating buses per year would additional savings of over $1.3 million over six years. A doubling of natural gas prices over the whole six years is predicted to lead to higher costs; roughly $2.2 million more than the BAU case.

Even in the case of a doubling in natural gas prices throughout the six year scenario time period, Metro Transit operational prices are expected to be reduced by over $1 million in 2018 (in 2012 dollars) (Table 4.9, row 7). By contrast, a 20% increase in diesel prices over the same time period would significantly increase savings for all three scenarios, and would make all three scenarios a net-savings by 2018 (Table 4.11).

Table 4.11 CBA Scenarios for Metro Transit Fleet Compared to BAU Case and a 20% Increase in Diesel Price with an Installed Compressor ($2012)

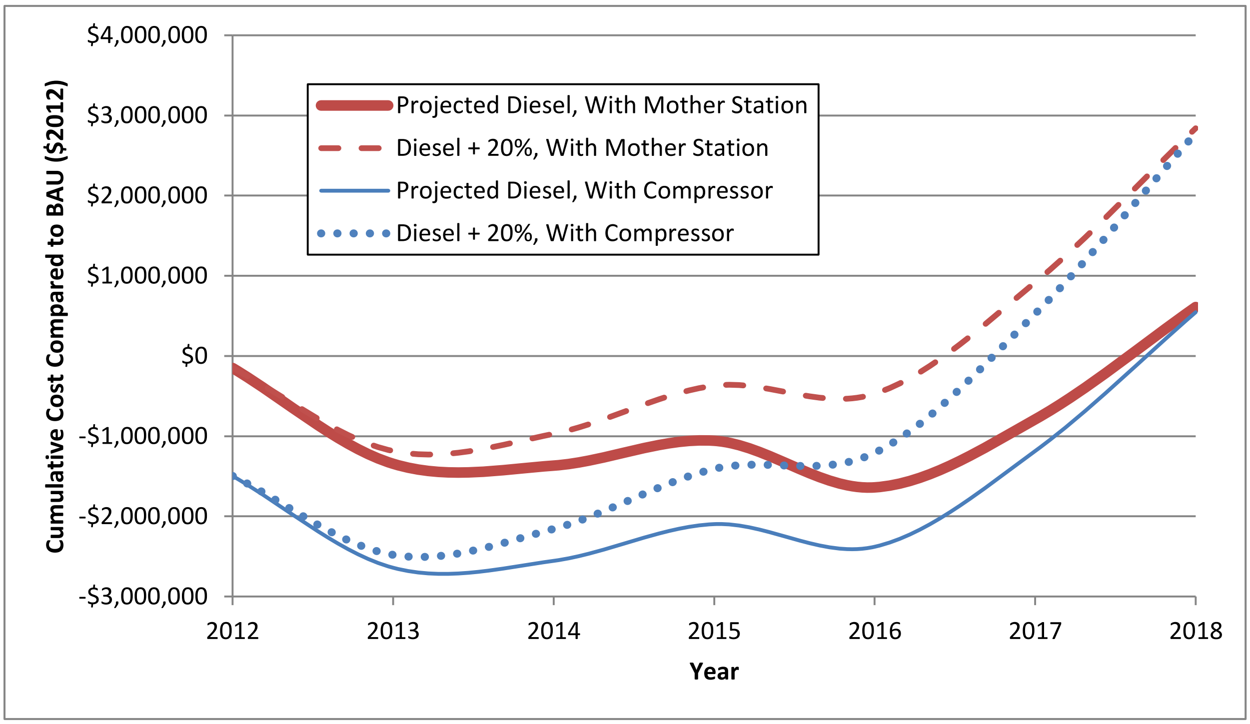
Year	BAU (Diesel +20%)	Transit Replacement		
		Planned	Aggressive	Doubling NG Cost
2012	$27,665,000	$29,161,000	$29,161,000	$29,161,000
2013	$26,604,000	$27,588,000	$27,732,000	$27,784,000
2014	$26,423,000	$26,099,000	$26,081,000	$26,385,000
2015	$25,946,000	$25,198,000	$25,028,000	$25,552,000
2016	$25,263,000	$25,063,000	$24,755,000	$25,651,000
2017	$24,603,000	$22,868,000	$22,431,000	$23,532,000
2018	$23,546,000	$21,295,000	$20,650,000	$21,945,000
TOTAL	**$180,050,000**	**$177,272,000**	**$175,838,000**	**$180,010,000**
Difference	**-**	**$2,778,000**	**$4,212,000**	**$40,000**

Table 4.12 CBA Scenarios for Metro Transit Fleet Compared to BAU Case and a 20% Increase in Diesel Price Using the Stanfield Airport Mother Station ($2012)

Year	BAU (Diesel +20%)	Transit Replacement		
		Planned	Aggressive	Doubling NG Cost
2012	$27,665,000	$27,815,000	$27,815,000	$27,815,000
2013	$26,604,000	$27,639,000	$27,810,000	$27,835,000
2014	$26,423,000	$26,208,000	$26,242,000	$26,494,000
2015	$25,946,000	$25,346,000	$25,252,000	$25,700,000
2016	$25,263,000	$25,363,000	$25,153,000	$25,951,000
2017	$24,603,000	$23,213,000	$22,897,000	$23,878,000
2018	$23,546,000	$21,624,000	$21,094,000	$22,274,000
TOTAL	**$180,050,000**	**$177,208,000**	**$176,263,000**	**$179,947,000**
Difference	**-**	**$2,842,000**	**$3,787,000**	**$103,000**

There appears to be very little difference in costs by 2018 by instead souring natural gas via the Stanfield Airport Mother Station (Tables 4.10 and 4.12). While the initial capital costs are much less, the higher fuel premiums give a smaller payback with time, and indicate that beyond 2018, a full compressor station would be more cost-effective (Note the steeper curves associated with the compressor station scenarios in Figure 4.2). Further study would be required to properly assess the trade-off between future cost savings of a CNG compressor and its increased risk in liability or operations.

Figure 4.2 Cumulative Cost of Planned CNG Replacement Scenario Relative to BAU for Metro Transit Fleet ($2012)



Similar reductions in GHG emissions are realized by witching to CNG technology for the Metro Transit fleet as was found for the municipal support fleet (Table 4.13). Other than minimal increases in methane emissions, GHG and CAC emissions from a lifecycle perspective are predicted to decrease.

Table 4.13 Estimated Change in GHG and CAC emissions from Metro Transit Fleet

Scenario		Emissions (tonnes/year)								
		CO_2	CH_4	N_2O	CO_{2eq}	CO	NOx	VOC	SOx	PM
BAU		37,159	24	2	38,224	15	42	7	21	4
Replacement	Planned	34,605	47	2	36,233	12	37	7	17	3
	Aggressive	34,051	52	2	35,802	12	36	7	16	3

4.3 SOLID WASTE FLEET

The residential solid waste fleet is another potential, albeit less compatible service sector to benefit from conversion to a CNG fleet. The solid waste fleet is purchased at the beginning of the service contract, and it was therefore assumed for purposes of this study that the fleet would either be composed of all diesel or all CNG vehicles. Based on price estimates from industry for side and rear loaders, the total seven-year NPV cost for solid waste was predicted to be $39,317,346 (Table 4.14).

Table 4.14 CBA Scenarios for Residential Solid Waste Fleet Including a Compressor Station ($2012)

Year	BAU	CNG	Double NG Cost
2012	$15,726,000	$19,301,000	$19,745,000
2013	$4,270,000	$3,073,000	$3,517,000
2014	$4,174,000	$2,941,000	$3,379,000
2015	$4,033,000	$2,820,000	$3,256,000
2016	$3,864,000	$2,692,000	$3,112,000
2017	$3,704,000	$2,571,000	$2,980,000
2018	$3,545,000	$2,460,000	$2,859,000
TOTAL	**$39,317,000**	**$35,859,000**	**$38,849,000**
Difference	**-**	**$3,458,000**	**$468,000**

Table 4.15 CBA Scenarios for Residential Solid Waste Fleet Using the Stanfield Airport Mother Station ($2012)

Year	BAU	CNG	Double NG Cost
2012	$15,726,000	$18,271,000	$18,715,000
2013	$4,270,000	$3,294,000	$3,738,000
2014	$4,174,000	$3,152,000	$3,590,000
2015	$4,033,000	$3,021,000	$3,457,000
2016	$3,864,000	$2,883,000	$3,303,000
2017	$3,704,000	$2,753,000	$3,162,000
2018	$3,545,000	$2,633,000	$3,033,000
TOTAL	**$39,317,000**	**$36,008,000**	**$38,998,000**
Difference	**-**	**$3,309,000**	**$319,000**

Switching to CNG fleet presents an opportunity for savings approaching $3.5 million throughout the lifetime of the solid waste management contract (Table 4.14). The initial capital costs are significantly higher, but the fuel savings eventually shifts the project into saving by 2015 (Figure 4.3). A doubling of natural gas costs is still predicted to make CNG conversion slightly cost-effective by 2018, with a total savings of just under $500,000. A hypothetical 20% increase in diesel prices through to 2018 further improves the savings for residential municipal solid waste collection, to $6 million and $3 million for the CNG conversion and the doubling of natural gas prices scenarios, respectively (Table 4.16).

There appears to be a negligible difference in cost savings between installing a compressor station on-site and purchasing CNG from the Stanfield Airport Mother Station (Tables 4.15, 4.17, and Figure 4.3). Similar to the Metro Transit fleet, additional analyses are required to determine the trade-off between the higher fuel savings in the future and the increased liability of installing and managing a compressor station. An additional synergy might also exist with the solid waste management companies by also switching over their corporate fleets; however such an analysis is beyond the scope of the current study.

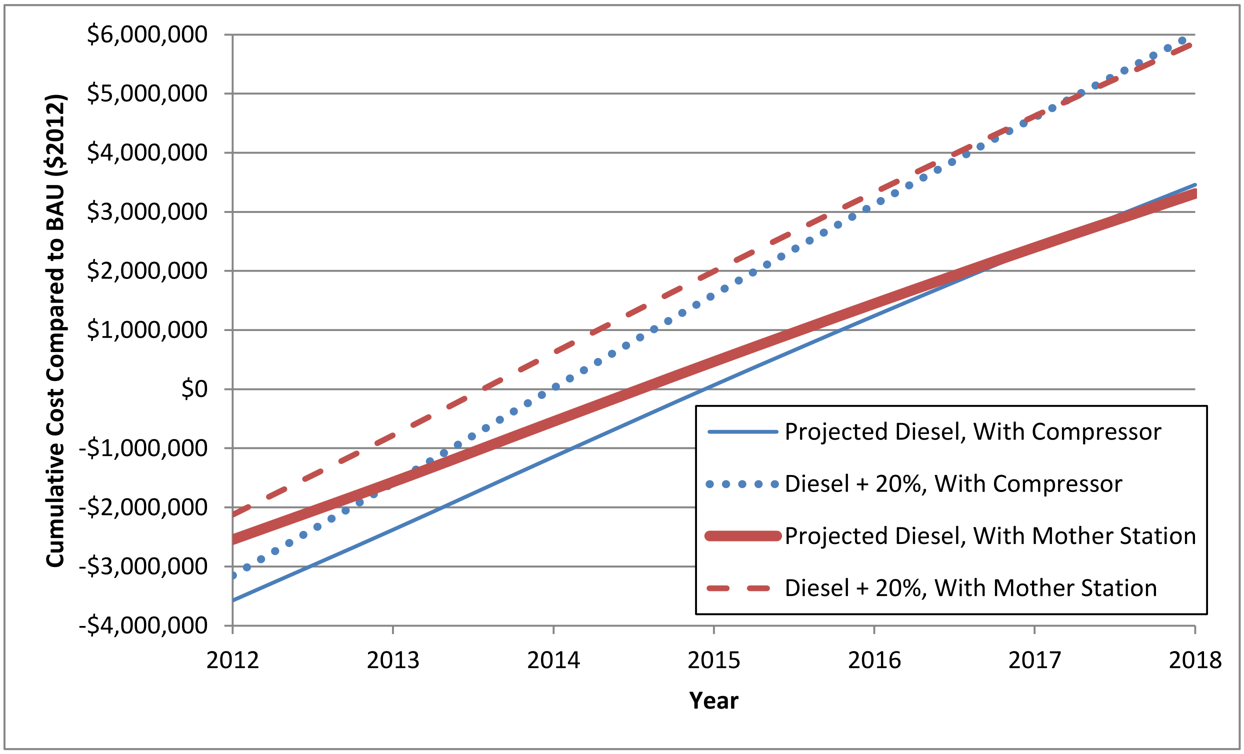
Table 4.16 CBA Scenarios for Residential Solid Waste Fleet Compared to BAU Case and a 20% Increase in Diesel Prices with a Compressor Station ($2012)

Year	BAU (Diesel + 20%)	CNG	Double NG Cost
2012	$16,148,000	$19,301,000	$19,745,000
2013	$4,639,000	$3,073,000	$3,517,000
2014	$4,547,000	$2,941,000	$3,379,000
2015	$4,399,000	$2,820,000	$3,256,000
2016	$4,217,000	$2,692,000	$3,112,000
2017	$4,045,000	$2,571,000	$2,980,000
2018	$3,874,000	$2,460,000	$2,859,000
TOTAL	**$41,869,000**	**$35,858,000**	**$38,848,000**
Difference	**-**	**$6,011,000**	**$3,021,000**

Table 4.17 CBA Scenarios for Residential Solid Waste Fleet Compared to BAU Case and a 20% Increase in Diesel Prices Using the Stanfield Airport Mother Station ($2012)

Year	BAU (Diesel + 20%)	CNG	Double NG Cost
2012	$16,148,000	$18,271,000	$18,715,000
2013	$4,639,000	$3,294,000	$3,738,000
2014	$4,547,000	$3,152,000	$3,590,000
2015	$4,399,000	$3,021,000	$3,457,000
2016	$4,217,000	$2,883,000	$3,303,000
2017	$4,045,000	$2,753,000	$3,162,000
2018	$3,874,000	$2,633,000	$3,033,000
TOTAL	**$41,869,000**	**$36,007,000**	**$38,998,000**
Difference	**-**	**$5,862,000**	**$2,871,000**

Figure 4.3 Cumulative Cost of CNG Replacement Scenario Relative to BAU for Residential Solid Waste Fleet ($2012)



Vehicle emissions are again similar to previous estimates for transit and municipal support vehicles. GHG emissions are predicted to fall by approximately 15%, with CAC emissions reduced by between 20% (VOC) and 65% (SOx) (Table 4.18).

Table 4.18 Estimated Change in GHG and CAC emissions from Residential Solid Waste Fleet

Scenario	Emissions (tonnes/year)								
	CO_2	CH_4	N_2O	CO_{2eq}	CO	NOx	VOC	SOx	PM
BAU	3,709	2	0	3,815	1.47	4.20	0.71	2.13	0.41
CNG	2,894	10	0	3,180	0.65	2.53	0.57	0.76	0.19

5.0 Outlook and Conclusion

There appears to be substantial opportunities within HRM municipal fleets to convert from conventional fossil fuels to CNG technologies. The argument for converting smaller vehicles, vehicles with special usage requirements, or vehicles of infrequent use is more difficult. Larger vehicles – those with the highest consumption patterns -- are much more likely to reduce costs to the municipality. Additionally, the results of the CBA appear to be more sensitive to the price of diesel than to the price of natural gas, particularly when considering the feasibility of converting the Metro Transit Fleet. There appeared to be little difference to direct total costs by 2018 whether HRM installed a CNG compression station or purchased CNG from the Stanfield Airport Mother Station.

Looking after 2018, and assuming that no additional vehicles are purchased and that fleet operating levels remain constant out to 2030, we can also calculate the simple payback of the conversions for each fleet (Tables 5.1 and 5.2). It is again evident that converting transit and solid waste fleets to CNG will provide significant cost savings to HRM when considering the lifetime of CNG vehicles and fueling infrastructure. The simple payback analysis also shows that even with low natural gas prices and higher than anticipated diesel fuel prices, the support fleet conversion to CNG simple payback is close to the estimated lifetime of the vehicles themselves. Most scenarios predict it would take over 20 years to reclaim the investment on the support vehicles.

For the transit and solid waste fleets, the conversion to CNG is attractive. After achieving simple payback, both fleets show savings on the order of $1-2 million per annum for HRM, even if natural gas prices double compared to current predictions (for example, Table 4.9, row 7).

Table 5.1 Simple Payback for CNG Conversion of Each Fleet

Fleet	Scenario	Simple Payback (years)	
		With Compressor Station	Mother-Daughter Approach
Maintenance	Planned	> 20	16
	Enhanced	10	8
	Double Price for NG	> 20	> 20
Transit	Planned	7	7
	Enhanced	7	7
	Double Price for NG	10	11
Solid Waste	Full Conversion	4	4
	Double Price for NG	7	7

Table 5.2 Simple Payback for CNG Conversion of Each Fleet with a 20% Increase of Diesel Fuel

Fleet	Scenario	Simple Payback (years)	
		With Compressor Station	Mother-Daughter Approach
Maintenance	Planned	17	10
	Enhanced	8	7
	Double Price for NG	> 20	> 20
Transit	Planned	6	6
	Enhanced	6	6
	Double Price for NG	7	7
Solid Waste	Full Conversion	3	3
	Double Price for NG	5	5

Real data from government and industry, including fuel consumption, travel distances, maintenance costs, and infrastructure upgrades, were used where possible to develop the CBA. Many assumptions were nevertheless required to for an adequate treatment of the expected costs to HRM. Assumptions for future fuel prices were unavoidable; however the sensitivity analyses for each fleet indicated that a doubling of natural gas costs would have a significant effect on the cost-effectiveness of a CNG conversion. An average doubling of natural gas prices over six years is unlikely. Still, natural gas price volatility exceeds that of either gasoline or diesel, and should be considered when budgeting fuel consumption for natural gas. A full suite of sensitivity analyses considering maintenance, fuel prices, and capital costs should be part of a full CBA analysis, but was beyond the scope of this report.

6.0 References

Alternative Fuels Data Center (2013). Fuel Properties Comparison. Source: http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf

Alterman, S. (2012). Natural Gas Price Volatility in the UK and North America. *The Oxford Institute for Energy Studies*.

Barnett, Russell K. (No Date). *Making the Switch to Natural Gas Vehicles – The Smithtown Story*. Town of Smithtown.

Energy Information Administration (EIA) (2012). Short-term Energy and Summer Fuels Outlook. Source: http://www.eia.gov/forecasts/steo/.

Jenmar Concepts (2012). Evaluation of technical and Economic Parameters of Natural Gas Delivery Using Compressed Natural Gas (CNG) Technologies. QUEST Nova Scotia Doc. No. QN-0009-00 Rev 2.

Johnson, Caley (2010). *Business Case for Compressed Natural Gas in Municipal Fleets*. National Renewable Energy Laboratory (NREL) Technical Report NREL/TP-7A2-47919.

Marbek (2010). Study of Opportunities for Nautral Gas in the Trasnportation Sector.

McIntyre, H. (2012). Edmonton Transit wants to pilot natural gas buses. *Metro News.* Source: http://metronews.ca/news/edmonton/116055/edmonton-transit-wants-to-pilot-natural-gasbuses/.

Natural Gas Use in Transportation Rountable (2010). Natural Gas Use in the Transportation Sector: Deployment Roadmap.

(S&T)^2 Consultants (2012). GHGenius Model 4.02: Volume 1, Model Background and Structure. Source: http://www.ghgenius.ca/.

Samara, Farid (2012). Compressed natural Gas in Metro Transit Fleets. Heritage Gas.

Standards Council of Canada (SCC) (2012). Natural Gas for Transportation Deployment Roadmap.

Watt, Glen M. (No Date). *Natural Gas Vehicle Transit Bus Fleets: The Current International Experience*. International Association for Natural Gas Vehicles (Inc.).