PUBLIC WORKS COMMITTEE
REPORT 22-001
1:30 p.m.
Monday, January 10, 2022
Council Chambers
Hamilton City Hall
71 Main Street West

Present:	Councillors N. Nann (Chair), R. Powers (Vice-Chair), J.P. Danko, J. Farr, T. Jackson, M. Pearson and A. VanderBeek
Absent with Regrets:	Councillor L. Ferguson - Personal Councillor E. Pauls - Personal Councillor S. Merulla - Personal Councillor T. Whitehead - Personal

---

THE PUBLIC WORKS COMMITTEE PRESENTS REPORT 22-001 AND RESPECTFULLY RECOMMENDS:

1. 2022 Volunteer Committee Budget - Keep Hamilton Clean and Green Committee (PW22002) (City Wide) (Item 10.1)

That the Keep Hamilton Clean and Green Committee's 2022 base budget submission attached as Appendix "A" to Report PW22002 in the amount of $18,250, representing a zero-net levy impact from the previous year budget, be approved and referred to the 2022 operating budget process for consideration.

2. 2022 Lymantria dispar dispar (LDD) Moth Treatment Plan (PW21069(a)) (City Wide) (Item 10.2)

(a) That the single source procurement of Zimmer Air Services Inc. for the aerial treatment of *Lymantria dispar dispar* (LDD) Aerial Control program, pursuant to Procurement Policy #11 – Non-competitive Procurement be approved; and,

(b) That the Mayor and City Clerk be authorized and directed to execute the contract and any ancillary documents between the City of Hamilton and Zimmer Air Services, for the aerial treatment of *Lymantria dispar dispar* (LDD) in a form satisfactory to the City Solicitor;

(c) That the project budget previously approved through Report PW21069 be amended from $3,500,000 to $2,000,000 for 2022 and $1,000,000 for 2023, to be funded from the Tax Stabilization Reserve (#110046);

(d) That staff be directed to return to Council with an Information Report in Q1 2023 detailing the success of the 2022 treatment program and provide an update on further treatment applications to be completed in 2023;

3. Natural Gas Waste Collection Trucks (PW22003) (City Wide) (Item 10.3)

(a) That the following appendices attached to Public Works Committee Report 22-001 be received:

(i) City of Hamilton Compressed Natural Gas (CNG) Packer Truck Fuelling Study Report as identified in Appendix “A” attached to Public Works Committee Report 22-001;

(ii) City of Hamilton Compressed Natural Gas (CNG) Packer Truck Fuelling Supplemental Study Report as identified in Appendix “B” attached to Public Works Committee Report 22-001;

(iii) City of Hamilton Compressed Natural Gas (CNG) Packer Truck Fuelling 2nd Supplemental Study Report as identified in Appendix “C” attached to Public Works Committee Report 22-001;

(b) That Council approve funding to support the cost premium of 10 CNG waste collection trucks and related facility ancillary requirements in the amount of $700,000 to the Fleet Project ID 4942151100 from:

(i) Unallocated Capital Reserve (#108020) in the amount of $200,000;

(ii) Appropriate from Capital Project 5121855137 Waste Management R&D Program in the amount of $10,000;

(iii) Internal Loan from the Energy Conservation Initiatives Reserve 112272 in the amount of $490,000 amortized over 7 years;

(c) That the estimated fuel savings of $70,000 per year from the new CNG vehicles funded in Recommendation (b) be used to repay the funds borrowed, plus applicable interest, to the Energy Conservation Initiatives Reserve (112272) as indicated in Appendix “D” attached to Public Works Committee Report 22-001 from the Public Works Waste Division Dept ID 512560;

(d) That a new Capital Project be set up with a budget of $490,000 funded from the Energy Conservation Initiatives Reserve #112272 to fund future incremental costs from Fleet and Facilities for projects and/or purchases which qualify according to the Corporate Energy and Sustainability Policy as determined by the Manager, Energy Initiatives;

(e) That the Goods and Services be procured through a Purchase Order, a formal Contract or any other process as approved by the Director of Financial Services and Corporate Controller and that the General Manager of Public Works, or their designate, be authorized to negotiate and enter into a single source procurement and execute the completion of all associated documents with Envoy Energy Fuels Inc. for the supply, installation and management of CNG mobile refuelling equipment, commodity and operational requirements for the life of the 10 CNG vehicles to be procured, in a form satisfactory to the City Solicitor.

4. Green Venture (PW22004) (City Wide) (Item 10.4)

(a) That annual funding of approximately $65,000 to Green Venture for the purpose of funding community programs delivered through the Public Works Department be extended to Green Venture until the Lease expiry of January 14, 2025 at 22 Veevers Drive to align the service end date with the current lease expiry date.

5. Barton & Fifty Road Environmental Assessment Cycling Infrastructure (Hamilton Cycling Committee - Citizen Committee Report) (Item 10.5)

(a) That the following recommendations respecting the Barton & Fifty Road Environmental Assessment Cycling Infrastructure from the Hamilton Cycling Committee, be received and referred to the Barton & Fifty Road Municipal Class Environmental Assessment - Cycling Infrastructure.

(i) That Barton Street East cycling lanes be separated and protected according to best practices and make connections to local schools in the area; and,

(ii) That Barton Street East cycling lanes be in the direction of expected automobile traffic, unless a suitable space with limited driveways can be made for a bi-directional bicycle track; and

(iii) That Fifty Road cycling lanes cross the Queen Elizabeth Way bridge and connect to existing Winona cycling infrastructure; and

(iv) That Fifty Road cycling lanes be extended to the South Service Road to connect to existing cycling infrastructure east of the Hamilton border, into Niagara Region.

6. Installation of Speed Cushions as a Traffic Calming Measure on Presidio Drive (Ward 6) (Item 11.1) (REVISED)

WHEREAS, residents on Presidio Drive in Ward 6 have advocated for the installation of speed cushions to address roadway safety concerns as a result of speeding; and

WHEREAS, signatures were collected from 26 residents resulting in support by 22 of 28 homes on Presidio Drive for the installation of speed cushions as a traffic calming measure;

THEREFORE, BE IT RESOLVED:

(a) That Transportation and Operations Maintenance staff be authorized and directed to install 3 speed cushions as a traffic calming measure on Presidio Drive as part of the 2022 Traffic Calming Program’s spring application, as follows;

(i) between the westerly curve of Presidio Drive and Enola Avenue;

(ii) between Elona Avenue and Osgoode Court; and

(iii) between Osgoode Court and Eaglewood Drive.

(b) That all costs associated with the installation of 3 speed cushions as a traffic calming measure on Presidio Drive be funded from Project ID 4031911606, at an upset limit, including contingency, not to exceed $21,000, to be completed under contract # C15-12-22.

(c) That the Mayor and City Clerk be authorized and directed to execute any required agreement(s) and ancillary documents, with such terms and conditions in a form satisfactory to the City Solicitor.

FOR INFORMATION:

(a) CHANGES TO THE AGENDA (Item 2)

The Committee Clerk advised of the following changes to the agenda:

6. DELEGATION REQUESTS

6.2 Ian Borsuk, Environment Hamilton, respecting Natural Gas Waste Collection Trucks (Item 10.3) (for today's meeting)

7. CONSENT ITEMS

7.2 Citizen Committee Member Resignation – Yaejin Kim, Hamilton Cycling Committee

10. DISCUSSION ITEMS

10.2 2022 Lymantria dispar dispar (LDD) Moth Treatment Plan (PW21069(a)) (City Wide), Appendix B
(WITHDRAWN)

The agenda for the January 10, 2022 Public Works Committee meeting was approved, as amended.

(b) DECLARATIONS OF INTEREST (Item 3)

There were no declarations of interest.

(c) APPROVAL OF MINUTES OF PREVIOUS MEETING (Item 4)

(i) December 6, 2021 (Item 4.1)

The Minutes of the December 6, 2021 meeting of the Public Works Committee were approved, as presented.

(d) DELEGATION REQUESTS (Item 6)

(i) Nick Becker, Victoria Park Assembly, respecting Lighting at Victoria Park's Baseball Diamonds (for a future meeting) (Item 6.1)

The delegation from Nick Becker, Victoria Park Assembly, respecting Lighting at Victoria Park’s Baseball Diamonds, was approved for a future meeting.

(ii) Ian Borsuk, Environment Hamilton, respecting Natural Gas Waste Collection Trucks (PW22003) (City Wide) (Item 10.3) (for today's meeting) (Item 6.2)

The delegation request from Ian Borsuk, Environment Hamilton, respecting Environment Hamilton, respecting Natural Gas Waste Collection Trucks (PW22003) (City Wide) (Item 10.3), was approved for today’s meeting.

For further disposition respecting Item 6.2, refer to Item (f) (i).

(e) CONSENT ITEMS (Item 7)

Consent Items 7.1 and 7.2 were received:

(i) Citizen Committee Member Resignation - Joachim Brouwer, Hamilton Cycling Committee (Item 7.1)

(ii) Citizen Committee Member Resignation - Yaejin Kim, Hamilton Cycling Committee (Item 7.2)

(f) PUBLIC HEARINGS / DELEGATIONS (Item 9)

(i) Delegation respecting Item 10.3 - Natural Gas Waste Collection Trucks (PW22003) (City Wide) (Item 9.1)

Ian Borsuk, Environment Hamilton addressed the Committee respecting Natural Gas Waste Collection Trucks (PW22003) (City Wide) (Item 10.3).

The delegation from Ian Borsuk, Environment Hamilton, respecting Natural Gas Waste Collection Trucks (PW22003) (City Wide) (Item 10.3), was received and referred to the consideration of Item 10.3.

For further disposition of this matter, refer to Item 3.

(g) DISCUSSION ITEMS (Item 10)

(i) Barton & Fifty Road Environmental Assessment Cycling Infrastructure (Hamilton Cycling Committee - Citizen Committee Report) (Item 10.5)

(a) That Barton Street East cycling lanes be separated and protected according to best practices and make connections to local schools in the area; and,

(b) That Barton Street East cycling lanes be in the direction of expected automobile traffic, unless a suitable space with limited driveways can be made for a bi-directional bicycle track; and

(c) That Fifty Road cycling lanes cross the Queen Elizabeth Way bridge and connect to existing Winona cycling infrastructure; and

(d) That Fifty Road cycling lanes be extended to the South Service Road to connect to existing cycling infrastructure east of the Hamilton border, into Niagara Region.

Committee Report (Item 10.5) respecting the Barton & Fifty Road Environmental Assessment Cycling Infrastructure was ***amended*** as follows:

(a) That the following recommendations respecting the Barton & Fifty Road Environmental Assessment Cycling Infrastructure from the Hamilton Cycling Committee, be received and referred to the Barton & Fifty Road Municipal Class Environmental Assessment - Cycling Infrastructure.

(i) That Barton Street East cycling lanes be separated and protected according to best practices and make connections to local schools in the area; and,

(ii) That Barton Street East cycling lanes be in the direction of expected automobile traffic, unless a suitable space with limited driveways can be made for a bi-directional bicycle track; and

(iii) That Fifty Road cycling lanes cross the Queen Elizabeth Way bridge and connect to existing Winona cycling infrastructure; and

(iv) That Fifty Road cycling lanes be extended to the South Service Road to connect to existing cycling infrastructure east of the Hamilton border, into Niagara Region.

For further disposition of this matter, refer to Item 5.

(h) GENERAL INFORMATION / OTHER BUSINESS (Item 14)

The following amendments to the Public Works Committee's Outstanding Business List, were approved.

(1) Items Considered Complete and Needing to be Removed (Item 14.1 (a)):

(i) Lymantria Dispar Dispar (LDD) Moth Control Program Addressed as Item 10.2 on today's agenda - Report (PW21069(a))
Item on OBL: ABX
(Item 14.1 (a) (i))

(i) ADJOURNMENT (Item 15)

There being no further business, the meeting adjourned at 2:16 p.m.

Respectfully submitted,

Councillor N. Nann, Chair,
Public Works Committee

Carrie McIntosh
Legislative Coordinator
Office of the City Clerk

City of Hamilton Compressed Natural Gas (CNG) Packer Truck Fueling Study Report

Submitted To:

Tom Kagianis

Superintendent Capital Planning & Contract Management
Tel: (905) 546-2424 ext. 5105
Email: Tom.Kagianis@hamilton.ca

Energy, Fleet & Facilities
Public Works
330 Wentworth Street, L8L 5W2

FINAL REPORT

2020 03 03

Submitted By:

Rob Adams
P.Eng, CPA, CMA, PMP, CMC, MBA
radams@marathontech.ca

Marathon Technical Services
Six Venus Crescent,
Heidelberg, ON
N0B 2M1

p 519.699.8250
f 519.699.9255
radams@marathontech.ca

marathon

Executive Summary:

The City of Hamilton, Energy, Fleet & Facilities Public Works department (the City) contracted with Marathon Technical Services (Marathon or MTS), to study the technical and financial viability of transitioning the current diesel fleet of 37 packer (refuse collection) trucks to CNG. This analysis was focused on infrastructure and operation costs.

A total of five scenarios were evaluated, the first two involving fast fill fueling at a rebuilt Wentworth CNG station, the third involving fast fill fueling at Wentworth using gas compressed in the proposed HSR CNG station on the adjacent property and the last two evaluating time fill at the Burlington Street location where the packer trucks are domiciled. All five scenarios are technically feasible.

Marathon assembled capital cost and operating cost data from its own sources and from the City. Where possible, City data and HSR data, rather than general industry data, have been used to ensure that data is accurate and applicable to this situation.

A conservative mix of costs was used for analysis over a 21-year life cycle based on truck replacement at 7-year increments as discussed in the report. The 21-year period corresponds to three full life cycles of the Classification 78 packer trucks and the normal expected life of the CNG station. Net Present Value (NPV) and payback were used as quantitative evaluation metrics. Two of the scenarios have a positive NPV and all achieve payback within the project period.

Although fast fill at Wentworth (Scenario 3) achieved the highest NPV and payback ($1.25M and the fastest payback--10 Years), it is heavily dependent on the HSR project timing and operations. Given the long-term nature of this CNG packer truck transition, Marathon recommends constructing a time fill fueling station with two 636 scfm compressors and 37 time fill stalls at the Burlington Street packer truck operations location (Scenario 5). This location and approach de-couples the packer truck project from the current HSR project, gives a convenient fueling location that will save labour and truck mileage and still has the second highest NPV ($102K and the second fastest payback--13 Years).

Marathon also performed a sensitivity analysis to investigate the impact of fleet growth. It was found that the addition of trucks to the fleet increases the economic and environmental benefits of the project. Furthermore, the earlier in the period that vehicles are added, the greater the benefits.

Marathon recommends that the City of Hamilton proceed with the project to transition its diesel packer fleet to CNG. There are two scenarios that show a positive economic impact and all scenarios provide carbon reduction and the ability to implement RNG in the future resulting in carbon elimination.

It is estimated that this project will create a savings of 5,537 tonnes CO_2e over the lifecycle of the project --projecting a “green” image for the City. This represents a

17.3 percent reduction from the diesel fleet and based on US EPA data, this is the equivalent of taking about 57 passenger vehicles off the road.

Hamilton has its own RNG supply. Transportation is an excellent application for RNG and can make a CNG vehicle even more environmentally responsible than an electric vehicle—avoiding the pollution of battery production. Unlike Battery Electric Trucks (BET) which have a very limited selection of vehicle types and are early in the development and commercialization phase, CNG packer trucks are widely available, industry tested and have the daily range to exceed the distance of the longest current City of Hamilton diesel truck routes.

Table of Contents:

Introduction:

The City of Hamilton (the City, or Hamilton) is evaluating the possible transition of its diesel-powered packer truck refuse collection fleet to Compressed Natural Gas (CNG). The City has over three decades of successful CNG heavy fleet experience at the Hamilton Street Railway (HSR).

CNG is a fuel that is capital intensive but low cost to operate and provides toxic gas and greenhouse gas (GHG) emissions reduction when compared with diesel. It is also the most proven alternative fuel in heavy vehicle applications.

To evaluate the qualitative and quantitative issues with the transition of the 37 packer trucks from diesel to CNG, the City has contracted with Marathon Technical Services (Marathon) to assemble required data and provide a rigorous study of the costs and technical viability of this transition.

Marathon has been contracted to perform the following scope:

1. Review truck procurement, truck operations, truck fuel data for the existing fleet and any internal project analysis/reports and project a sizing of the station required based on time fuel and separately based on fast fill.

2. Review drawings of sites (as available) to determine which sites are viable for time fill or fast fill.

3. Review of 3 to 5 fueling location alternatives from the following list:
    a. Removal of the existing Wentworth CNG station equipment (except the dryer) and reuse of the existing fueling infrastructure for the installation of new CNG station sized to fast fill only the packer fleet using the islands previously used for HSR bus fueling (with new dispensers).
    b. As per option a above but also with a time fill barricade on the adjacent property.
    c. Construction of a time fill fueling station at the 1579 Burlington St. truck parking facility.

4. For the options above, Marathon will:
    a. Determine gas pressure and availability with Enbridge.
    b. Provide an ROM cost estimate for the capital cost.
    c. Provide an estimate of the time required for design, equipment delivery and installation.
    d. Provide a narrative discussion of the relative Pros and Cons of each fueling option.

5. Marathon will investigate the current Operating Engineer requirements and determine what workarounds are possible, if required.

6. Marathon will investigate interim/fast deployment fueling options including portable fueling. (deadheading to Mount Hope was evaluated as a temporary measure as was the use of a tube trailer to bring gas to Wentworth) (The options investigated were applied only as a temporary measure for one of the scenarios.)

7. Marathon will identify potential incentives/grants that might decrease the truck purchase or station construction costs.

8. Marathon will provide a written report including findings, analysis and recommendations based on the above bullets.

9. Packer truck types are classified as follows:
   a. Classification 78—full sized rear loader
   b. Classification 157—full sized side loader
   c. Classification 157A—mini-packer
   d. Classification 170A—60/40 split rear loader

10. Life cycle cost analysis for the initial and subsequent purchase and integration of CNG packer trucks into the collection fleet. The initial purchase will be for approximately 16 rear loader trucks to go into service in 2021, an additional 10 side loader and 2 mini-packer trucks added to the service in 2022 and another 9 trucks in 2024. This analysis will identify the net present value (NPV) of the CNG program and will also identify the expected environmental and other benefits. Marathon will make recommendations related to the implementation of this program.

11. It is understood that City trucks are maintained off site by service providers and thus no garage upgrades related to CNG are required or anticipated at this time and no consulting associated with upgrades is included in this scope.

Analysis Assumptions and Data Sources:

The life cycle cost analysis uses data from a variety of sources and covers a wide range of data to address all readily quantifiable cost elements to provide a comprehensive and conservative analysis. The list below summarizes the cost elements and data sources that were determined or assumed in this study:

1. The lifecycle analysis is based on a 21-year life cycle with year 0 being 2021 and running to 2041. This 21-year life cycle was selected as it corresponds to three full 7-year truck life cycles for the initial truck procurement and corresponds to a typical CNG station life.

2. Discount rate--5% (Marathon standard, confirmed with the City of Hamilton). See Glossary in Appendix A for definition of discount rate.

3. Inflation--2.5 percent to 3.0 percent (dependent on item) (Marathon standard, confirmed with the City of Hamilton). See Appendix C for individual rates used.

4. HST was applied at a net rate of 1.76 percent on the full capital cost of the CNG station and the upcharge/differential cost for the CNG trucks over the diesel truck cost. As discussed with the City, it is understood that diesel fuel, electricity, natural gas, CNG station maintenance costs and truck operating and maintenance costs already include HST embedded in the costs provided by the City.

5. Fleet replacement schedule used was as communicated by the City. See Appendix E. Truck life was assumed to be 7 years, the same as diesel with no differential salvage value assigned (as provided by the City).

6. Truck capital cost differential compared to clean diesel was $45,000 plus HST (ie the CNG trucks are more expensive than the diesel trucks) for all full sized CNG packer trucks (as provided by the City). The two mini-packer trucks (classification 157A) are much lower capital cost than the other ten full-sized Classification 157 packer trucks in this group, but it is the differential cost compared to diesel that is relevant to this study. Given that these mini-packer trucks have smaller engines and less CNG tankage, a estimate of $30,000 plus HST was used for the mini-packers.

7. Truck maintenance cost differential—no differential truck maintenance cost compared with clean diesel was assumed. Although CNG and diesel trucks have both been widely used in this application for a number of years, there is still a variety of opinions as to which fuel has lower truck maintenance costs including the prevailing opinion that there is no difference. HSR indicated that their current experience is there is no difference in maintenance costs between these fuels for their fleet of heavy buses—this is the assumption used in this report.

8. Future CNG vehicle fuel consumption is equal to diesel since it was assumed that there is no increase or decrease in routes or total distance except as studied in the sensitivity analysis. This is a conservative assumption since if additional trucks are required to meet a growing population (significant population growth is very likely over a 21-year period). Based on the conservatively sized CNG station used in the 37-truck baseline scenario, additional CNG trucks will have only a very small station capital cost impact (as noted in the two sensitivity analyses performed), but will provide a substantial additional fuel cost savings compared to diesel trucks.

9. Current diesel prices were supplied by the City and based on 2018/2019 average diesel fuel cost per litre then inflated at 3.0 percent per annum.

10. Engine efficiency—CNG engines are assumed to be 88 percent of diesel engine efficiency (Cummins). CNG engines are spark ignition with lower compression ratio than diesel and thus diesel engines have a higher thermal efficiency than CNG, although this advantage is narrowing making this a conservative assumption.

11. Station capital costs for all five scenarios are broken out in Appendix D. At the bottom of each station cost breakdown are several factored costs, these include:

    a. Installation cost factor—The capital costs estimated in this report are not based on a detailed design since the project has not yet advanced to that stage. Marathon has used an experience-based cost factor (a multiplier on top of the equipment cost) to reflect the cost to install this equipment on site. The value used for this multiplier reflects Marathon's opinion of the likely cost based on site conditions (for example cost factors are higher at Burlington Street since more site development and services work is required) and local construction costs. Marathon has presented a conservative cost for the stations.
    b. Contingency—It is common to add contingency to a project to account for unknowns and factors outside of the Owner's control—for example exchange rates on equipment purchases, or unknown site conditions. 10 percent has been used as this is a common contingency rate.
    c. Contractor Markup for Overhead and Profit, Bonds, General (Specification) conditions—A general contractor will add a percentage to account for their overhead and profit and for contract terms. This has been shown as separate from the equipment and installation costs, although this is sometimes included in those other cost categories.

d. Design and Construction Management (CM) Fee—The City will contract the design of these facilities and may contract out the construction management of the project. 15 percent has been carried as a combined percentage for these services. This is a common rate used for municipal CNG projects.

12. Gas utility commodity and gas distribution charges were based on 2018/2019 HSR CNG station charges as provided by the City. These were inflated at 2.5 percent per annum. Enbridge has confirmed that ample natural gas supply is available at both sites at a delivery pressure of 80 psig—this supply pressure will be discussed in the recommendations section.

13. Electricity charges were based on 2018/2019 HSR CNG station charges as provided by the City. Electricity costs were initially calculated based on the total load that the City attributes to the HSR CNG station. As a check of this calculation, Marathon also calculated the expected load of a new CNG station and multiplied it by the total cost per kWh that HSR paid in 2019. The second calculation netted a higher cost per unit of gas compressed and thus it was used as the conservative assumption. Electricity was inflated at 3.0 percent per annum. See calculations at the bottom of the table in Appendix G.

14. CNG station maintenance cost was based on the greater of the pro-rated 2018/2019 HSR CNG station maintenance charges as provided by the City and an inflation adjusted fixed monthly charge of $5000 per month (2019 value). The HSR data was calculated on a pro-rated $\$/m^3$ of gas throughput then multiplied by the annual throughput at the new packer fleet station—note that the packer fleet station is considerably smaller than HSR’s CNG station. Annual costs were inflated at 3.0 percent per annum—the higher than inflation rate was used to address cost increases expected as the station ages. The fixed monthly charge was consistently higher than the HSR data, so the fixed monthly charge governed—this is a conservative assumption.

15. GHG calculations are based on motor fuel data for the Canadian National Inventory Report (NIR) Table A6-12.

16. Trucks will continue to be serviced off site by third party maintenance shops, therefore no Hamilton shop upgrades for CNG are required or included.

17. No government grants or other incentives or subsidies are currently available or included in the cost estimates.

18. For scenario 3, the cost of both the driver time and the truck cost per km were included for a one-year period from Wentworth to Mount Hope. This

was included as a 23.2 km round trip (at $1.88 inflation adjusted per km) consuming one hour of total labour per truck trip.

19. For scenario 3, as an alternative to deadheading the trucks to Mount Hope HSR for fueling for 12 months, the City requested that Marathon evaluate the technical viability and economics of fueling a CNG trailer at HSR Mount Hope and trucking the gas to Burlington Street to fuel the fleet at that location for the 12 month period. Temporary fueling at Burlington Street will require either a temporary time fill or temporary fast fill which will incur considerable sunk cost. It should also be noted that the trailer must have its own compressor, or an external compressor must be installed to pump down the trailer.

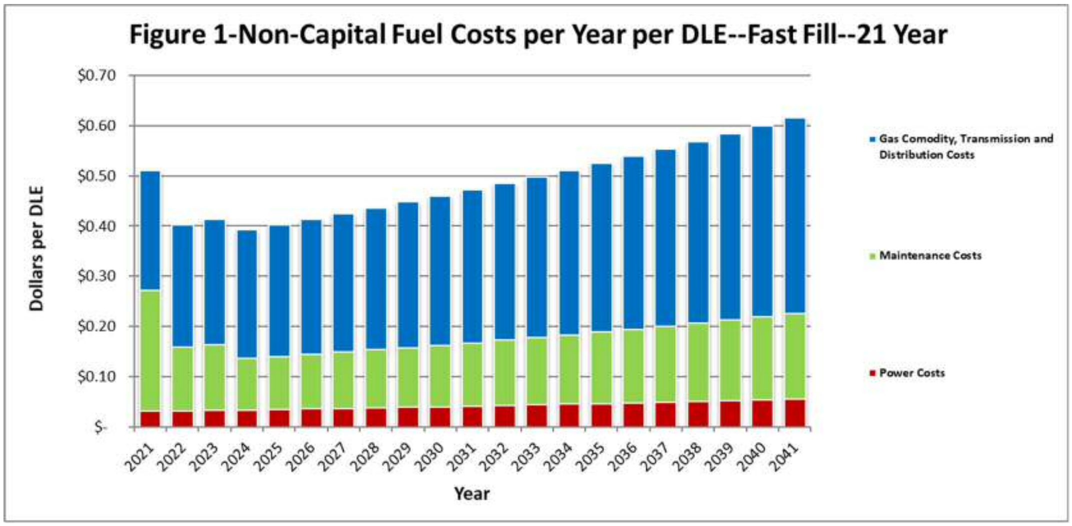
    Marathon has considered the trailer use approach and has developed a lower cost option. To investigate this approach, Marathon proposes to install the new permanent packer truck CNG fast fueling equipment (CNG storage and two new high flow dispensers as well as controls and ancillary equipment) at Wentworth and bring the trailer to that site for fueling during the 12-month period. The trailer gas will be used to continuously and automatically recharge the permanent gas storage and the new dispensers will provide a fueling experience for staff that duplicates the permanent station operation. After the 12-month period, the Wentworth packer truck CNG fueling station will be connected to the new HSR fueling station adjacent to the Wentworth site. The new HSR station will take over for the gas trailer. This approach eliminates the sunk cost issue with temporary fueling at Burlington Street.

    Marathon has identified a supplier in Ontario that can furnish a trailer with sufficient gas storage for several days (up to one week) of initial-year (2021) fueling volumes. The trailer includes its own 75 Hp electric drive compressor which could be powered at Wentworth using the electrical service for the existing CNG station and the trailer can be fueled at HSR Mount Hope. Marathon received pricing on this trailer option based on a per mile transportation charge and separately on a trailer rental for one year. Marathon is not currently confident in the pricing provided by this vendor so for the purposes of this study, it has been assumed that the trucks will deadhead to Mount Hope for the 12 month period—this is the conservative (ie highest cost) assumption and the one that the City has the most control over.

    If the City proceeds with Scenario 3, the use of the trailer option should be revisited.

20. In scenarios 4 and 5, fueling the fleet at Burlington Street provides operational savings (Scenario 5) and simplicity (Scenarios 4 and 5). An attempt to partially capture this benefit was made by including the truck per km operating cost savings (at $1.88 inflation adjusted per km). The $1.88

was adjusted downward to reflect the lower cost of CNG compared to diesel—the recalculated CNG cost per km for 2020 is $1.34. See Figure 1 below that illustrates the low non-capital cost of CNG—note for comparison that diesel in 2020 is projected to be $1.06 for City trucks.



Driver labour savings <u>has not been included</u> due to the challenge in realizing this cost savings (ie, routes would need to be reworked and extended to make use of the time savings). The cost included for deadheading from Burlington to Wentworth assumes half the fleet must make the 9.1 km round trip daily. (the other half of the fleet are assumed to incorporate a fueling stop into their collection route).

21. A sensitivity analysis was performed to illustrate the effect of fleet growth over time. To quantify this impact, an additional analysis was made with an increase of one truck for each Classification 78, 157 and 170A (3 trucks in total) at the time of the second procurement of each. This adds to the truck capital cost but also increases the diesel consumption displaced with CNG. This is a relatively modest fleet growth of less than 10 percent over the 21-year period. A second analysis with 2 of each of the full-sized trucks (6 trucks in total) is also provided—the additional trucks are added at the third procurement—we believe that this second sensitivity analysis will most accurately project the actual conditions. It should be noted that the fueling station costed in this report will easily accommodate this fleet growth and much more.

Approach/Methodology:

A 21-year life cycle cost analysis was built by Marathon Technical Services using inputs from a variety of sources (as previously outlined). 21 years was selected as it represents three truck life cycles for the initial group of 16 classification 78 packer trucks—other packer truck types also include 3 truck procurement cycles although truck classification types 157/157A and 170A will have two years and four years of truck life (respectively) left at the end of the 21-year period. It is assumed that if the City intends to continue with CNG after the 21-year period, that a capital update/upgrade to the CNG station will be made and the trucks will continue to serve out their full 7-year life. If the City decides to transition away from CNG at the end of the 21 years, the CNG station (which at that time will be fully depreciated) will continue to be used until the last packer trucks reach the end of their life and then the station will be retired.

The focus of this analysis was to identify and quantify those items that are differential costs for CNG compared to clean diesel—it should be stressed that <u>there may be additional costs that are not identified in the analysis because they apply to both CNG and Diesel</u>. These additional costs might include the base cost of a diesel truck (only the differential is used herein), end of life truck salvage value, packer truck maintenance costs (as previously noted), truck licensing costs, and truck driver costs as examples.

A total of 5 CNG station scenarios were conceived. Each scenario was then evaluated in the customized spreadsheet to determine the NPV over the 21 years, the payback year and a cashflow for each scenario (cash flow tables not included in this report for brevity but available separately if desired).

A scenario that was considered but not further evaluated was the construction of a time fill facility at the Wentworth station. This scenario was of interest only because it was a time fill option that could leverage the Wentworth infrastructure. A preliminary evaluation raised serious concerns about the lack of space required for this time fill area (considerable onsite parking would be lost) and more importantly about the logistical challenges and on-going costs associated with having the packer fleet domiciled remote from the Burlington Street operations.

See Appendix B for concept level station layouts drawings for Scenarios 1, 2 and 3 (Wentworth--Drawing G-01) and Scenarios 4 and 5 (Burlington--Drawing G-02). More detail related to the equipment associated with each scenario is listed and costed in Appendix D.

A brief description of the scenarios that were evaluated follows:

Scenario 1--Rebuild Wentworth Fast Fill

The existing fast fill CNG station at Wentworth is well beyond its normal life. This station equipment could be swapped out with new equipment using the existing electrical and gas supply, pipe racks, control building, dryer and building and potentially the existing pads. A generator has been added for redundancy. Under this scenario, all CNG packer trucks would fast fill at Wentworth. The equipment required is listed below:

- Existing CNG Dryer
- Two new 250 Hp (w/ VFD) 636 scfm compressors
- 70 MCF storage
- New Fast Fill Priority/ESD Panel
- Two Combo Dispensers
- Fuel Management Terminal
- No Time Fill System
- Recapture Defueling System
- New Compressed Air System
- New Electrical Control panels in Existing Building
- New Diesel Generator

Scenario 2--Rebuild Wentworth Fast Fill and Tie-in to Future Adjacent HSR

The existing fast fill CNG station at Wentworth is well beyond its normal life. This station equipment could be swapped out with new equipment using the existing electrical and gas supply, pipe racks, control building, dryer and building and potentially the existing pads. No generator has been added and smaller storage was included due to the capacity and redundancy provided by a piped connection to the new (adjacent) HSR station. Under this scenario, all CNG packer trucks would fast fill at Wentworth. The equipment required is listed below:

- Existing CNG Dryer
- Two new 250 Hp (w/ VFD) 636 scfm compressors
- 35 MCF storage
- New Fast Fill Priority/ESD Panel
- Two Combo Dispensers
- Fuel Management Terminal
- No Time Fill System
- Recapture Defueling System
- New Compressed Air System
- New Electrical Control panels in Existing Building
- No Diesel Generator

Scenario 3--Accelerate HSR Initial Station

The new HSR fueling station construction would be accelerated, at least for the portion of the equipment required to fuel packer trucks. The accelerated HSR station would be constructed to be available one year after the initial packer truck arrivals-- this scenario assumes that one year of deadheading of the first 16 trucks to HSR Mount Hope will be required (the mileage and labour cost of this deadheading is included in the analysis). Note that costs associated with the new equipment installed on the HSR site have been removed from this analysis (ie HSR is paying for the dryer, compressors and generator) and only packer truck incremental costs are shown for fast fill of packer trucks on Wentworth site. A pipe feeding storage on the current Wentworth site would be installed and fastfiill dispensers on the Wentworth site would be used to fuel trucks—packer trucks would not be fueled on the HSR site. The equipment required is listed below:

- HSR CNG Dryer
- HSR-Two new 250 Hp (w/ VFD) 636 scfm compressors (minimum)
- 70 MCF storage
- New Fast Fill Priority/ESD Panel
- Two Combo Dispensers
- Fuel Management Terminal
- No Time Fill System
- HSR--Recapture Defueling System
- HSR--New Compressed Air System
- New Electrical Control panels in Existing Building
- HSR--Diesel Generator

Scenario 4--New Burlington Street Fast Fill and Time Fill

Construct a new standalone fueling station at the Burlington Street site complete with a diesel generator for redundancy. The station would primarily fuel using a time fill fueling manifold, however, a small storage and a single fast fill dispenser would be installed to allow fast fill as well—in the event a truck returns from service and must fuel quickly to allow it to go into service. The equipment required is listed below:

- Relocate Existing CNG Dryer
- Two new 250 Hp (w/ VFD) 636 scfm compressors
- 35 MCF storage
- New Fast Fill Priority/ESD Panel
- One Combo Dispenser
- Fuel Management Terminal
- 37 Time Fill Posts with Barricade
- Recapture Defueling System
- New Compressed Air System
- New Electrical Control panels in Existing Building

- New Diesel Generator

Scenario 5--New Burlington Street with Time Fill Only

Construct a new standalone fueling station at the Burlington Street site complete with a diesel generator for redundancy. The station would only fuel using a time fill fueling manifold. It would be possible to allow space for a future small storage and a single fast fill dispenser to allow the future installation of fast fill as well. The equipment required is listed below:

- Relocate Existing CNG Dryer
- Two new 250 Hp (w/ VFD) 636 scfm compressors
- 37 Time Fill Posts with Barricade
- Recapture Defueling System
- New Compressed Air System
- New Electrical Control panels in Existing Building
- New Diesel Generator

Findings-Quantitative

The primary means of quantitative evaluation of the project is the Net Present Value (NPV) of the Costs and Savings compared to Clean Diesel trucks and operation (savings are calculated as the cost of diesel that is displaced).

A payback analysis was also performed (note that the time value of money and discount rate is not used in a payback analysis). See Glossary in Appendix A for additional definition of payback analysis. Although payback analysis does not include any discounting to current dollars (as used in NPV), it uses cash flow over the life of the project in dollar costs as incurred in each of the 21 years—these costs are escalated using the inflation rates indicated in Appendix C so they represent the cash outlay in a given year. Capital costs such as the CNG station and the upcharge on the packer trucks as well as operating costs such as the electricity and maintenance to operate the CNG station are offset against the cost that would have been spent purchasing diesel fuel. Thus, the payback year is the year when the savings on CNG offsets the cost of CNG capital and operating costs. The summary table on the next page provides a breakdown of the cost categories in 2019 dollars (ie the NPV). Negative numbers are costs and positive numbers are savings versus diesel or current practice.

Net Present Value of All Costs-21 Year--Baseline Scenario with 37 Trucks

	Scenario	1	2	3	4	5
		Rebuild Wentworth Fast Fill	Rebuild Wentworth Fast Fill and Tie-in to Future Adjacent HSR	Accelerate HSR Initial Station Configuration to be Available One Year After Initial Packer Truck Arrivals--Note that HSR Station Dryer, Compressor and Generator Costs have been Removed and Only Packer Truck Fast Fill Storage, Dispensing and Controls System Costs are Shown for Wentworth Site	New Burlington Street Fast Fill and Time Fill	New Burlington Street Time Fill Only
	Description	NPV				
1	Diesel Fuel and DEF	$ 11,154,085	$ 11,154,085	$ 11,154,085	$ 11,154,085	$ 11,154,085
2	CNG Fast Fill Only Station	$ (4,131,583)	$ (3,224,902)	$ (1,246,687)		
3	CNG Time Fill Station					$ (4,050,875)
4	CNG Fast Fill and Time Fill Station				$ (4,832,201)	
5	Gas Utility Commodity and Transportation Costs	$ (2,520,301)	$ (2,520,301)	$ (2,520,301)	$ (2,520,301)	$ (2,520,301)
6	Gas Compression Electrical Costs--note that fast fueling at Wentworth will take place from 2pm to 5pm which is high-peak in the summer and mid-peak in the winter. Rates change frequently but mid-peak is approximately 50% higher than off-peak and high-peak is approximately 100% higher than off-peak. Baseline data for HSR is primarily off-peak usage. To be conservative, the high-peak rates are assumed so HSR power costs are doubled.	$ (340,128)	$ (340,128)	$ (340,128)	$ (340,128)	$ (340,128)
7	Compression System O&M--Note that Scenario 3 is not discounted to reflect the use of HSR equipment as it is assumed that the Packer Fleet will reimburse HSR for fuel at a rate that will compensate HSR for these costs.	$ (1,110,363)	$ (1,110,363)	$ (1,110,363)	$ (1,110,363)	$ (1,110,363)
8	Incremental Cost of Vehicles	$ (4,255,284)	$ (4,255,284)	$ (4,255,284)	$ (4,255,284)	$ (4,255,284)
9	Deadheading--Burlington to Wentworth--Truck O&M Savings, not including Labour				$ 1,224,615	$ 1,224,615
10	Fast Fill Deadheading--Wentworth St. to Mount Hope (Year 1) round trip--Labour			$ (297,201)		
11	Fast Fill Deadheading--Wentworth St. to Mount Hope (Year 1) round trip--Mileage			$ (135,375)		
12	**Total NPV for Life Cycle (see Glossary in Appendix A for explanation of NPV)**	**$ (1,203,575)**	**$ (296,894)**	**$ 1,248,744**	**$ (679,578)**	**$ 101,748**
	Description	Payback Year				
13	**Payback Achieved in Year: (see Glossary in Appendix A for explanation of Payback)**	**16**	**16**	**10**	**16**	**13**

Quantitative Findings-Summary Points:

It should be understood that the best alternative(s) will provide a blend of qualitative and quantitative benefits. The table on the preceding page is only quantitative.

1. See Appendix D for station capital cost estimates and Appendix F for fuel consumption and GHG emission calculations.

2. Scenarios 3 and 5 are currently returning a positive NPV and all Scenarios are achieving payback between 10 and 16 years of the 21-year period.

3. The table on the previous page shows the Net Present Value (NPV) to be highest for scenario 3—Wentworth fast fill scenario using HSR compression and other infrastructure (NPV=$1.25M). This high NPV is due to significant leveraging of the investment in the new HSR facility, thus this scenario is very dependent on the HSR facility being constructed in a schedule not exceeding one year after the initial 16 packer trucks are put into service—the deadheading cost from Wentworth to Mount Hope for fueling accounts for about $433K per year and this assumes that fueling is done on regular time (not overtime).

4. Scenario 5 also has a positive NPV ($102K) and provides a number of operational advantages, however it should be noted that scenario 4 and 5 are both very dependent on the assumed truck mileage savings of a 50 percent reduction in trips to Wentworth street for fueling.

5. The lowest NPV scenario was number 1—the rebuild of the Wentworth fast fill. This scenario showed an NPV of -$1.20M.

6. It should be noted that all of the scenarios result in Classification 157, 157A and 170A trucks that are early or mid-way through their life cycle at the end of the 21 years. If the City decided to transition away from CNG in 21 years, the CNG station could continue to operate for another 5 years to recoup the cost of the trucks. This would add to the economic value of all scenarios.

7. Fleet expansion is likely in the future to meet a growing City; however, no fleet growth is included in these baseline calculations (a conservative assumption) (see the sensitivity analysis findings for additional information). Marathon calculated a compression capacity requirement of 522 scfm for fast fill and 196 scfm for time fill of the 37 trucks. The best “fit” compressor provides 636 scfm of compression (two compressors are included for redundancy for a total of 1272 scfm if both are operable) and thus the conservatively sized station used in this analysis can comfortably handle an expanded Hamilton packer truck fleet.

Findings-Qualitative and Quantitative Benefits of Time fill at the Burlington Street Location:

Scenarios 4 and 5 are both based on the use of a predominantly or completely time fill approach to fueling at the Burlington Street location. Time fill in this location has several benefits:

1. Time fill of trucks takes place over a period of many hours. This additional fill time allows the heat generated during fueling to partially dissipate while fueling progresses and thus results in cooler, denser gas in truck tanks after fueling—this translates into a more complete fill and improved range.

2. Given that packer trucks are typically parked for 12 to 16 hours, time fill is well adapted to packer truck operations. The picture below is of a large refuse time fill designed by Marathon and installed in Tucson Arizona.

3. Time fill can significantly reduce the number of compressor starts and stops which leads to reduced wear and tear on station equipment. Time fill equipment is also simpler than fast fill dispensing equipment and thus is less prone to breakdown.

4. With much more time available for time filling, a (much) smaller compressor can be used. This analysis assumes the same two 636 scfm compressors as the fast fill scenarios to allow for the future use of the station as a relatively high capacity fast fill station and because these larger compressors are more robust and durable than smaller compressors.

5. The elimination of the need to drive trucks to another location for the sole purpose of fueling reduces unnecessary truck operating costs. This analysis has assumed that half of the truck fleet would be required to make an unnecessary trip to Wentworth for fast fueling if fueling did not take place at Burlington street. Based on this assumption, (not including labour costs) the added cost over the **life cycle has an NPV of $1,224,615**. This has been included in the analysis and plays a pivotal role in the overall NPV.

6. It is anticipated that there will be a reduction of personnel time required related to the use of time fill rather than fast fill fueling (Burlington Street options). Based on an estimated 10 minutes of time reduction per vehicle per night (conservative), this results in an **NPV lifecycle labor reduction equivalent to $2,330,426.** This has not been included in the cost summary since a rework and extension of existing routes would be required to realize this time/labour reduction.

7. Fueling at Burlington Street consolidates the trucks to the location of dispatch, simplifying operations.

Findings-Qualitative and Quantitative Benefit Summary by Scenario

Pros and Cons of each Scenario:

Scenario 1--Rebuild Wentworth Fast Fill

Pros:

1. It uses the existing developed location and services, making it the fastest to deploy (same for scenario 2).

2. This scenario is schedule independent of the HSR project.

Cons:

3. Requires trucks to fuel at Wentworth—lacks the operational simplicity and convenience of consolidating fueling to truck domicile location at Burlington Street.

4. One of the highest capital cost scenarios ($4.1M).

Scenario 2--Rebuild Wentworth Fast Fill and Tie-in to Future Adjacent HSR

Pros:

1. It uses the existing developed location and services, making it the fastest to deploy (same for scenario 1).

2. Second lowest capital cost ($3.2M).

Cons:

3. Requires trucks to fuel at Wentworth—lacks the operational simplicity and convenience of consolidating fueling to truck domicile location at Burlington Street.

4. This scenario is somewhat schedule dependent of the HSR project—for station redundancy.

Scenario 3--Accelerate HSR Initial Station

Pros:

1. Highest NPV ($1.25M). Fastest payback (10 Years).

2. Lowest capital cost ($1.25M)—less than half of the next lowest cost alternative.

3. Leverages the HSR station making more use of those assets. Packer truck and HSR bus schedules have little to no overlap.

Cons:

4. Requires trucks to fuel at Wentworth—lacks the operational simplicity and convenience of consolidating fueling to truck domicile location at Burlington Street.

5. This scenario is very schedule dependent of the HSR project—for gas drying, compression and redundancy.

6. This scenario requires one year of deadheading of packer trucks to Mount Hope for fuel at an included cost of about $433K. If the HSR station were delayed, this annual cost would continue to accrue. Any non-revenue time on the street increases vehicle wear and tear and introduces additional operating risk. The alternative of trailering gas to the Wentworth site also creates risk due to equipment failure without redundancy, third party equipment operating on City property and the risk of trucking the gas through the City.

7. Although this scenario is appealing from a cost perspective, the heavy reliance on the HSR project, coupled with the need for ongoing fueling of the fleet at Wentworth reduces the desirability of this option significantly.

Scenario 4--New Burlington Street Fast Fill and Time Fill

Pros:

1. This scenario is schedule independent of the HSR project.

2. Convenience and operational simplicity of consolidating fueling to the Burlington Street truck domicile location.

3. Benefits of time fill, with the option to perform some fast fill when necessary.

Cons:

4. Second lowest NPV (-$680K).

5. Highest capital cost ($4.8M) of all scenarios as the new site will require development.

Scenario 5--New Burlington Street with Time Fill only

Pros:

1. Second highest NPV ($102K) and second fastest payback (13 Years).

2. This scenario is schedule independent of the HSR project.

3. Convenience and operational simplicity of consolidating fueling to the Burlington Street truck domicile location.

4. Benefits of time fill.

Cons:

5. Third highest capital cost ($4.1M) of all scenarios as the new site will require development.

6. No fast fill facility is provided, although, space could be left for a future fast fill storage and island if desired. It should also be noted that with the planned compressors, one compressor will time fill one truck directly in 10 to 15 minutes, thus the need for fast fill is very low.

Findings-Sensitivity Analysis to Test the Impact of Fleet Growth:

Sensitivity Analysis 1--One Additional Heavy Truck of Classification 78, 157 and 170A added at Second Procurement Cycle (total 40 trucks):

	Net Present Value of All Costs-21 Year Sensitivity Analysis with 37 Trucks in First Truck Procurement and 40 Trucks after Second Truck Procurement	1	2	3	4	5
	Scenario	Rebuild Wentworth Fast Fill	Rebuild Wentworth Fast Fill and Tie-in to Future Adjacent HSR	Accelerate HSR Initial Station Configuration to be Available One Year After Initial Packer Truck Arrivals--Note that HSR Station Dryer, Compressor and Generator Costs have been Removed and Only Packer Truck Fast Fill Storage, Dispensing and Controls System Costs are Shown for Wentworth Site	New Burlington Street Fast Fill and Time Fill	New Burlington Street Time Fill Only
	Description	NPV				
1	Diesel Fuel and DEF	$ 11,734,773	$ 11,734,773	$ 11,734,773	$ 11,734,773	$ 11,734,773
2	CNG Fast Fill Only Station	$ (4,131,583)	$ (3,224,902)	$ (1,246,687)		
3	CNG Time Fill Station					$ (4,086,936)
4	CNG Fast Fill and Time Fill Station				$ (4,868,262)	
5	Gas Utility Commodity and Transportation Costs	$ (2,645,908)	$ (2,645,908)	$ (2,645,908)	$ (2,645,908)	$ (2,645,908)
6	Gas Compression Electrical Costs--note that fast fueling at Wentworth will take place from 2pm to 5pm which is high-peak in the summer and mid-peak in the winter. Rates change frequently but mid-peak is approximately 50% higher than off-peak and high-peak is approximately 100% higher than off-peak. Baseline data for HSR is primarily off-peak usage. To be conservative, the high-peak rates are assumed so HSR power costs are doubled.	$ (357,415)	$ (357,415)	$ (357,415)	$ (357,415)	$ (357,415)
7	Compression System O&M--Note that Scenario 3 is not discounted to reflect the use of HSR equipment as it is assumed that the Packer Fleet will reimburse HSR for fuel at a rate that will compensate HSR for these costs.	$ (1,110,363)	$ (1,110,363)	$ (1,110,363)	$ (1,110,363)	$ (1,110,363)
8	Incremental Cost of Vehicles	$ (4,467,884)	$ (4,467,884)	$ (4,467,884)	$ (4,467,884)	$ (4,467,884)
9	Deadheading--Burlington to Wentworth--Truck O&M Savings, not including Labour				$ 1,287,671	$ 1,287,671
10	Fast Fill Deadheading--Wentworth St. to Mount Hope (Year 1) round trip--Labour			$ (297,201)		
11	Fast Fill Deadheading--Wentworth St. to Mount Hope (Year 1) round trip--Mileage			$ (135,375)		
12	**Total NPV for Life Cycle (see Glossary in Appendix A for explanation of NPV)**	**$ (978,380)**	**$ (71,698)**	**$ 1,473,940**	**$ (427,387)**	**$ 353,939**
	Description	Payback Year				
13	**Payback Achieved in Year: (see Glossary in Appendix A for explanation of Payback)**	**16**	**16**	**11**	**16**	**13**

It is clear from the above sensitivity analysis 1 that the NPVs are all improving although the payback is not improving due to the additional truck purchases in later years. The ranking of scenarios does not change since the capital station costs do not change (other than additional time fill posts in Scenarios 4 and 5). Operating costs are variable and increase according to fuel usage.

Note that if additional trucks were introduced even sooner, the benefits would be more pronounced.

Sensitivity Analysis 2--One Additional Heavy Truck of Classification 78, 157 and 170A added at Second (total 40 trucks) and One More at Third Procurement Cycle (total 43 trucks):

Net Present Value of All Costs-21 Year
Sensitivity Analysis with 37 Trucks in First Truck Procurement, 40 Trucks after Second Truck Procurement and 43 Trucks after Third Truck Procurement

	Scenario	1	2	3	4	5
		Rebuild Wentworth Fast Fill	Rebuild Wentworth Fast Fill and Tie-in to Future Adjacent HSR	Accelerate HSR Initial Station Configuration to be Available One Year After Initial Packer Truck Arrivals--Note that HSR Station Dryer, Compressor and Generator Costs have been Removed and Only Packer Truck Fast Fill Storage, Dispensing and Controls System Costs are Shown for Wentworth Site	New Burlington Street Fast Fill and Time Fill	New Burlington Street Time Fill Only
	Description	**NPV**				
1	Diesel Fuel and DEF	$ 11,977,661	$ 11,977,661	$ 11,977,661	$ 11,977,661	$ 11,977,661
2	CNG Fast Fill Only Station	$ (4,131,583)	$ (3,224,902)	$ (1,246,687)		
3	CNG Time Fill Station					$ (4,122,997)
4	CNG Fast Fill and Time Fill Station				$ (4,904,323)	
5	Gas Utility Commodity and Transportation Costs	$ (2,697,517)	$ (2,697,517)	$ (2,697,517)	$ (2,697,517)	$ (2,697,517)
6	Gas Compression Electrical Costs--note that fast fueling at Wentworth will take place from 2pm to 5pm which is high-peak in the summer and mid-peak in the winter. Rates change frequently but mid-peak is approximately 50% higher than off-peak and high-peak is approximately 100% higher than off-peak. Baseline data for HSR is primarily off-peak usage. To be conservative, the high-peak rates are assumed so HSR power costs are doubled.	$ (364,645)	$ (364,645)	$ (364,645)	$ (364,645)	$ (364,645)
7	Compression System O&M--Note that Scenario 3 is not discounted to reflect the use of HSR equipment as it is assumed that the Packer Fleet will reimburse HSR for fuel at a rate that will compensate HSR for these costs.	$ (1,110,363)	$ (1,110,363)	$ (1,110,363)	$ (1,110,363)	$ (1,110,363)
8	Incremental Cost of Vehicles	$ (4,565,239)	$ (4,565,239)	$ (4,565,239)	$ (4,565,239)	$ (4,565,239)
9	Deadheading--Burlington to Wentworth--Truck O&M Savings, not including Labour				$ 1,315,881	$ 1,315,881
10	Fast Fill Deadheading--Wentworth St. to Mount Hope (Year 1) round trip--Labour			$ (297,201)		
11	Fast Fill Deadheading--Wentworth St. to Mount Hope (Year 1) round trip--Mileage			$ (135,375)		
12	**Total NPV for Life Cycle (see Glossary in Appendix A for explanation of NPV)**	**$ (891,687)**	**$ 14,995**	**$ 1,560,633**	**$ (348,546)**	**$ 432,780**
	Description	**Payback Year**				
13	**Payback Achieved in Year: (see Glossary in Appendix A for explanation of Payback)**	**16**	**16**	**11**	**16**	**13**

Sensitivity analysis 2 shows additional NPV improvement, even though the costs of the additional CNG trucks in procurement 3 for truck classifications 157 and 170 are not fully utilized by the end of the 21-year period.

Note that if additional trucks were introduced even sooner, the benefits would be more pronounced. Given the expected growth of the City, Marathon believes that Sensitivity Analysis 2 is the most likely reflection of actual project economics.

Findings-Environmental:

The growing concern over climate change and the recent advancements in controlling toxic tailpipe emissions has caused a shift in focus toward greenhouse gases and most notably toward CO_2 reduction. Unlike other pollutants that can be reduced by exhaust treatment, CO_2 is simply a product of combustion—thus, if a hydrocarbon (HC) fuel is consumed, CO_2 is produced. In fact, there are basically three ways to reduce CO_2 emissions of a vehicle:

1. Reduce fuel consumption through greater engine or drive train efficiency (reduce weight, use a hybrid drive system, etc.).

2. Use a low carbon fuel such as CNG or Renewable Natural Gas (RNG).

3. Use an energy source that has no tailpipe emissions (Battery Electric or hydrogen) however, these technologies are not yet field proven or durable to the extent that diesel and CNG are, and these energy sources can emit as much GHG as CNG depending on how the hydrogen or electricity is produced.

The first point above is relatively straightforward, since CO_2 production is linked to fuel consumption, any improvement in fuel consumption will provide a similar reduction in CO_2 emissions.

The second point is not as obvious. The products of complete combustion of any hydrocarbon fuel are CO_2 and H_2O, thus if one uses a fuel that is inherently lower in carbon content per unit of energy output, there will be lower CO_2 emissions. This study has included an analysis of the annual and lifecycle GHG reduction associated with the transition from diesel to CNG trucks and a further analysis to illustrate the reduction if RNG were used instead of CNG. Southern California Gas Company has claimed that more than half of the natural gas dispensed to vehicles in California is RNG (https://www.socalgas.com/smart-energy/renewable-gas/what-is-renewable-natural-gas).

The GHG analysis indicated above is provided in Appendix F. Based on this data, the replacement of the diesel fleet with a CNG fleet will provide a reduction of 5,537 tonnes CO_2e over the lifecycle of the project, an amount equal to about 57 passenger vehicles (using US EPA equivalents) and about a 17.3 percent reduction from the diesel trucks.

Note that RNG is functionally identical to CNG—there is no difference in the CNG station or vehicle and in most cases, the molecules consumed in the vehicle are not the RNG molecules produced at the source—an accounting exercise is used to track the RNG through the pipeline system—analogous to deposits and withdrawals from a bank.

An RNG scenario was not analyzed since the costs are identical, (with the possible exception of the fuel cost) to the costs in the 5 scenarios that were investigated. Thus, the decision on whether to transition to CNG and which fueling plan and location to adopt is independent of the decision to utilize RNG.

RNG can be used to displace any portion of gas consumed. Many of the large fleets in California use 100 percent RNG. The use of 100 percent RNG results in near zero GHG emissions as no new carbon is introduced and methane that would have naturally been released to the environment is captured and used. The GHG reduction for RNG is calculated to be 31,965 tonnes CO_2e over the lifecycle of the project— an amount equal to about 331 passenger vehicles (using US EPA equivalents) and representing an almost complete elimination of GHGs. Therefore, RNG can provide a scenario that emits essentially no CO_2 making it comparable to, or lower in GHGs than electric trucks powered from Ontario's grid.

It is understood that the City has a limited supply of RNG and there will be internal competition for its use. Vehicle applications provide a very publicly visible way of promoting the use of this green fuel—one that has been widely used by the company Waste Management in promoting their fleet. The use of RNG allows the City to use mature and proven CNG truck technology whereas, BET truck technology is still very developmental and there are very limited packer truck types currently available and vehicle range is considerably less than with CNG.

Findings-CNG Truck Range:

The City's maximum route at this time is 180 km. Current major CNG packer truck suppliers advertise trucks with total capacity of 60 to 105 Diesel Gallon Equivalent (DGE) or 228 to 399 Diesel Litre Equivalent (DLE). The difference in tank volume is related to different positioning of tanks on the trucks (see following page). Tank location options on the truck is limited by truck type—for example, a rear loader will not have a tailgate tank option. Using the City's current average fuel economy and factoring in for the portion of the tank capacity that is not useable due to incomplete filling and due to residual pressure when the tank is functionally empty, these trucks have a range of 180 to 300 km. Thus, it will be important for the City to be vigilant in optimizing the range on these trucks since a truck with a 225 to 250 km range would be needed for a 180 km route. It should also be noted that time fill improves the vehicle range by an estimated 10 percent due to the lower tank temperatures during time filling, compared to fast filling.

Back of Cab/Front Body (Rear Loader shown) CNG Tanks-Picture Credit Agility Fuel Solutions

Roof Mounted CNG Tanks (Side Loader shown)-Picture Credit Agility Fuel Solutions

Tailgate CNG Tanks (Front Loader shown)-Picture Credit Agility Fuel Solutions

Findings-Operating Engineers:

Marathon spoke with the Technical Standards and Safety Authority (TSSA) (Brian Gee) by email and by phone. The major takeaways from the correspondence were:

1. The 150 Hp threshold above which an operating engineer or compressor operator is required, is still in place, however, TSSA is having internal discussions related to relaxing or removing this requirement. Mr. Gee indicated that he believed this will happen, but not before next June at the earliest and likely later—perhaps much later.

2. TSSA will allow up 150 Hp for the compressor itself and does not include ancillary loads such as fans.

3. TSSA will allow more than one 150 Hp compressor to be installed provided there is an interlock to limit operation to one compressor to avoid exceeding the 150 Hp threshold.

4. TSSA will allow larger compressors (perhaps 200 to 250 Hp) if they are horsepower limited to 150 Hp. This could be accomplished using a VFD to avoid exceeding the 150 Hp threshold. TSSA would also require a device such as current monitoring to verify that the 150 Hp limit is not exceeded. This approach gives the City the opportunity to increase flow in the future if you either; add an operating engineer, or if the requirement is removed in the future.

Conclusions and Recommendations:

1. It is recommended that the City of Hamilton proceed with the CNG project.

2. All of the identified scenarios are technically feasible. Marathon has considered the balance between qualitive and quantitative factors and based on a balanced approach between these two general criteria, Marathon has rank ordered the scenarios by overall desirability are as following:
    1) Scenario 5--New Burlington Street with Time Fill only
    2) Scenario 3--Accelerate HSR Initial Station and provide packer truck fueling on the 330 Wentworth site using gas compressed at the new HSR site.
    3) Scenario 2--Rebuild Wentworth Fast Fill and Tie-in to Future Adjacent HSR
    4) Scenario 1--Rebuild Wentworth Fast Fill

    Scenario 4 was eliminated since it would primarily provide the same benefits as Scenario 5 but at higher cost. Scenario 5 can provide a “fast” (10 to 15 minutes) time fill of a single vehicle making it almost as fast as the fast fill portion of Scenario 4. It is also a possibility that fast fill capability for packer trucks could be included with the new HSR station at lower cost than Scenario 4.

    Scenario 3 is lower initial cost and thus, higher NPV, however, the NPV is spread across 21 years. This equates to an actual average benefit of $55K per year in current dollars. This is a relatively low price for the operational convenience and efficiency of having the fueling operation at Burlington Street.

    Given the long term nature of this project, Marathon recommends constructing the fueling facility at Burlington Street as this decouples the project from the current HSR project, gives a convenient fueling location that will save labour and truck mileage and still has a high NPV and the second best payback.

3. The sensitivity analysis demonstrates that more trucks will add to the financial viability of the transition to CNG. This is not a surprising conclusion since CNG is an inexpensive fuel but with high infrastructure costs. More throughput does not (in this case) add to the capital cost significantly but it does increase the amount of diesel that is displaced which in turn improves the NPV of all of the Scenarios. It should also be noted that adding trucks earlier improves the NPV more than later fleet growth.

4. Enbridge has indicated that both locations have ample gas supply and are they are currently proposing an 80 psig delivery pressure—note that the Wentworth site has historically had a 200 psig delivery pressure. Marathon

recommends negotiating for higher inlet pressure as this will reduce the electricity and maintenance costs on the compressors (although they are still likely to be 4 stage compressors unless much higher pressure is available). Unregulated utility pressure is often the best overall approach from an Owner and Utility perspective.

5. It is estimated that this project will create a savings of 5,537 tonnes CO_2e over the lifecycle of the project --projecting a “green” image for the City. If there is fleet growth beyond 37 trucks, the environmental benefit will be increased.

6. Hamilton has its own RNG supply. Transportation is an excellent application for RNG and can make a CNG vehicle even more environmentally responsible than an electric vehicle—avoiding the pollution of battery production. The CNG vehicle has the power and range to match the current diesel routes whereas a fleet size increase is often necessary with electric vehicles.

7. Given the unknowns related to future TSSA regulations, if the City proceeds with time fill, there are two approaches:

    a. Install two 150 Hp/380 scfm compressors with interlocks so they cannot operate simultaneously. This will provide ample flow to serve the time fill station for 37 trucks and beyond.

    b. Install two 250 Hp/ 636 scfm compressors with VFDs and interlocks to prevent the compressors from operating simultaneously and at a power consumption level exceeding 150 Hp.

    Marathon recommends the second alternative (b) above since it provides the ability to significantly upgrade the station flow rate in the future. The analysis in this report was based on the second alternative (b). Note that the first alternative will slightly reduce the capital cost.

Appendix A

Glossary of Terms

ACH	Air Changes per Hour
AHJ	Authority having Jurisdiction (the regulatory body with the authority to mandate design)
BET	Battery Electric Truck
CH_4	Methane—natural gas is about 90 to 95 percent methane.
CNG	Compressed Natural Gas
CO_2e	Carbon Dioxide Equivalent—a means of comparing other GHGs to CO_2 and also to combine the effects of multiple GHGs to a common unit for simplification of quantification.
DGE	Diesel Gallon Equivalent (the amount of CNG required to provide an amount of energy equal to one USG of diesel fuel).
Discount Rate	This is a percentage used to discount a future value back to a present value to be used in the calculation of the Net Present Value (NPV). The discount rate used is often the borrowing rate, however, it could also be the minimum acceptable rate of return also called the “hurdle rate”. This should not be confused with the Internal Rate of Return (IRR) which is the rate at which the project has a net present value of zero—ie the rate at which the project is “breakeven”.
ESD	Emergency Shut Down
F	Fahrenheit
GGE	Gasoline Gallon Equivalent (the amount of CNG required to provide an amount of energy equal to one USG of gasoline=5.66 pounds of CNG).
GHG	Greenhouse Gas—CO_2 (Carbon Dioxide), CH_4(methane) and N_2O (Nitrous Oxide) are the most common greenhouse gases.
HP or Hp	Horsepower
HSR	Hamilton Street Railway
HST	Harmonized Sales Tax—the sales tax in place in Ontario. At the time of this report, the City pays a net tax rate of 1.76 percent.
HVAC	Heating Ventilation and Air Conditioning

IR Infrared

LCA Life Cycle Analysis

LEL Lower Explosive Limit (this is 5 percent gas in air by volume—thus 20 percent LEL is 1 percent gas in air by volume)

LNG Liquefied Natural Gas

m^3 Cubic meter of natural gas

NG Natural Gas

NGV Natural Gas for Vehicles or Natural Gas Vehicle (depending on context)

NPV Net Present Value is the value of the project expressed in current dollars. It is calculated by “discounting” the future cost and savings back to current dollars using the “discount rate.”

Payback or Simple Payback is based on a cash flow analysis and is the time (expressed in years in this report) required for the income (or in this case the savings compared to a diesel fleet) to exceed the capital and operating expenditures. Future costs and savings are increased using inflation factors to their value in future years but there is no cost of money or “discount rate” applied) as this is not a Net Present Value. As with all analysis herein, the analysis is based on differential costs and savings only compared to the diesel baseline.

PSI Pounds per Square Inch

PSIG Pounds per Square Inch Gauge (Atmospheric pressure is 0 psig)

RNG Renewable Natural Gas—natural gas sourced from landfills or digesters.

SCF Standard Cubic Feet (the volume of gas within one cubic foot at atmospheric pressure and 60 F)

USG US Gallon

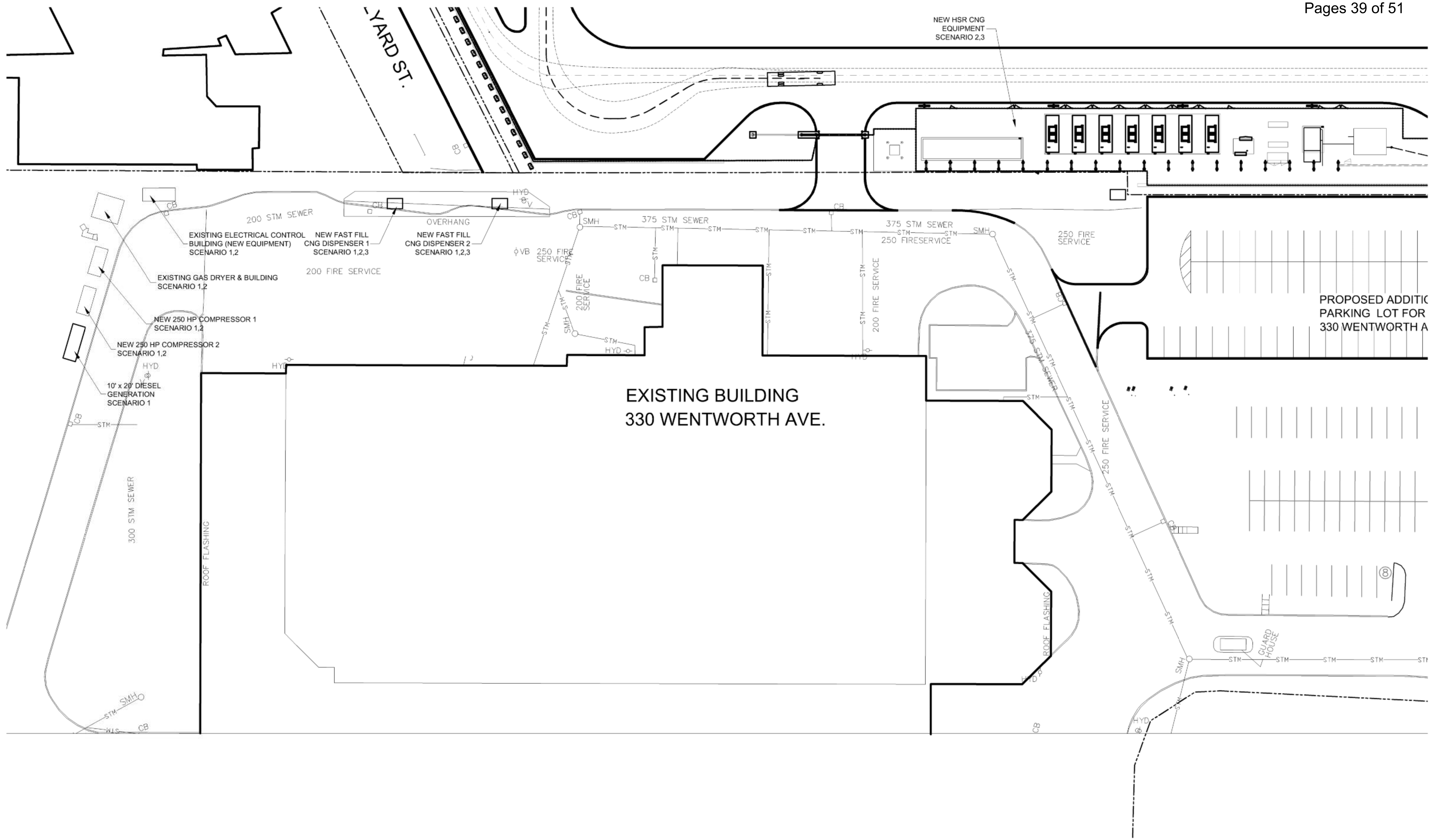
VFD Variable Frequency Drive—allows AC motors to operate at part speed.

Appendix B

Site Layout Drawings:

G-01 Hamilton Packer Truck CNG Concept Layout-330 Wentworth St., Hamilton ON

G-02 Hamilton Packer Truck CNG Concept Layout-1579 Burlington St., Hamilton ON



PROJECT ENGR./ARCH:	
DESIGNER:	Robert R. Adams
DRAWN BY:	KH
SCALE:	NTS
DATE:	12/10/2019
CHECKED BY:	
CHECKED/APPROVED BY:	

MarathonTechnical Services
6 Venus Crescent,
Heidelberg, Ontario,
N0B 2M1

REVISIONS

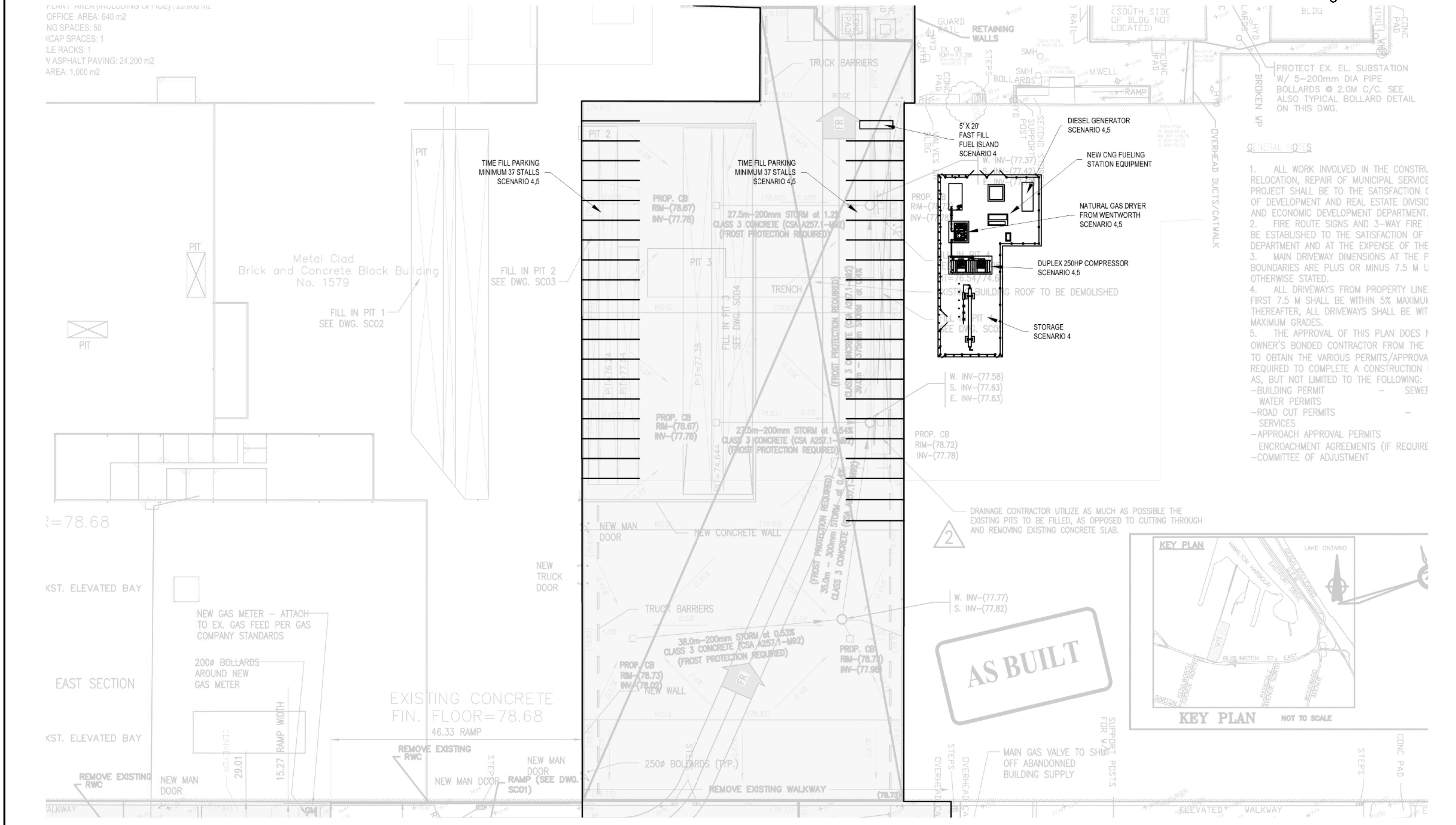
NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D

PROJECT: HAMILTON PACKER TRUCK CNG STATION CONCEPT LAYOUT

SHEET TITLE: 330 WENTWORTH ST. HAMILTON, ONT

WORK PROJECT NO.

G-01



PROJECT ENGR./ARCH:		
DESIGNER:	Robert R. Adams	
DRAWN BY:	KH	
SCALE:	NTS	
DATE:	12/10/2019	
CHECKED BY:		
CHECKED/APPROVED BY:		

MarathonTechnical Services
6 Venus Crescent,
Heidelberg, Ontario,
N0B 2M1

REVISIONS

NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D

PROJECT: HAMILTON PACKER TRUCK CNG STATION CONCEPT LAYOUT

SHEET TITLE: 1579 BURLINGTON ST. HAMILTON, ONT.

WORK PROJECT NO.

G-02

Appendix C

General Cost Inputs

Maximum Finance Term (Years):	
Term for Accounting Depreciation (Years):	21
Discount Rates:	
Standard	5.00%
Inflation Rates:	
General:	2.50%
Natural Gas:	2.50%
Power:	3.00%
Maintenance: (New Equipment)	3.00%
Diesel Fuel	3.00%
Working Days per Year:	260

Trucks:		
Classification 78		
Number of Trucks		16
2019 Replacement Cost	$	242,000
Percentage Premium for CNG		
Dollar Premium for CNG--includes 1.76% HST	$	45,792
Initial Replacement Year		2021
Lifespan (years)		7
Annual litres of Diesel Consumed per truck:		14,509
Classification 157		
Number of Trucks		10
2019 Replacement Cost	$	300,000
Percentage Premium for CNG		
Dollar Premium for CNG--includes 1.76% HST	$	45,792
Initial Replacement Year		2022
Lifespan (years)		7
Annual litres of Diesel Consumed per truck:		21,145
Classification 157A		
Number of Trucks		2
2019 Replacement Cost	$	166,000
Percentage Premium for CNG		
Dollar Premium for CNG--includes 1.76% HST	$	30,528
Initial Replacement Year		2022
Lifespan (years)		7
Annual litres of Diesel Consumed per truck:		6,305
Classification 170A		
Number of Trucks		9
2020 Replacement Cost	$	330,000
Percentage Premium for CNG		
Dollar Premium for CNG--includes 1.76%	$	45,792
Initial Replacement Year		2024
Lifespan (years)		7
Annual litres of Diesel Consumed per truck:		15,598

Gas Charges: All energy charges below are charged on a per M3 basis.		
Using HSR Data		
Total paid for natural gas 2018-2019 (all of Calendar 2018 plus first 8 months of 2019)	$	2,246,896
Total Gas Throughput (m3) 2018-2019 (all of		8,893,093
Natural Gas Commodity, Transmission and Distribution Cost $/m3	$	0.2200
CNG Station Power:		
Prime Mover (HP)		250 x 2
Ancillary Loads-Pumps, Fans, Controls (%)		10%
Flow Provided		636*2
Utility Pressure (PSIG)		80
Total kWh (all of Calendar 2018 plus first 8 months of 2019 multiplied by 19.8% as directed by Hamilton)		1,023,088
Calculated power cost/kWh--based on Hamilton provided estimated station consumption percentage at HSR	$	0.1444
Using HSR Data		
Total paid by HSR for CNG Station Electricity for 2018-2019 (all of Calendar 2018 plus first 8 months of 2019--using 19.8% of cost as directed by Hamilton)	$	147,706
Total Gas Throughput 2018-2019 (all of Calendar 2018 plus first 8 months of 2019) (m3)		8,893,093
Electricity Cost $/m3--current HSR based data for throughput and fraction of power attributable to HSR ($/m3)	$	0.0166
Electricity cost per kWh including all costs--based on HSR 2019 Data ($/kWh)	$	0.1490
Separate electricity calculation using HSR per kWh electricity cost and calculated load at new site ($/m3)	$	0.02804
CNG Station Maintenance:		
Cost Per Therm:		
Cost per m3:		
Minimum Monthly Cost:	$	5,000
Using HSR Data		
Total paid to maintain station 2018-2019 (all of Calendar 2018 plus first 8 months of 2019)	$	583,554
Total Gas Throughput 2018-2019 (all of Calendar 2018 plus first 8 months of 2019)(m3)		8,893,093
Maintenance Cost $/m3	$	0.0656

Appendix D

Station Capital Cost-all Scenarios

Station Cost Estimate--Scenario 1
Rebuild Wentworth Fast Fill

Qty	Equipment Description	Unit Cost	Extended Cost
1	CNG Dryer-use existing Wentworth Dryer		$ -
2	CNG Compressor(s) with enclosures-250 Hp/636 scfm	$ 400,000	$ 800,000
2	CNG Storage--35MCF	$ 140,000	$ 280,000
1	Storage Priority/ESD Panel	$ 75,000	$ 75,000
2	CNG High Flow/Standard Flow "Combo" Dispensers	$ 80,000	$ 160,000
0	Time Fill Panel	$ 40,000	$ -
0	Time Fill Posts	$ 5,000	$ -
1	Defueling System (with Recapture)	$ 100,000	$ 100,000
1	Air Compressor and Dryer	$ 30,000	$ 30,000
1	Miscellaneous Valves and Equipment	$ 20,000	$ 20,000
1	MCC/MSP	$ 80,000	$ 80,000
1	Master PLC Panel (MCP)	$ 60,000	$ 60,000
1	SCADA System	$ 40,000	$ 40,000
1	Fuel Management System	$ 30,000	$ 30,000
1	600V/600kW Diesel Generator and ATS	$ 300,000	$ 300,000
1	Equipment Freight	$ 30,000	$ 30,000
			$ -
	Equipment Subtotal		$ 2,005,000
	Installation Cost Factor	50%	$ 1,002,500
	Subtotal CNG Station Equipment Infrastructure Installation Cost:		$ 3,007,500
	Contingency	10.00%	$ 300,750
	Escalation (included in LCA)	0.00%	$ -
	Contractor Markup-Overhead and Profit, Bonds, General Conditions	10.00%	$ 300,750
	Design/CM Fee	15.00%	$ 451,125
	Subtotal Before Tax		$ 4,060,125
	HST	1.76%	$ 71,458
	Total Station Cost Estimate		**$ 4,131,583**

Station Cost Estimate--Scenario 2
Rebuild Wentworth Fast Fill and Tie-in to Future Adjacent HSR

Qty	Equipment Description	Unit Cost	Extended Cost
1	CNG Dryer-use existing Wentworth Dryer		$ -
2	CNG Compressor(s) with enclosures-250 Hp/636 scfm	$ 400,000	$ 800,000
1	CNG Storage--35MCF	$ 140,000	$ 140,000
1	Storage Priority/ESD Panel	$ 75,000	$ 75,000
2	CNG High Flow/Standard Flow "Combo" Dispensers	$ 80,000	$ 160,000
0	Time Fill Panel	$ 40,000	$ -
0	Time Fill Posts	$ 5,000	$ -
1	Defueling System (with Recapture)	$ 100,000	$ 100,000
1	Air Compressor and Dryer	$ 30,000	$ 30,000
1	Miscellaneous Valves and Equipment	$ 20,000	$ 20,000
1	MCC/MSP	$ 80,000	$ 80,000
1	Master PLC Panel (MCP)	$ 60,000	$ 60,000
1	SCADA System	$ 40,000	$ 40,000
1	Fuel Management System	$ 30,000	$ 30,000
0	Diesel Generator and ATS--redundancy provided by proximity and Piping Tie in to HSR	$ 300,000	$ -
1	Equipment Freight	$ 30,000	$ 30,000
			$ -
	Equipment Subtotal		$ 1,565,000
	Installation Cost Factor	50%	$ 782,500
	Subtotal CNG Station Equipment Infrastructure Installation Cost:		$ 2,347,500
	Contingency	10.00%	$ 234,750
	Escalation (included in LCA)	0.00%	$ -
	Contractor Markup-Overhead and Profit, Bonds, General Conditions	10.00%	$ 234,750
	Design/CM Fee	15.00%	$ 352,125
	Subtotal Before Tax		$ 3,169,125
	HST	1.76%	$ 55,777
	Total Station Cost Estimate		**$ 3,224,902**

Station Cost Estimate--Scenario 3
Accelerate HSR Initial Station Configuration to be Available One Year After Initial Packer Truck Arrivals--Note that HSR Station Cost have been Removed and Only Packer Truck Incremental Costs are Shown for Fastfill of Packer Trucks on Wentworth Site

Qty	Equipment Description	Unit Cost	Extended Cost
0	CNG Dryer-New HSR Dryer		$ -
0	New HSR Compressors	$ 400,000	$ -
2	CNG Storage--35MCF	$ 140,000	$ 280,000
1	Storage Priority/ESD Panel	$ 75,000	$ 75,000
2	CNG High Flow/Standard Flow "Combo" Dispensers	$ 80,000	$ 160,000
0	Time Fill Panel	$ 40,000	$ -
0	Time Fill Posts	$ 5,000	$ -
0	Defueling System (with Recapture)--use HSR	$ 100,000	$ -
0	Air Compressor and Dryer--use Compressed Ai	$ 30,000	$ -
1	Miscellaneous Valves and Equipment	$ 20,000	$ 20,000
0	MCC/MSP--Located at HSR	$ 80,000	$ -
1	Master PLC Panel (MCP)--Remote Dispenser Panel Only	$ 30,000	$ 30,000
0	SCADA System--Use HSR	$ 40,000	$ -
1	Fuel Management System	$ 30,000	$ 30,000
0	New HSR Generator	$ 300,000	$ -
1	Equipment Freight	$ 10,000	$ 10,000
			$ -
	Equipment Subtotal		$ 605,000
	Installation Cost Factor	50%	$ 302,500
	Subtotal CNG Station Equipment Infrastructure Installation Cost:		$ 907,500
	Contingency	10.00%	$ 90,750
	Escalation (included in LCA)	0.00%	$ -
	Contractor Markup-Overhead and Profit, Bonds, General Conditions	10.00%	$ 90,750
	Design/CM Fee	15.00%	$ 136,125
	Subtotal Before Tax		$ 1,225,125
	HST	1.76%	$ 21,562
	Total Station Cost Estimate		**$ 1,246,687**

Station Cost Estimate--Scenario 4
New Burlington Street Fast Fill and Time Fill

Qty	Equipment Description	Unit Cost	Extended Cost
1	CNG Dryer-relocate existing Wentworth Dryer	$ -	$ -
2	CNG Compressor(s) with enclosures-250 Hp/636 scfm	$ 400,000	$ 800,000
1	CNG Storage--35MCF	$ 140,000	$ 140,000
1	Storage Priority/ESD Panel	$ 75,000	$ 75,000
1	CNG High Flow/Standard Flow "Combo" Dispensers	$ 80,000	$ 80,000
1	Time Fill Panel	$ 40,000	$ 40,000
37	Time Fill Posts	$ 5,000	$ 185,000
1	Defueling System (with Recapture)	$ 100,000	$ 100,000
1	Air Compressor and Dryer	$ 30,000	$ 30,000
1	Miscellaneous Valves and Equipment	$ 20,000	$ 20,000
1	MCC/MSP	$ 80,000	$ 80,000
1	Master PLC Panel (MCP)	$ 60,000	$ 60,000
1	SCADA System	$ 40,000	$ 40,000
1	Fuel Management System	$ 30,000	$ 30,000
1	Diesel Generator and ATS	$ 300,000	$ 300,000
1	Equipment Freight	$ 30,000	$ 30,000
			$ -
	Equipment Subtotal		$ 2,010,000
	Installation Cost Factor	75%	$ 1,507,500
	Subtotal CNG Station Equipment Infrastructure Installation Cost:		$ 3,517,500
	Contingency	10.00%	$ 351,750
	Escalation (included in LCA)	0.00%	$ -
	Contractor Markup-Overhead and Profit, Bonds, General Conditions	10.00%	$ 351,750
	Design/CM Fee	15.00%	$ 527,625
	Subtotal Before Tax		$ 4,748,625
	HST	1.76%	$ 83,576
	Total Station Cost Estimate		**$ 4,832,201**

Station Cost Estimate--Scenario 5
New Burlington Street Time Fill Only

Qty	Equipment Description	Unit Cost	Extended Cost
1	CNG Dryer-relocate existing Wentworth Dryer	$ -	$ -
2	CNG Compressor(s) with enclosures-250 Hp/636 scfm	$ 400,000	$ 800,000
0	CNG Storage--35MCF	$ 140,000	$ -
0	Storage Priority/ESD Panel	$ 75,000	$ -
0	CNG High Flow/Standard Flow "Combo" Dispensers	$ 80,000	$ -
1	Time Fill Panel	$ 40,000	$ 40,000
37	Time Fill Posts	$ 5,000	$ 185,000
1	Defueling System (with Recapture)	$ 100,000	$ 100,000
1	Air Compressor and Dryer	$ 30,000	$ 30,000
1	Miscellaneous Valves and Equipment	$ 20,000	$ 20,000
1	MCC/MSP	$ 80,000	$ 80,000
1	Master PLC Panel (MCP)	$ 60,000	$ 60,000
1	SCADA System	$ 40,000	$ 40,000
0	Fuel Management System	$ 30,000	$ -
1	Diesel Generator and ATS	$ 300,000	$ 300,000
1	Equipment Freight	$ 30,000	$ 30,000
			$ -
	Equipment Subtotal		$ 1,685,000
	Installation Cost Factor	75%	$ 1,263,750
	Subtotal CNG Station Equipment Infrastructure Installation Cost:		$ 2,948,750
	Contingency	10.00%	$ 294,875
	Escalation (included in LCA)	0.00%	$ -
	Contractor Markup-Overhead and Profit, Bonds, General Conditions	10.00%	$ 294,875
	Design/CM Fee	15.00%	$ 442,313
	Subtotal Before Tax		$ 3,980,813
	HST	1.76%	$ 70,062
	Total Station Cost Estimate		**$ 4,050,875**

Appendix E

Truck Replacement Schedule and Differential Cost

City of Hamilton Compressed Natural Gas (CNG) Packer Truck Fueling Study Report

Calculation of Vehicle Differential Cost

	Vehicle Purchase and Retirement Schedule	NPV of Vehicle Premium	Vehicle CNG Differential Cost	Year 0 2021	Year 1 2022	Year 2 2023	Year 3 2024	Year 4 2025	Year 5 2026	Year 6 2027	Year 7 2028	Year 8 2029	Year 9 2030	Year 10 2031
	Packer Fleet													
	Classification 78--Vehicles Purchased			16	0	0	0	0	0	0	16	0	0	0
	Classification 78--Vehicles Retired			0	0	0	0	0	0	0	16	0	0	0
A	Differential Cost per Vehicle includes 1.76% HST		$ 45,792	$ 46,937	$ 48,110	$ 49,313	$ 50,546	$ 51,809	$ 53,105	$ 54,432	$ 55,793	$ 57,188	$ 58,618	$ 60,083
	Total Differential Cost			$ 750,989	$ -	$ -	$ -	$ -	$ -	$ -	$ 892,690	$ -	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0			0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	$ 1,921,348		$ 750,989	$ -	$ -	$ -	$ -	$ -	$ -	$ 634,418	$ -	$ -	$ -
	Classification 157--Vehicles Purchased			0	10	0	0	0	0	0	0	10	0	0
	Classification 157--Vehicles Retired			0	0	0	0	0	0	0	0	10	0	0
B	Differential Cost per Vehicle includes 1.76% HST		$ 45,792	$ 46,937	$ 48,110	$ 49,313	$ 50,546	$ 51,809	$ 53,105	$ 54,432	$ 55,793	$ 57,188	$ 58,618	$ 60,083
	Total Differential Cost			$ -	$ 481,102	$ -	$ -	$ -	$ -	$ -	$ -	$ 571,879	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0			0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	$ 1,172,251		$ -	$ 458,193	$ -	$ -	$ -	$ -	$ -	$ -	$ 387,070	$ -	$ -
	Classification 157A--Vehicles Purchased			0	2	0	0	0	0	0	0	2	0	0
	Classification 157A--Vehicles Retired			0	0	0	0	0	0	0	0	2	0	0
C	Differential Cost per Vehicle includes 1.76% HST		$ 30,528	$ 31,291	$ 32,073	$ 32,875	$ 33,697	$ 34,540	$ 35,403	$ 36,288	$ 37,195	$ 38,125	$ 39,078	$ 40,055
	Total Differential Cost			$ -	$ 64,147	$ -	$ -	$ -	$ -	$ -	$ -	$ 76,251	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0			0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	$ 156,300		$ -	$ 61,092	$ -	$ -	$ -	$ -	$ -	$ -	$ 51,609	$ -	$ -
	Classification 170A--Vehicles Purchased			0	0	0	9	0	0	0	0	0	0	9
	Classification 170A--Vehicles Retired			0	0	0	0	0	0	0	0	0	0	9
D	Differential Cost per Vehicle includes 1.76% HST		$ 45,792	$ 46,937	$ 48,110	$ 49,313	$ 50,546	$ 51,809	$ 53,105	$ 54,432	$ 55,793	$ 57,188	$ 58,618	$ 60,083
	Total Differential Cost			$ -	$ -	$ -	$ 454,912	$ -	$ -	$ -	$ -	$ -	$ -	$ 540,748
	Cost Differential Recapture on Retirement--assumed $0			0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	$ 1,005,385		$ -	$ -	$ -	$ 392,970	$ -	$ -	$ -	$ -	$ -	$ -	$ 331,972
	Packer Fleet Total Vehicle Differential Cost			**$ 750,989**	**$ 545,249**	**$ -**	**$ 454,912**	**$ -**	**$ -**	**$ -**	**$ 892,690**	**$ 648,130**	**$ -**	**$ 540,748**
	NPV Packer Fleet Total Vehicle Differential Cost			**$ 750,989**	**$ 519,285**	**$ -**	**$ 392,970**	**$ -**	**$ -**	**$ -**	**$ 634,418**	**$ 438,680**	**$ -**	**$ 331,972**
	NPV of Vehicle Cost Differential:	**$ 4,255,284**												

	Vehicle Purchase and Retirement Schedule	Year 11 2032	Year 12 2033	Year 13 2034	Year 14 2035	Year 15 2036	Year 16 2037	Year 17 2038	Year 18 2039	Year 19 2040	Year 20 2041
	Packer Fleet										
	Classification 78--Vehicles Purchased	0	0	0	16	0	0	0	0	0	0
	Classification 78--Vehicles Retired	0	0	0	16	0	0	0	0	0	0
A	Differential Cost per Vehicle includes 1.76% HST	$ 61,585	$ 63,125	$ 64,703	$ 66,320	$ 67,978	$ 69,678	$ 71,420	$ 73,205	$ 75,036	$ 76,911
	Total Differential Cost	$ -	$ -	$ -	$ 1,061,128	$ -	$ -	$ -	$ -	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	$ -	$ -	$ -	$ 535,942	$ -	$ -	$ -	$ -	$ -	$ -
	Classification 157--Vehicles Purchased	0	0	0	0	10	0	0	0	0	0
	Classification 157--Vehicles Retired	0	0	0	0	10	0	0	0	0	0
B	Differential Cost per Vehicle includes 1.76% HST	$ 61,585	$ 63,125	$ 64,703	$ 66,320	$ 67,978	$ 69,678	$ 71,420	$ 73,205	$ 75,036	$ 76,911
	Total Differential Cost	$ -	$ -	$ -	$ -	$ 679,785	$ -	$ -	$ -	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	$ -	$ -	$ -	$ -	$ 326,988	$ -	$ -	$ -	$ -	$ -
	Classification 157A--Vehicles Purchased	0	0	0	0	2	0	0	0	0	0
	Classification 157A--Vehicles Retired	0	0	0	0	2	0	0	0	0	0
C	Differential Cost per Vehicle includes 1.76% HST	$ 41,057	$ 42,083	$ 43,135	$ 44,214	$ 45,319	$ 46,452	$ 47,613	$ 48,804	$ 50,024	$ 51,274
	Total Differential Cost	$ -	$ -	$ -	$ -	$ 90,638	$ -	$ -	$ -	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	$ -	$ -	$ -	$ -	$ 43,598	$ -	$ -	$ -	$ -	$ -
	Classification 170A--Vehicles Purchased	0	0	0	0	0	0	9	0	0	0
	Classification 170A--Vehicles Retired	0	0	0	0	0	0	9	0	0	0
D	Differential Cost per Vehicle includes 1.76% HST	$ 61,585	$ 63,125	$ 64,703	$ 66,320	$ 67,978	$ 69,678	$ 71,420	$ 73,205	$ 75,036	$ 76,911
	Total Differential Cost	$ -	$ -	$ -	$ -	$ -	$ -	$ 642,779	$ -	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	$ -	$ -	$ -	$ -	$ -	$ -	$ 280,442	$ -	$ -	$ -
	Packer Fleet Total Vehicle Differential Cost	**$ -**	**$ -**	**$ -**	**$ 1,061,128**	**$ 770,423**	**$ -**	**$ 642,779**	**$ -**	**$ -**	**$ -**
	NPV Packer Fleet Total Vehicle Differential Cost	**$ -**	**$ -**	**$ -**	**$ 535,942**	**$ 370,587**	**$ -**	**$ 280,442**	**$ -**	**$ -**	**$ -**

Appendix F

Diesel, CNG and RNG Consumption and GHG Emissions

Calculation of Total Fuel Used Per Year-Diesel and CNG and Associated CO_2e Reduction

	Diesel/ CNG Efficiency	Fuel Consumption per Day per Truck (Litres of Diesel)	Fuel Consumption per Year per Truck (Litres of Diesel)		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
					2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Packer Fleet--CNG Trucks in Fleet																									
Classification 78--Vehicles in Fleet					16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Classification 157--Vehicles in Fleet					0	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Classification 157A--Vehicles in Fleet					0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Classification 170A--Vehicles in Fleet					0	0	0	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Total CNG Trucks					**16**	**28**	**28**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**
Packer Fleet--Diesel Displaced by CNG (litres)																									
Classification 78		55.80	14,509		232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137
Classification 157		81.33	21,145		-	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450
Classification 157A		24.25	6,305		-	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610
Classification 170A		59.99	15,598		-	-	-	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382
Total Diesel Displaced by CNG Trucks (litres):					**232,137**	**456,197**	**456,197**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**	**596,579**
Packer Fleet--CNG Consumed (m^3)																									
Classification 78--300 Series					271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725
Classification 157					-	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511
Classification 157A					-	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761
Classification 170A					-	-	-	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323
Total CNG Consumed (m^3):	**0.88**				**271,725**	**533,997**	**533,997**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**	**698,319**
Packer Fleet--GHG---CO_2e Carbon Accounting	**Emission Factors**	**Total GHG Emission Savings**																							
Diesel																									
Emission Factor--CO_2 Emissions per Unit (gCO_2e/l) (Table A6-11 NIR Chapter 2)	2690																								
CO_2e for Diesel Displaced--tonnes CO_2e					624.4	1,227.2	1,227.2	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8
CNG																									
Emission Factor--CO2 Emissions per Unit (gCO2e/l) (Table A6-11 NIR Chapter 2)	1.9																								
Emission Factor--CO2 Emissions per Unit (gCO2e/m3)--converted	1900																								
CO_2e for CNG Consumed--Tonnes CO2e					516.3	1,014.6	1,014.6	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8	1,326.8
Net CO_2e Reduction for CNG					108.2	212.6	212.6	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0	278.0
Lifecycle Total for CNG (tonnes CO_2e):		**5,537.1**																							
Percent Reduction From Diesel		**17.3%**																							
RNG																									
Emission Factor--CO_2 Emissions per Unit ($kgCO_2e/m^3$) (BC Government)	0.011																								
CO_2e for CNG Consumed--tonnes CO2e					0.002989	0.005874	0.005874	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682	0.007682
Net CO_2e Reduction for RNG					624.4	1,227.2	1,227.2	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8	1,604.8
Lifecycle Total for RNG (tonnes CO_2e):		**31,965.0**																							
Percent Reduction From Diesel		**100.0%**																							

Appendix G

Diesel and CNG Consumption and Electricity Calculations

City of Hamilton Compressed Natural Gas (CNG) Packer Truck Fueling Study Report

Calculation of Total Fuel Used Per Year

	Vehicle Purchase and Retirement Schedule	Diesel/ CNG Efficiency	Fuel Consumption per Day per Truck (Litres of Diesel)	Fuel Consumption per Year per Truck (Litres of Diesel)	Spare Ratio	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	
						2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	
	Packer Fleet																										
	Classification 78--Vehicles Purchased					16							16							16							
	Classification 78--Vehicles Retired												16							16							
	Fleet Size--Number of Vehicles of this Type					16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	
	Spare Ratio not applied as Annual Totals are Used					16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	
A	Number of Diesel Litres Consumed Each Year for Vehicle Type			14,509		232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	232,137	
	Number of Diesel Litres Consumed Each Day for Vehicle Type (assumes 260 equal consumption days per year)		55.80			893	893	893	893	893	893	893	893	893	893	893	893	893	893	893	893	893	893	893	893	893	
	Total m3 of CNG per Year for Vehicle Type	0.88				271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	271,725	
	Classification 157--Vehicles Purchased						10							10							10						
	Classification 157-Vehicles Retired													10							10						
	Fleet Size--Number of Vehicles of this Type					0	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	
	Spare Ratio not applied as Annual Totals are Used					**0**	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	
B	Number of Diesel Litres Consumed Each Year for Vehicle Type			21,145		-	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	211,450	
	Number of Diesel Litres Consumed Each Day for Vehicle Type (assumes 260 equal consumption days per year)		81.33			-	813	813	813	813	813	813	813	813	813	813	813	813	813	813	813	813	813	813	813	813	
	Total m3 of CNG per Year for Vehicle Type	0.88				-	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	247,511	
	Classification 157A--Vehicles Purchased						2							2							2						
	Classification 157A--Vehicles Retired													2							2						
	Fleet Size--Number of Vehicles of this Type					0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	Spare Ratio not applied as Annual Totals are Used					**0**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
B	Number of Diesel Litres Consumed Each Year for Vehicle Type			6,305		-	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	12,610	
	Number of Diesel Litres Consumed Each Day for Vehicle Type (assumes 260 equal consumption days per year)		24.25			-	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	
	Total m3 of CNG per Year for Vehicle Type	0.88				-	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	14,761	
	Classification 170A--Vehicles Purchased								9							9							9				
	Classification 170A--Vehicles Retired															9							9				
	Fleet Size--Number of Vehicles of this Type					0	0	0	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	
	Spare Ratio not applied as Annual Totals are Used					**0**	0	0	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	
C	Number of Diesel Litres Consumed Each Year for Vehicle Type			15,598		-	-	-	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	140,382	
	Number of Diesel Litres Consumed Each Day for Vehicle Type (assumes 260 equal consumption days per year)		59.99			-	-	-	540	540	540	540	540	540	540	540	540	540	540	540	540	540	540	540	540	540	
	Total m3 of CNG per Year for Vehicle Type	0.88				-	-	-	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	164,323	
																											Life Cycle
	Packer Fleet Total Annual Fuel Consumption (m3)					271,725	533,997	533,997	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	698,319	13,637,742
																											-
	Minimum Firm Compression Required in SCFM based on a daily compression time of :				8 Hours	76	150	150	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	
	Minimum Firm Compression Required in SCFM based on a daily compression time of :				3 Hours	203	399	399	522	522	522	522	522	522	522	522	522	522	522	522	522	522	522	522	522	522	
	Electicity/Power Calculation																										
	Flow per 250 hp Compressor (scfm) (m3/Hr)	636	1090																								
	Calculation of Hours of Compressor Operation per year					249	490	490	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	
	Total Hp per Compressor (250 Hp Compressor) plus 10 percent for fans and control loads times .8 for average operating load	250	275	220																							
	Calculation of kWh per hour			205																							
	Calculation of kWh per year					51,128	100,478	100,478	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	131,397	
	Rate per kwh (from HSR total power cost data)		$0.1490			7,618																					
	Energy cost per m3 for Year 0 ($/m3)					**0.02804**																					

City of Hamilton Compressed Natural Gas (CNG) Packer Truck Fueling

Supplemental Study

Submitted To:

Tom Kagianis

Superintendent Capital Planning
& Contract Management
Tel: (905) 546-2424 ext. 5105
Email: Tom.Kagianis@hamilton.ca

Energy, Fleet & Facilities
Public Works
330 Wentworth Street, L8L 5W2

FINAL REPORT

2021 03 19

Submitted By:

Rob Adams

P.Eng, CPA, CMA, PMP, CMC, MBA

radams@marathontech.ca

Marathon Technical Services

Six Venus Crescent,
Heidelberg, ON
N0B 2M1

p 519.699.8250
f 519.699.9255
radams@marathontech.ca

marathon

Executive Summary:

The City of Hamilton, Energy, Fleet & Facilities Public Works department (the City) contracted with Marathon Technical Services (Marathon or MTS), to study the technical and financial viability of fueling 16 of the fleet of 37 packer (refuse collection) trucks with CNG over a 7-year project life.

This analysis focused on a non-conventional infrastructure procurement approach—"Fuel as a Service". This "Fuel as a Service" contracting method is well suited to this project and allows the City to complete a small scale, shorter term project that was studied in Marathon's 2020 report.

This approach reduces or eliminates capital expenditure by the City and allows a shorter term, lower risk project that is geared to the 7-year life of the initial truck order. Ownership of the equipment is retained by the contractor and equipment is removed at their expense at the conclusion of the contract. This approach allows the City to quickly and inexpensively adopt lower carbon CNG truck technology that is available today, while preserving the option of electric trucks in the future when these become more technically and cost competitive.

A total of three companies and four approaches were evaluated. In every case, fueling will be performed as "time fill" with no "fast fill" provided. All fueling will take place at the Burlington Street truck facility. The solutions proposed by the companies consulted, have additional capacity that would allow the City to extend and expand the project at nominal cost. All four options are technically feasible.

Net Present Value (NPV) was used as quantitative evaluation metric. None of the four options returned a positive net present value although these solutions have excess capacity and equipment life (other than Company C) that would allow the City to purchase additional CNG trucks and extend the contract resulting in a much better project economic return. NPV as studied, ranged from -$293,440 to -$2,693,534 indicating that the CNG project costs are not fully offset by diesel cost savings.

The average lead time from award of contract to a fully permitted and operational station was 12-months with no solution approach providing any notable lead time advantage.

It is estimated that this project will create a savings of 757 tonnes CO_2e over the lifecycle of the project --projecting a "green" image for the City. This represents a 17.3 percent reduction from the diesel fleet and based on US EPA data. This total project savings is lower than the 2020 study due to the shorter project length and reduction in truck count.

Table of Contents:

Introduction:

The City of Hamilton (the City, or Hamilton) is evaluating the possible transition of a portion of its diesel-powered packer truck refuse collection fleet to Compressed Natural Gas (CNG). The City has over three decades of successful CNG heavy fleet experience at the Hamilton Street Railway (HSR).

CNG is a fuel that is capital intensive but low cost to operate and provides toxic gas and greenhouse gas (GHG) emissions reduction when compared with diesel. It is also the most proven alternative fuel in heavy vehicle applications. This supplemental study follows a study in 2020 that evaluated the possibility of changing the entire City fleet of garbage trucks to CNG. The scaled down approach in this supplemental study is shortened to a 7-year project term, matching a single purchase of 16 trucks. This smaller, shorter term project allows the City to implement CNG trucks into its fleet now and retain the option to transition to electric trucks when those become more economically and technically viable.

Marathon has been contracted to perform the following scope:

1. Assume a single purchase of 16 trucks that require fueling over a 7-year period.

2. Assume that fueling will take place at the existing City truck facility on Burlington Street. A concept level plan that was prepared for the 2020 study has been included in this supplemental study for reference in Appendix B. Note that the scale of equipment is likely to change from this drawing to match this de-scoped study.

3. Review of four fueling alternatives provided by three well experienced industry contractors using a “Fuel as a Service” contracting approach. This approach is based on the contractor assuming:
    a. All of the equipment and installation capital costs.
    b. All of the operation and maintenance costs.
    c. All repair costs.
    d. All station licensing and permitting costs.
    e. All trucking of gas to site for the trailer option.
    f. In one case the commodity and utility gas cost.
    g. See Appendix C for a description of the request for information forwarded to the station vendors.

4. For the options above, Marathon used assumptions consistent with the 2020 analysis to allow some level of comparison between reports.

5. Marathon has updated the Operating Engineer requirements and the impact of changes.

6. Project life cycle cost analysis for the initial and subsequent purchase and integration of CNG packer trucks into the collection fleet. The initial and sole purchase will be for approximately 16 rear loader trucks to go into service in 2021. This analysis will identify the net present value (NPV) of the CNG program and will also identify the expected environmental and other benefits. Marathon will make recommendations related to the implementation of this program.

7. It is understood that City trucks are maintained off site by service providers and thus no garage upgrades related to CNG are required or anticipated at this time and no consulting associated with upgrades is included in this scope.

Analysis Assumptions and Data Sources:

The life cycle cost analysis uses data from a variety of sources and covers a wide range of data to address all readily quantifiable cost elements to provide a comprehensive and conservative analysis. The list below summarizes the cost elements and data sources that were determined or assumed in this study:

1. The lifecycle analysis is based on a 7-year life cycle with year 0 being 2021. This 7-year life cycle was selected as it corresponds to one full 7-year truck life cycle for the truck procurement.

2. Discount rate: 5% (Marathon standard, confirmed with the City of Hamilton). See Glossary in Appendix A for definition of discount rate.

3. Inflation: 2.5 percent to 3.0 percent (dependent on item) (Marathon standard, confirmed with the City of Hamilton). See Tables 3 to 6 for individual rates used.

4. HST was applied at a net rate of 1.76 percent on the cost of CNG contractor services and on the upcharge/differential cost for the CNG trucks over the diesel truck cost. As discussed with the City, it is understood that diesel fuel, electricity, natural gas, CNG station maintenance costs and truck operating and maintenance costs already include HST embedded in the costs provided by the City.

5. The station concepts proposed do not include a standby power (generator), thus in the event of a protracted power outage, it will be necessary to deadhead trucks to another site-most likely to HSR.

6. Two of the three companies responded with a concept that includes an on-site redundant compressor. The other respondent proposes a trailer mounted compressor which can be changed out in the event of a compressor failure. If a spare compressor is not available in a timely manner, it will be necessary to deadhead trucks to another site-most likely to HSR. Note that performance penalties can be built into the service contract to fund such an occurrence.

7. Truck capital cost differential compared to clean diesel was $45,000 plus HST (ie the CNG trucks are more expensive than the diesel trucks) for all full sized CNG packer trucks (as provided by the City).

8. Truck maintenance cost differential—no differential truck maintenance cost compared with clean diesel was assumed. Although CNG and diesel trucks have both been widely used in this application for a number of years, there is still a variety of opinions as to which fuel has lower truck maintenance costs including the prevailing opinion that there is no difference. HSR indicated that their current experience is there is no difference in

maintenance costs between these fuels for their fleet of heavy buses—this is the assumption used in this report.

9. Future CNG vehicle fuel consumption is equal to diesel since it was assumed that there is no increase or decrease in routes or total distance except as studied in the sensitivity analysis. This is a conservative assumption since if additional trucks are required to meet a growing population (significant population growth is likely over a 7-year period).

10. Current diesel prices were supplied by the City and based on 2018/2019 average diesel fuel cost per litre then inflated at 3.0 percent per annum.

11. Engine efficiency—CNG engines are assumed to be 88 percent of diesel engine efficiency (Cummins). CNG engines are spark ignition with lower compression ratio than diesel and thus diesel engines have a higher thermal efficiency than CNG, although this advantage is narrowing making this a conservative assumption.

12. Gas utility commodity and gas distribution charges were based on 2018/2019 HSR CNG station charges as provided by the City. These were inflated at 2.5 percent per annum. Enbridge has confirmed that ample natural gas supply is available at the Burlington Street site at a delivery pressure of 80 psig.

13. No gas utility service cost has been included as it has been assumed that the station load will pay the utility for this new gas service.

14. Electricity charges were based on 2018/2019 HSR CNG station charges as provided by the City. Electricity costs were initially calculated based on the total load that the City attributes to the HSR CNG station.

15. GHG calculations are based on motor fuel data for the Canadian National Inventory Report (NIR) Table A6-12.

16. Trucks will continue to be serviced off site by third party maintenance shops, therefore no Hamilton shop upgrades for CNG are required or included.

17. No government grants or other incentives or subsidies are currently available or included in the cost estimates.

Approach/Methodology:

A 7-year life cycle cost analysis was built by Marathon Technical Services using inputs from a variety of sources (as previously outlined). Seven years was selected as it represents one truck life cycle for the sole group of 16 packer trucks. It is assumed that if the City intends to continue with CNG after the seven-year period which may include having more than 16 trucks, it will renegotiate the contract with the contractor—this should lower the unit cost of fuel. If the City decides to transition away from CNG at the end of the seven years, the CNG station will be decommissioned and removed by the contractor.

The focus of this analysis was to identify and quantify those items that are differential costs for CNG compared to clean diesel—it should be stressed that there may be additional costs that are not identified in the analysis because they apply to both CNG and Diesel. These additional costs might include the base cost of a diesel truck (only the differential is used herein), end of life truck salvage value, packer truck maintenance costs (as previously noted), truck licensing costs, and truck driver costs as examples.

A total of three CNG station scenarios were conceived. Each scenario was then evaluated in the customized spreadsheet to determine the NPV over the seven years. Unlike the 2020 analysis, a payback year was not calculated since the payments are spread over the seven-year period with little to no upfront costs to pay back. Cash flow information is provided in the spreadsheets by cost category.

See Appendix B for concept level station layout drawing from the 2020 analysis. The layout for the concepts in this report will be similar to this layout but with fewer time fill locations and less compression equipment.

The Fuel as a Service contracting approach has the following features:

1. Little to no upfront cost.
2. No cost at end of contract.
3. No asset ownership.
4. Most costs including cost of capital are embedded in annual and/or throughput related charges. While this is beneficial to the City, the contractor will need to cover these costs so the City will be required to enter into a take-or-pay contract.

A brief description of the Fuel as a Service concept equipment and cost structure follows on Table 1 and 2 respectively.

Figure 1 provides photographs of equipment similar to Company A concept. Figure 2 provides photographs of equipment similar to Companies B and C concepts.

Table 1-List of Equipment for Fuel as a Service

		Company A	Company B	Company C
Fuel Station Concept:		Trailer mounted compressor and storage (gas from HSR) gas dispensed to time fill manifold. No Fast Fill.	Conventional compressor station (gas from utility line) gas dispensed to time fill manifold. No Fast Fill.	Conventional compressor station (gas from utility line) gas dispensed to time fill manifold. No Fast Fill.
Dryer:		None required as gas is already dry from HSR station.	Single Tower--PSB 10-3 DDP	Single Tower
Compressor(s):		One--trailer mounted hydraulic compressor. 1x75Hp	One duplex (two compressors in total) stationary compressor package. 2x100Hp	Three simplex (three compressors in total) stationary compressor package. 3x50Hp
	Redundancy:	Exchanging compressor trailers if compressor fault cannot be rectified. Willing to accept a penalty for not fueling.	Second compressor to automatically start upon compressor fault.	Third compressor to automatically start upon compressor fault.
	Equipment Age:	<5 years	New--conservative case	~30 years old
Storage:		Trailer Mounted	One 23' 5500psig tube with 345m^3 capacity	Not required for time fill with compression from utility line.
Time Fill Posts Included:		16	16	16
Electric Generator:		None--fueling will not occur with power outage.	None--fueling will not occur with power outage.	None--fueling will not occur with power outage.

Table 2-List of Cost Structure for Fuel as a Service Contractors

		Company A	Company B	Company C
Assumed station annual throughput (m^3)		271,429	271,429	271,429
All In Fixed Cost:	Annual Cost: (based on a throughput charge of $0.729/$m^3$)	None required as gas is already dry from HSR station.		$ 198,000
All In per m^3 Cost:	Year 1 to 3	$ 0.40		
	Year 4 to 5	$ 0.42		
	Year 6 to 7	$ 0.45		
Fixed plus Throughput Cost:	Annual Cost:		$ 444,000	
	Per m^3 Cost:		$ 0.270	
Annual Cost Escalation (percent):		As noted in throughput cost schedule.	Canadian CPI	0%
Length of contract (years):		7	7	7
Initial Capital costs to City:		$ -	$ -	$ -
End of Term Costs to City:		$ -	$ -	$ -
Year 1 costs for Contractor Services:		$ 108,572	$ 517,286	$ 197,872
Costs Included:				
All equipment costs for equipment in Equipment list.		Yes	Yes	Yes
All installation costs for station equipment and time fill except as excluded below.		Yes	Yes	Yes
All Equipment O&M		Yes	Yes	Yes
All Equipment Repairs		Yes	Yes	Yes
All costs to load fuel at HSR and truck to Burlington Street		Yes	N/A	N/A
Cost Exclusions:		Gas service not required	Cost of Gas Service	Cost of Gas Service
		Natural Gas Cost	Natural Gas Cost	Natural Gas Cost
		Cost of Electricity--this is added to Marathon Total Fuel Cost Estimate	Cost of Electricity--this is added to Marathon Total Fuel Cost Estimate	Cost of Electricity--this is added to Marathon Total Fuel Cost Estimate
		Site lighting, bollards and curbstones--other minor installation costs. A $100,000 contingency has been added to address this.	Site lighting, bollards and curbstones--other minor installation costs. A $100,000 contingency has been added to address this.	Site lighting, bollards and curbstones--other minor installation costs. A $100,000 contingency has been added to address this.
				Electrical Upgrade (this has been added by Marathon)

Figure 1—Trailer mounted CNG Station (left) and time fill barricade (below).

Figure 2—Conventional CNG Station with CNG dryer (blue), two compressors for redundancy (silver enclosures), one storage tube (white tube with panel) (left).

Findings- Benefits of Time fill at the Burlington Street Location (abbreviated from the 2020 report):

Time fill in this location has several benefits:

1. Time fill of trucks takes place over a period of many hours. This additional fill time allows the heat generated during fueling to partially dissipate while fueling progresses and thus results in cooler, denser gas in truck tanks after fueling—this translates into a more complete fill and improved range.

2. Given that packer trucks are typically parked for 12 to 16 hours, time fill is well adapted to packer truck operations.

3. Time fill can significantly reduce the number of compressor starts and stops which leads to reduced wear and tear on station equipment. Time fill equipment is also simpler than fast fill dispensing equipment and thus is less prone to breakdown.

4. With much more time available for time filling, a (much) smaller compressor can be used than is used for fast fill.

5. The elimination of the need to drive trucks to another location for the sole purpose of fueling reduces unnecessary truck operating costs.

6. It is anticipated that there will be a reduction of personnel time required related to the use of time fill rather than fast fill fueling. This has not been included in the cost summary since a rework and extension of existing routes would be required to realize this time/labour reduction.

7. Fueling at Burlington Street consolidates the trucks to the location of dispatch, simplifying operations.

Findings-Quantitative

The primary means of quantitative evaluation for the project is the Net Present Value (NPV) of the costs and savings compared to Diesel trucks and operation (savings are calculated based on the cost of diesel that is displaced).

Costs are broken down as contractor costs, non-contractor City costs (such as power and gas), and the upcharge on the trucks have been used to offset the diesel expenditure that is displaced through the use of CNG.

Tables 3 through 6 on the next four pages provide the cost breakdown and totals as well as GHG emission savings.

Table 3--Company A--Trailer Concept using HSR Fuel				Year						
	NPV Calculations			0	1	2	3	4	5	6
Company A-using HSR Fuel	Contractor Costs	Assumed station annual throughput (m^3)		271,429	271,429	271,429	271,429	271,429	271,429	271,429
		All In per m^3 Contractor Cost:		$ 0.400	$ 0.400	$ 0.400	$ 0.420	$ 0.420	$ 0.450	$ 0.450
		Contingency for Lighting, Bollards, other minor site work.		$ 100,000						
		Total Annual Contractor Cost:		$ 208,572	$ 108,572	$ 108,572	$ 114,000	$ 114,000	$ 122,143	$ 122,143
		Discount Rate:	5.00%	$ 208,572	$ 103,402	$ 98,478	$ 98,478	$ 93,788	$ 95,702	$ 91,145
		NPV--Contractor Cost with net HST at 1.76% added:	**$ 803,460**							
	City Fuel Costs not Including Contractor Costs	Gas Commodity & Utility Cost based on HSR Data: (per m3)	2.50%	$ 0.231	$ 0.237	$ 0.243	$ 0.249	$ 0.255	$ 0.262	$ 0.268
		HSR Compression Electricity and Station Maintenance Costs:	3.00%	$ 0.099	$ 0.102	$ 0.105	$ 0.109	$ 0.112	$ 0.115	$ 0.119
		On-site Electrical Compression Costs based on HSR (per m3)	3.00%	$ 0.030	$ 0.031	$ 0.032	$ 0.033	$ 0.033	$ 0.034	$ 0.036
		Total City Costs Related to Fuel and not Covered in Contractor Costs:		$ 97,779	$ 100,399	$ 103,090	$ 105,853	$ 108,690	$ 111,605	$ 114,598
		Total City Costs Related to Fuel and not Covered in Contractor Costs discounted for Time:	5.00%	$ 97,779	$ 95,618	$ 93,505	$ 91,440	$ 89,420	$ 87,445	$ 85,515
		NPV--City Cost:	**$ 640,723**							
	Contractor Plus City Fuel Costs	Total Annual Fuel Cost including Contractor and City Costs:		$ 306,351	$ 208,971	$ 211,661	$ 219,853	$ 222,691	$ 233,748	$ 236,741
		Total Annual Fuel Cost including Contractor and City Costs Discounted for Time:	5.00%	$ 306,351	$ 199,020	$ 191,983	$ 189,917	$ 183,208	$ 183,148	$ 176,660
		NPV--Contractor+City Cost:	**$ 1,430,287**							
		Cost per Diesel Litre Equivalent (DLE):		$ 1.16	$ 0.79	$ 0.80	$ 0.83	$ 0.85	$ 0.89	$ 0.90
	Displaced Diesel Costs	Diesel+DEF Annual Cost (Total $)		$ 271,492	$ 279,637	$ 288,026	$ 296,667	$ 305,567	$ 314,734	$ 324,176
		Diesel+DEF Annual Cost (Total $) Discounted for Time	5.00%	$ 271,492	$ 266,321	$ 261,248	$ 256,272	$ 251,391	$ 246,602	$ 241,905
		NPV--Diesel+DEF Annual Cost (Total $)	**$ 1,795,233**							
	Truck Capital Cost Premium	**Differential Cost Premium for CNG vs Diesel Trucks**	**$ 750,989**							
	Net Project NPV	**Net Project NPV (-ve favours Diesel, +ve favours CNG)**	**$ (386,043)**							
	Carbon Reduction-Tonnes CO2	**757.2**		108.2	108.2	108.2	108.2	108.2	108.2	108.2

Table 4--Company A--Trailer Concept using Contractor Fuel				Year						
	NPV Calculations			0	1	2	3	4	5	6
Company A- using ComTech Fuel	**Contractor Costs**	Assumed station annual throughput (m^3)		271,429	271,429	271,429	271,429	271,429	271,429	271,429
		All In per m^3 Contractor Cost including Gas:		$ 0.700	$ 0.700	$ 0.700	$ 0.720	$ 0.720	$ 0.750	$ 0.750
		Contingency for Lighting, Bollards, other minor site work.		$ 100,000						
		Total Annual Contractor Cost:		$ 290,000	$ 190,000	$ 190,000	$ 195,429	$ 195,429	$ 203,572	$ 203,572
		Discount Rate:	5.00%	$ 290,000	$ 180,953	$ 172,336	$ 168,819	$ 160,780	$ 159,504	$ 151,908
		NPV--Contractor Cost with net HST at 1.76% added:	**$ 1,306,903**							
	City Fuel Costs not Including Contractor Costs	Gas Commodity & Utility Cost based on HSR Data: (per m3)	N/A							
		HSR Compression Electricity and Station Maintenance Costs:	N/A							
		On-site Electrical Compression Costs based on HSR (per m3)	3.00%	$ 0.030	$ 0.031	$ 0.032	$ 0.033	$ 0.033	$ 0.034	$ 0.036
		Total City Costs Related to Fuel and not Covered in Contractor Costs:		$ 8,073	$ 8,315	$ 8,565	$ 8,822	$ 9,087	$ 9,359	$ 9,640
		Total City Costs Related to Fuel and not Covered in Contractor Costs discounted for Time:	5.00%	$ 8,073	$ 7,919	$ 7,769	$ 7,621	$ 7,475	$ 7,333	$ 7,193
		NPV--City Cost:	**$ 53,384**							
	Contractor Plus City Fuel Costs	Total Annual Fuel Cost including Contractor and City Costs:		$ 298,074	$ 198,316	$ 198,565	$ 204,251	$ 204,515	$ 212,931	$ 213,212
		Total Annual Fuel Cost including Contractor and City Costs Discounted for Time:	5.00%	$ 298,074	$ 188,872	$ 180,104	$ 176,439	$ 168,255	$ 166,837	$ 159,102
		NPV--Contractor+City Cost:	**$ 1,337,684**							
		Cost per Diesel Litre Equivalent (DLE):		$ 1.13	$ 0.75	$ 0.75	$ 0.78	$ 0.78	$ 0.81	$ 0.81
	Displaced Diesel Costs	Diesel+DEF Annual Cost (Total $)		$ 271,492	$ 279,637	$ 288,026	$ 296,667	$ 305,567	$ 314,734	$ 324,176
		Diesel+DEF Annual Cost (Total $) Discounted for Time	5.00%	$ 271,492	$ 266,321	$ 261,248	$ 256,272	$ 251,391	$ 246,602	$ 241,905
		NPV--Diesel+DEF Annual Cost (Total $)	**$ 1,795,233**							
	Truck Capital Cost Premium	**Differential Cost Premium for CNG vs Diesel Trucks**	**$ 750,989**							
	Net Project NPV	**Net Project NPV (-ve favours Diesel, +ve favours CNG)**	**$ (293,440)**							
	Carbon Reduction-Tonnes CO2		**757.2**	108.2	108.2	108.2	108.2	108.2	108.2	108.2

Table 5--Company B--Conventional CNG Station Concept				**Year**						
	NPV Calculations			**0**	**1**	**2**	**3**	**4**	**5**	**6**
Company B	**Contractor Costs**	Assumed station annual throughput (m^3)		271,429	271,429	271,429	271,429	271,429	271,429	271,429
		Annual Contractor Cost (Capital Recovery):		$ 444,000	$ 444,000	$ 444,000	$ 444,000	$ 444,000	$ 444,000	$ 444,000
		Per m^3 Contractor O&M Cost:		$ 0.270						
		Annual Cost Escalation (percent):	2.50%	$ 0.27	$ 0.28	$ 0.28	$ 0.29	$ 0.30	$ 0.31	$ 0.31
		Contingency for Lighting, Bollards, other minor site work.		$ 100,000						
		Total Annual Contractor Cost:		$ 617,286	$ 519,118	$ 520,996	$ 522,921	$ 524,894	$ 526,916	$ 528,989
		Discount Rate:	5.00%	$ 617,286	$ 494,398	$ 472,559	$ 451,719	$ 431,831	$ 412,853	$ 394,740
		NPV--Contractor Cost with net HST at 1.76% added:	**$ 3,333,032**							
	City Fuel Costs not Including Contractor Costs	Gas Commodity & Utility Cost based on HSR Data: (per m3)	2.50%	$ 0.231	$ 0.237	$ 0.243	$ 0.249	$ 0.255	$ 0.262	$ 0.268
		On-site Electrical Compression Costs based on HSR (per m3)	3.00%	$ 0.030	$ 0.031	$ 0.032	$ 0.033	$ 0.033	$ 0.034	$ 0.036
		Total City Costs Related to Fuel and not Covered in Contractor Costs:		$ 70,811	$ 72,621	$ 74,478	$ 76,383	$ 78,337	$ 80,341	$ 82,396
		Total City Costs Related to Fuel and not Covered in Contractor Costs discounted for Time:	5.00%	$ 70,811	$ 69,163	$ 67,554	$ 65,983	$ 64,448	$ 62,949	$ 61,485
		NPV--City Cost:	**$ 462,393**							
	Contractor Plus City Fuel Costs	Total Annual Fuel Cost including Contractor and City Costs:		$ 688,096	$ 591,739	$ 595,474	$ 599,304	$ 603,231	$ 607,257	$ 611,385
		Total Annual Fuel Cost including Contractor and City Costs Discounted for Time:	5.00%	$ 688,096	$ 563,561	$ 540,113	$ 517,701	$ 496,279	$ 475,802	$ 456,225
		NPV--Contractor+City Cost:	**$ 3,737,778**							
		Cost per Diesel Litre Equivalent (DLE):		$ 2.61	$ 2.25	$ 2.26	$ 2.27	$ 2.29	$ 2.30	$ 2.32
	Displaced Diesel Costs	Diesel+DEF Annual Cost (Total $)		$ 271,492	$ 279,637	$ 288,026	$ 296,667	$ 305,567	$ 314,734	$ 324,176
		Diesel+DEF Annual Cost (Total $) Discounted for Time	5.00%	$ 271,492	$ 266,321	$ 261,248	$ 256,272	$ 251,391	$ 246,602	$ 241,905
		NPV--Diesel+DEF Annual Cost (Total $)	**$ 1,795,233**							
	Truck Capital Cost Premium	**Differential Cost Premium for CNG vs Diesel Trucks**	**$ 750,989**							
	Net Project NPV	**Net Project NPV (-ve favours Diesel, +ve favours CNG)**	**$ (2,693,534)**							
	Carbon Reduction-Tonnes CO2	**757.2**		108.2	108.2	108.2	108.2	108.2	108.2	108.2

Table 6--Company C--Conventional CNG Station Concept				Year						
	NPV Calculations			0	1	2	3	4	5	6
Company C	Contractor Costs	Assumed station annual throughput (m^3)		271,429	271,429	271,429	271,429	271,429	271,429	271,429
		All In Contractor Fixed Cost (Capital Recovery + O&M):		$ 198,000	$ 198,000	$ 198,000	$ 198,000	$ 198,000	$ 198,000	$ 198,000
		Annual Cost Escalation (percent):	0	$ 198,000	$ 198,000	$ 198,000	$ 198,000	$ 198,000	$ 198,000	$ 198,000
		Contingency for Lighting, Bollards, other minor site work.		$ 100,000						
		Electrical Upgrade:		$ 150,000						
		Total Annual Contractor Cost:		$ 448,000	$ 198,000	$ 198,000	$ 198,000	$ 198,000	$ 198,000	$ 198,000
		Discount Rate:	5.00%	$ 448,000	$ 188,571	$ 179,592	$ 171,040	$ 162,895	$ 155,138	$ 147,751
		NPV--Contractor Cost with net HST at 1.76% added:	**$ 1,478,560**							
	City Fuel Costs not Including Contractor Costs	Gas Commodity & Utility Cost based on HSR Data: (per m3)	2.50%	$ 0.231	$ 0.237	$ 0.243	$ 0.249	$ 0.255	$ 0.262	$ 0.268
		On-site Electrical Compression Costs based on HSR (per m3)	3.00%	$ 0.030	$ 0.031	$ 0.032	$ 0.033	$ 0.033	$ 0.034	$ 0.036
		Total City Costs Related to Fuel and not Covered in Contractor Costs:		$ 70,811	$ 72,621	$ 74,478	$ 76,383	$ 78,337	$ 80,341	$ 82,396
		Total City Costs Related to Fuel and not Covered in Contractor Costs discounted for Time:	5.00%	$ 70,811	$ 69,163	$ 67,554	$ 65,983	$ 64,448	$ 62,949	$ 61,485
		NPV--City Cost:	**$ 462,393**							
	Contractor Plus City Fuel Costs	Total Annual Fuel Cost including Contractor and City Costs:		$ 518,811	$ 270,621	$ 272,478	$ 274,383	$ 276,337	$ 278,341	$ 280,396
		Total Annual Fuel Cost including Contractor and City Costs Discounted for Time:	5.00%	$ 518,811	$ 257,735	$ 247,146	$ 237,023	$ 227,343	$ 218,087	$ 209,236
		NPV--Contractor+City Cost:	**$ 1,915,380**							
		Cost per Diesel Litre Equivalent (DLE):		$ 1.97	$ 1.03	$ 1.03	$ 1.04	$ 1.05	$ 1.06	$ 1.06
	Displaced Diesel Costs	Diesel+DEF Annual Cost (Total $)		$ 271,492	$ 279,637	$ 288,026	$ 296,667	$ 305,567	$ 314,734	$ 324,176
		Diesel+DEF Annual Cost (Total $) Discounted for Time	5.00%	$ 271,492	$ 266,321	$ 261,248	$ 256,272	$ 251,391	$ 246,602	$ 241,905
		NPV--Diesel+DEF Annual Cost (Total $)	**$ 1,795,233**							
	Truck Capital Cost Premium	**Differential Cost Premium for CNG vs Diesel Trucks**	**$ 750,989**							
	Net Project NPV	**Net Project NPV (-ve favours Diesel, +ve favours CNG)**	**$ (871,136)**							
	Carbon Reduction-Tonnes CO2	**757.2**		108.2	108.2	108.2	108.2	108.2	108.2	108.2

Quantitative Findings-Summary Points:

A summary of the findings and additional considerations follows:

General:

1. None of the proposed approaches include standby power. This was eliminated to reduce cost. The City will need to deadhead the trucks to HSR for fuel in the event of a protracted power outage.

2. All of these alternatives are somewhat under-utilized with a fleet of 16 trucks. This provides an opportunity for the City to expand the number of trucks and/or extend the contract with a likely reduction in the overall per unit fuel cost. It is recommended that a procurement contract build in options to address these possibilities for future growth.

3. All of the alternatives studied appear to require a net investment by the City (ie the CNG total cost exceeds the diesel cost savings), however, this analysis does not include the very substantial impact of the upcoming rise in carbon fuel costs related to the federal government carbon tax escalations over the period of this project. This was not included in the analysis for four reasons:

    a) There could be a relaxation of these requirements due to public push-back or the installation of a new government.

    b) There will be some increase in both diesel and natural gas prices although it is expected that diesel price increases will be more pronounced.

    c) One purpose of a carbon tax is to reduce consumption so it is expected that market forces will reduce the non-tax portion of the fuel cost, making it difficult to predict final market prices.

    d) This report follows a 2020 report and to the extent possible, assumed prices and inflation rates used in the 2020 report have been carried forward on this report for consistency and to allow some comparison if desired.

Company A—HSR Fuel

1. Company A provided two concepts, the first being a trailer mounted CNG station (a compressor trailer plus a storage trailer) using gas compressed at the HSR station and delivered to the Burlington Street truck facility where trucks are time filled overnight. The HSR station is high capacity and the trailer filling will take place during the daytime when buses are not fueling. The use of the HSR station will increase the utilization of that existing asset.

2. Trucking CNG from a remote location introduces some risk to the project due to inclement weather, truck breakdowns, etc.

3. This scenario is the second lowest cost and is almost breakeven with the cost of diesel with a net cost of about $386,043 spread across seven years.

4. This approach was expected to be the fastest to deploy (along with Company A's alternative option), however, it was found that project time is equal to the conventional station proposals. This contractor has projected a 12-month time from contract award to fully permitted, operational station. This company is experiencing high demand for their mobile system and is gearing up to address this but is currently equipment limited. They anticipate improvement in this lead time in the future.

5. This approach (along with Company A's alternate option) requires less site work/improvements so the station will also be easy to decommission at contract completion.

6. Company A concepts include only one compressor on site. This means that in the event of a planned or unplanned protracted compressor outage, Company A will bring a "spare" compressor trailer to site and swap out with the existing compressor trailer.

7. This approach has been successfully used on similar fleets in Ontario and elsewhere.

Company A—Contractor Fuel

1. The second Company A approach is identical to the first except that the Contractor would supply the fuel rather than using fuel from HSR.

2. This scenario is the lowest cost and is almost breakeven with the cost of diesel with a net cost of about $293,440 spread across seven years.

3. See comments in previous bullet 8.

Company B—Utility Gas

1. Company B provided one concept with a conventional stationary CNG station with two 100 Hp compressors. The equipment as proposed is new equipment and is the most underutilized of all of the concepts, which means it has the greatest growth potential.

2. This scenario is the highest cost compared with the cost of diesel with a net cost of about $2,693,534 spread across seven years. This cost is much higher than the other concepts because the equipment is new, and the

installation is more extensive than Company A's installation due to the semi-permanent nature of this installation. This station is effectively a 20-year asset that is being depreciated over 7 years.

3. Gas is provided from a new utility service to the site.

4. Company B's concept includes two compressors on site. The second compressor will automatically start in the event of a fault on the other compressor.

5. This approach is the typical station design across North America and is consistent with the general approach of the 2020 study although somewhat scaled down to serve the smaller fleet and without some of the additional features (generator and fast fill) included in the 2020 study.

6. This contractor has projected a 6- to 18-month time from contract award to fully permitted, operational station.

<u>Company C—Utility Gas</u>

1. Company C provided one concept with a conventional stationary CNG station with three 50 Hp compressors.

2. This scenario is slightly more expensive than the two Company A approaches as compared with the cost of diesel with a net cost of about $871,136 spread across seven years. The major equipment as proposed is approximately 30 years old and has been fully depreciated on previous sites, allowing a lower project cost here.

3. Gas is provided from a new utility service to the site.

4. Company C's concept includes three compressors on site. The third compressor will automatically start in the event of a fault on one of the other compressors.

5. This approach is the typical station design across North America but uses older equipment that may not be suitable for operation beyond the 7-year project life.

6. This contractor has projected a 9- to 12-month time from contract award to fully permitted, operational station.

Findings-Environmental:

The growing concern over climate change and the recent advancements in controlling toxic tailpipe emissions has caused a shift in focus toward greenhouse gases and most notably toward CO_2 reduction. Unlike other pollutants that can be reduced by exhaust treatment, CO_2 is simply a product of combustion—thus, if a hydrocarbon (HC) fuel is consumed, CO_2 is produced. In fact, there are basically three ways to reduce CO_2 emissions of a vehicle:

1. Reduce fuel consumption through greater engine or drive train efficiency (reduce weight, use a hybrid drive system, etc.).

2. Use a low carbon fuel such as CNG or Renewable Natural Gas (RNG).

3. Use an energy source that has no tailpipe emissions (Battery Electric or hydrogen) however, these technologies are not yet field proven or durable to the extent that diesel and CNG are, and these energy sources can emit as much GHG as CNG depending on how the hydrogen or electricity is produced.

The first point above is relatively straightforward, since CO_2 production is linked to fuel consumption, any improvement in fuel consumption will provide a similar reduction in CO_2 emissions.

The second point is not as obvious. The products of complete combustion of any hydrocarbon fuel are CO_2 and H_2O, thus if one uses a fuel that is inherently lower in carbon content per unit of energy output, there will be lower CO_2 emissions. This study has included an analysis of the annual and lifecycle GHG reduction associated with the transition from diesel to CNG trucks. In each of the alternatives studied, the 7-year project saving is projected to be 757.2 tonnes CO_2.

Findings-Operating Engineers:

As noted in the 2020 report, there has been some adjustment to the Technical Standards and Safety Authority (TSSA) operating engineer requirements. It is now possible to apply for and receive a waiver from the requirement to staff a site with more than 150 Horsepower of reciprocating compressor(s) in simultaneous operation. This waiver is subject to a review of a safety plan, and further de-regulation is forthcoming.

While these developments are positive and may help with large stations like HSR, with the scaling down of the packer truck project, we are now down to a station size that is under the 150 Horsepower threshold, so this de-regulation does not impact this project. Note that Company B is proposing two 100 horsepower compressors, but these could be interlocked to prevent more than 100 Horsepower from operating at any time.

Conclusions and Recommendations:

1. It is recommended that the City of Hamilton proceed with the CNG project using a Fuel as a Service contracting approach.

2. All of the identified scenarios are technically feasible. Marathon has considered the balance between qualitive and quantitative factors and based on a balanced approach between these two general criteria, Marathon has rank ordered the scenarios by overall desirability are as following:
    1) Company A—Contractor Fuel
    2) Company A—HSR Fuel
    3) Company C—Utility Gas
    4) Company B—Utility Gas

    The two Company A proposals feature easier deployment and lowest cost. In the case where Company A is contracting for fuel, the cost was lower and can be locked in for the duration of the contract, giving the City more price certainty. This trailer mounted station approach does involve higher operational risk than the other alternatives since the CNG must be trucked to site and there is no redundant compressor on site. Marathon believes that this risk can be mitigated contractually using performance penalties for failure to fuel trucks, combined with an emergency plan to fuel at HSR, if required.

    The Company C proposal is somewhat appealing since it provides more on-site redundancy that Company A alternatives at a relatively low cost-premium. Marathon is concerned that the age of the equipment (~30 years) may lead to less operational stability and will not be as suited to a time extension to the contract as the other alternatives—this contract could end up being the most expensive if the City expands or extends its CNG fleet project.

    The Company B approach is in many ways the “best” and lowest risk approach since it includes new, modern, high-capacity equipment that can tolerate both more trucks and a longer project life. This station also includes full on-site compressor redundancy. The issue with this approach is its much higher cost.

3. Note that the lead time estimates ranged from 6- to 18-months with a typical/average lead time for the three vendors at 12-months. This was expected for the two conventional station solutions (Companies B and C) but much longer than expected for the trailer solution (Company A). The reason for the longer lead time with the trailers relates to equipment availability.

4. Enbridge has indicated (during the 2020 study) that the Burlington Street location has ample gas supply, and they are currently proposing an 80-psig delivery pressure.

5. It is estimated that this project will create a savings of 757.2 tonnes CO_2 over the lifecycle of the project --projecting a “green” image for the City.

6. Hamilton’s interest in this “Fuel as a Service” approach is to minimize its infrastructure commitment given the evolving Battery Electric Truck (BET) propulsion technology is still very new and essentially unproven in this application; however, it is expected that BETs will evolve to meet the operational challenges of a refuse collection fleet. It is unknown when this technology will be sufficiently proven to meet the City’s needs, so Marathon strongly recommends that any “Fuel as a Service” RFP and contract be written to provide the City with flexibility in throughput and contract duration both from a capacity and cost perspective. This will allow the City to make additional CNG truck purchases if required.

7. To ensure competitive bidding, the Fuel as a Service RFP will need to be performance/outcome oriented and allow a range of solutions that meet the City’s performance needs.

8. Further to the above recommendation, it is strongly recommended that the City include performance penalties on a per truck, per day basis for any trucks not fueled by a rollout deadline (perhaps 5:00 am).

Appendix A

Glossary of Terms

ACH Air Changes per Hour

AHJ Authority having Jurisdiction (the regulatory body with the authority to mandate design)

BET Battery Electric Truck

CH_4 Methane—natural gas is about 90 to 95 percent methane.

CNG Compressed Natural Gas

CO_2e Carbon Dioxide Equivalent—a means of comparing other GHGs to CO_2 and also to combine the effects of multiple GHGs to a common unit for simplification of quantification.

DGE Diesel Gallon Equivalent (the amount of CNG required to provide an amount of energy equal to one USG of diesel fuel).

Discount Rate This is a percentage used to discount a future value back to a present value to be used in the calculation of the Net Present Value (NPV). The discount rate used is often the borrowing rate, however, it could also be the minimum acceptable rate of return also called the "hurdle rate". This should not be confused with the Internal Rate of Return (IRR) which is the rate at which the project has a net present value of zero—ie the rate at which the project is "breakeven".

ESD Emergency Shut Down

F Fahrenheit

GGE Gasoline Gallon Equivalent (the amount of CNG required to provide an amount of energy equal to one USG of gasoline=5.66 pounds of CNG).

GHG Greenhouse Gas—CO_2 (Carbon Dioxide), CH_4(methane) and N_2O (Nitrous Oxide) are the most common greenhouse gases.

HP or Hp Horsepower

HSR Hamilton Street Railway

HST Harmonized Sales Tax—the sales tax in place in Ontario. At the time of this report, the City pays a net tax rate of 1.76 percent.

HVAC Heating Ventilation and Air Conditioning

IR	Infrared
LCA	Life Cycle Analysis
LEL	Lower Explosive Limit (this is 5 percent gas in air by volume—thus 20 percent LEL is 1 percent gas in air by volume)
LNG	Liquefied Natural Gas
m^3	Cubic meter of natural gas
NG	Natural Gas
NGV	Natural Gas for Vehicles or Natural Gas Vehicle (depending on context)
NPV	Net Present Value is the value of the project expressed in current dollars. It is calculated by "discounting" the future cost and savings back to current dollars using the "discount rate."

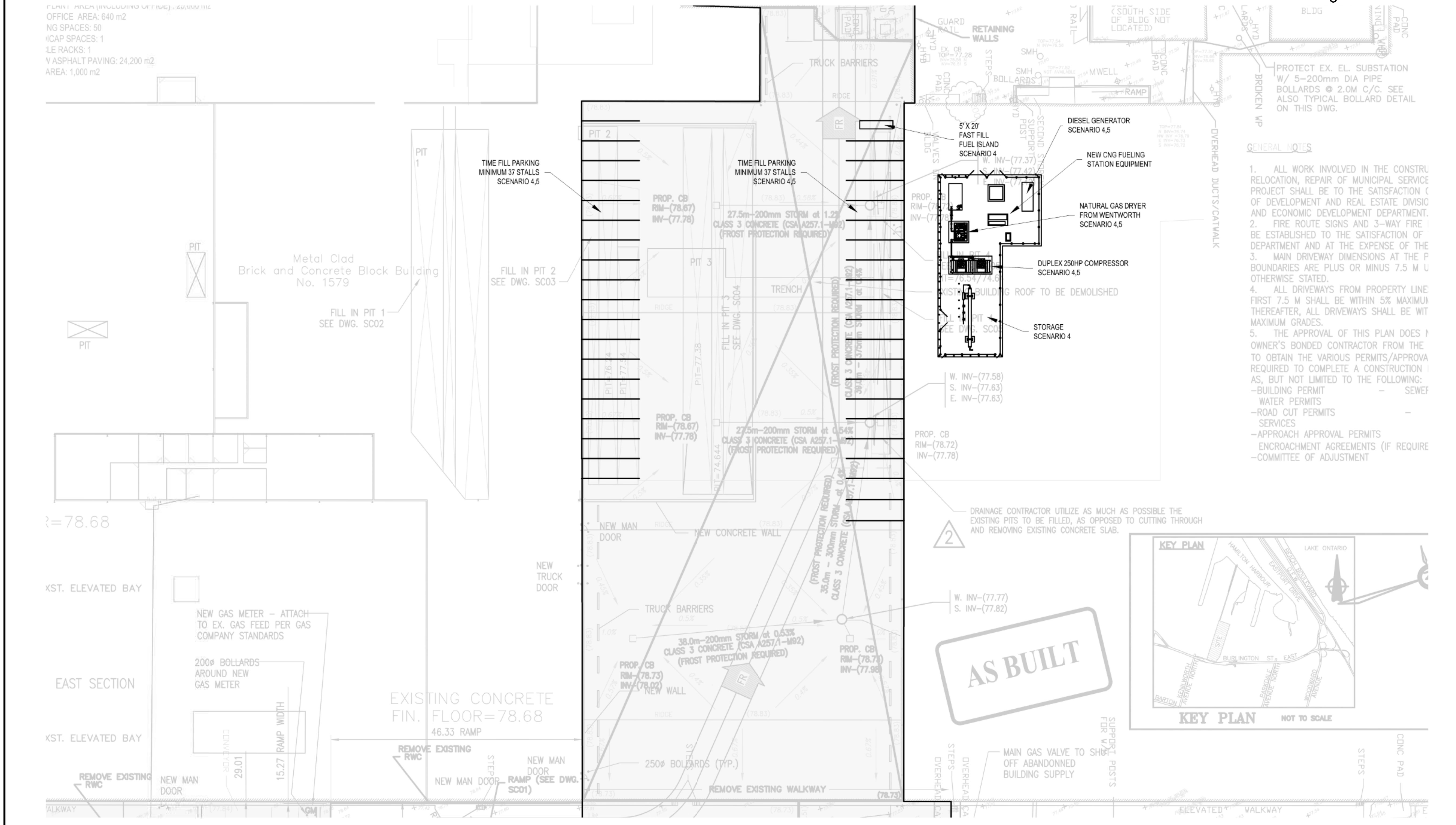
Payback or Simple Payback is based on a cash flow analysis and is the time (expressed in years in this report) required for the income (or in this case the savings compared to a diesel fleet) to exceed the capital and operating expenditures. Future costs and savings are increased using inflation factors to their value in future years but there is no cost of money or "discount rate" applied) as this is not a Net Present Value. As with all analysis herein, the analysis is based on differential costs and savings only compared to the diesel baseline.

PSI	Pounds per Square Inch
PSIG	Pounds per Square Inch Gauge (Atmospheric pressure is 0 psig)
RNG	Renewable Natural Gas—natural gas sourced from landfills or digesters.
SCF	Standard Cubic Feet (the volume of gas within one cubic foot at atmospheric pressure and 60 F)
USG	US Gallon
VFD	Variable Frequency Drive—allows AC motors to operate at part speed.

Appendix B

Site Layout Drawings:

G-02 Hamilton Packer Truck CNG Concept Layout-1579 Burlington St., Hamilton ON



PROJECT ENGR./ARCH:		PROJECT:	HAMILTON PACKER TRUCK CNG STATION CONCEPT LAYOUT
DESIGNER:	Robert R. Adams	SHEET TITLE:	1579 BURLINGTON ST. HAMILTON, ONT.
DRAWN BY:	KH	WORK PROJECT NO.	
SCALE:	NTS		G-02
DATE:	12/10/2019		
CHECKED BY:			
CHECKED/APPROVED BY:			

MarathonTechnical Services
6 Venus Crescent,
Heidelberg, Ontario,
N0B 2M1

REVISIONS

NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D

Appendix C

Request for Information Provided to Contractors

RFI Excerpt for CNG Station "Fuel as a Service" Concepts:

We have been commissioned to study fueling options for the City of Hamilton. They are interested in exploring fueling strategies that minimize their capital commitment and are therefore looking at options that include compression as a service by a third party.

We are projecting the following project parameters:

1. 271,725 m3 annual throughput for a 7-year period—this is based on a 5-day work week and use 8 hours per day.
2. 80 psig utility pressure.
3. The Contractor would supply, install, permit, operate, maintain and own the station equipment.
4. The facility will/may be removed in 7 years—any costs associated with the removal of the equipment should be included below.
5. The City would prefer that all installation costs be included in the costs of the fuel, however, if there are costs that the City must bear, these should be identified.
6. Assume that sufficient power is available in a building approximately 250 feet from the required location.
7. Do not include any fast fill capability at this time.
8. The attached site drawing was based on a larger project scope—it is provided for general site information only. The site is located at 1579 Burlington Street, Hamilton, ON.

I would like to receive estimated costs by January 22, 2021. Please note that this is an estimate for analysis and budget purposes only. This is not a proposal, quotation or bid. Marathon will provide any information supplied to the City of Hamilton. Please provide the following information:

9. We are anticipating the City installing a 16 truck time fill barricade—is this something you can provide or do we need to supply this?
10. Please identify any capital cost items that the City will incur.
11. What are the infrastructure requirements and space/area required for your system? – please clarify any that are City furnished.
12. Please provide basic equipment specifications including horsepower, amps, scfm, make and model of compressors, dryer and other major equipment, scf of any storage.
13. Is equipment new or used at start of contract?
14. Compressor redundancy is required.
15. Please provide the cost per m3 for:
    a. New gas service from utility.
    b. Capital recovery.
    c. Operation and maintenance.
    d. Any licenses, permits or any other fees.
    e. The price should not include the natural gas commodity or transportation/distribution costs.
    f. The price should not include power costs, but please indicate the size of the motors.
16. What is the annual cost escalation over the seven-year period?

City of Hamilton Compressed Natural Gas (CNG) Packer Truck Fueling

2nd Supplemental Study

Submitted To:

Tom Kagianis

Superintendent Capital Planning
& Contract Management
Tel: (905) 546-2424 ext. 5105
Email: Tom.Kagianis@hamilton.ca

Energy, Fleet & Facilities
Public Works
330 Wentworth Street, L8L 5W2

FINAL REPORT

2021 04 21

Submitted By:

Rob Adams
P.Eng, CPA, CMA, PMP, CMC, MBA
radams@marathontech.ca

Marathon Technical Services
Six Venus Crescent,
Heidelberg, ON
N0B 2M1

p 519.699.8250
f 519.699.9255
radams@marathontech.ca

Executive Summary:

The City of Hamilton, Energy, Fleet & Facilities Public Works department (the City) contracted with Marathon Technical Services (Marathon or MTS), to study the technical and financial viability of fueling 10 of the fleet of 37 packer (refuse collection) trucks with CNG over a 7-year project life based on a 2023 truck procurement.

This analysis focused on a non-conventional infrastructure procurement approach—"Fuel as a Service" and is an extension of the supplemental report submitted in March 2021. This "Fuel as a Service" contracting method is well suited to this project and allows the City to complete a small scale, shorter term project than was studied in Marathon's 2020 report.

This approach reduces or eliminates capital expenditure by the City and allows a shorter term, lower risk project that is geared to the 7-year life of the truck order. Ownership of the equipment is retained by the contractor and equipment is removed at their expense at the conclusion of the contract. This approach allows the City to quickly and inexpensively adopt lower carbon CNG truck technology that is available today, while preserving the option of electric trucks in the future when these become more technically and cost competitive.

A total of two companies and three approaches were evaluated (one company consulted in the March 2021 report did not respond with data for this report). In every case, fueling will be performed as "time fill" with no "fast fill" provided. All fueling will take place at the Burlington Street truck facility. All three options are technically feasible.

Net Present Value (NPV) was used as quantitative evaluation metric. None of the three options returned a positive net present value NPV as studied, ranging from $(137,225) to $(2,068,186), the negative values indicating that the CNG project costs are not fully offset by diesel cost savings. It should be noted that these values are similar than those calculated in the March 2021 Supplemental Study in spite of the reduced number of trucks because the per truck fuel consumption is higher with the 10 side loader trucks than with the rear loader evaluated in the previous supplemental study.

The average lead time from award of contract to a fully permitted and operational station was 12-months with no solution approach providing any notable lead time advantage.

It is estimated that this project will create a savings of 690 tonnes CO_2e over the lifecycle of the project --projecting a "green" image for the City. This represents a 17.3 percent reduction from the diesel fleet and based on US EPA data. This total project savings is lower than the 2020 study due to the shorter project length and reduction in truck count.

Table of Contents:

Introduction:

The City of Hamilton (the City, or Hamilton) is evaluating the possible transition of a portion of its diesel-powered packer truck refuse collection fleet to Compressed Natural Gas (CNG). The City has over three decades of successful CNG heavy fleet experience at the Hamilton Street Railway (HSR).

CNG is a fuel that is capital intensive but low cost to operate and provides toxic gas and greenhouse gas (GHG) emissions reduction when compared with diesel. It is also the most proven alternative fuel in heavy vehicle applications. This second supplemental study follows a study in 2020 that evaluated the possibility of changing the entire City fleet of garbage trucks to CNG and a first supplemental study (March 2021) that evaluated a single seven-year period with the procurement of 16 rear loader packer trucks. The scaled down approach in this supplemental study is based on a 7-year project term, matching a single purchase of 10 side loader packer trucks. This smaller, shorter term project allows the City to implement CNG trucks into its fleet in 2023 and retain the option to transition to electric trucks when those become more economically and technically viable.

Marathon has been contracted to perform the following scope:

1. Assume a single purchase of 10 trucks that require fueling over a 7-year period.

2. Assume that fueling will take place at the existing City truck facility on Burlington Street. A concept level plan that was prepared for the 2020 study has been included in this supplemental study for reference in Appendix B. Note that the scale of equipment is likely to change from this drawing to match this de-scoped study.

3. Review of three fueling alternatives provided by two well experienced industry contractors using a “Fuel as a Service” contracting approach. This approach is based on the contractor assuming:
    a. All of the equipment and installation capital costs.
    b. All of the operation and maintenance costs.
    c. All repair costs.
    d. All station licensing and permitting costs.
    e. All trucking of gas to site for the trailer option.
    f. In one case the commodity and utility gas cost.
    g. See Appendix C for a description of the request for information forwarded to the station vendors—this was as sent to the vendors.

4. For the options above, Marathon used assumptions consistent with the 2020 analysis and the March 2021 supplemental study to allow some level of comparison between reports.

5. Marathon has updated the Operating Engineer requirements and the impact of changes.

6. Project life cycle cost analysis for the initial and subsequent purchase and integration of CNG packer trucks into the collection fleet. The initial and sole purchase will be for approximately 10 side loader trucks to go into service in 2023. This analysis will identify the net present value (NPV) of the CNG program and will also identify the expected environmental and other benefits. Marathon will make recommendations related to the implementation of this program.

7. It is understood that City trucks are maintained off site by service providers and thus no garage upgrades related to CNG are required or anticipated at this time and no consulting associated with upgrades is included in this scope.

Analysis Assumptions and Data Sources:

The life cycle cost analysis uses data from a variety of sources and covers a wide range of data to address all readily quantifiable cost elements to provide a comprehensive and conservative analysis. The list below summarizes the cost elements and data sources that were determined or assumed in this study:

1. The lifecycle analysis is based on a 7-year life cycle with year 0 being 2023. This 7-year life cycle was selected as it corresponds to one full 7-year truck life cycle for the truck procurement.

2. Discount rate: 5% (Marathon standard, confirmed with the City of Hamilton). See Glossary in Appendix A for definition of discount rate.

8. Inflation: 2.5 percent to 3.0 percent (dependent on item) (Marathon standard, confirmed with the City of Hamilton). See Tables 3 to 6 for individual rates used. Costs have been inflated 4 years to reflect a 2023 project start (data used was 2019 data) then discounted 2 years to produce a 2021 NPV.

3. HST was applied at a net rate of 1.76 percent on the cost of CNG contractor services and on the upcharge/differential cost for the CNG trucks over the diesel truck cost. As discussed with the City, it is understood that diesel fuel, electricity, natural gas, CNG station maintenance costs and truck operating and maintenance costs already include HST embedded in the costs provided by the City.

4. The station concepts proposed do not include a standby power (generator), thus in the event of a protracted power outage, it will be necessary to deadhead trucks to another site-most likely to HSR.

5. One of the two companies responded with a concept that includes an on-site redundant compressor. The other respondent proposes a trailer mounted compressor which can be changed out in the event of a compressor failure. If a spare compressor is not available in a timely manner, it will be necessary to deadhead trucks to another site-most likely to HSR. Note that performance penalties can be built into the service contract to fund such an occurrence.

6. Truck capital cost differential compared to clean diesel was $45,000 plus HST (in 2019 dollars) (ie the CNG trucks are more expensive than the diesel trucks) for all full sized CNG packer trucks (as provided by the City).

7. Truck maintenance cost differential—no differential truck maintenance cost compared with clean diesel was assumed. Although CNG and diesel trucks have both been widely used in this application for a number of years, there is still a variety of opinions as to which fuel has lower truck maintenance

costs including the prevailing opinion that there is no difference. HSR indicated that their current experience is there is no difference in maintenance costs between these fuels for their fleet of heavy buses—this is the assumption used in this report.

8. Future CNG vehicle fuel consumption is equal to diesel since it was assumed that there is no increase or decrease in routes or total distance except as studied in the sensitivity analysis. This is a conservative assumption since if additional trucks are required to meet a growing population (significant population growth is likely over a 7-year period).

9. Current diesel prices were supplied by the City and based on 2018/2019 average diesel fuel cost per litre then inflated at 3.0 percent per annum.

10. Engine efficiency—CNG engines are assumed to be 88 percent of diesel engine efficiency (Cummins). CNG engines are spark ignition with lower compression ratio than diesel and thus diesel engines have a higher thermal efficiency than CNG, although this advantage is narrowing making this a conservative assumption.

11. Gas utility commodity and gas distribution charges were based on 2018/2019 HSR CNG station charges as provided by the City. These were inflated at 2.5 percent per annum. Enbridge has confirmed that ample natural gas supply is available at the Burlington Street site at a delivery pressure of 80 psig.

12. No gas utility service cost has been included as it has been assumed that the station load will pay the utility for this new gas service.

13. Electricity charges were based on 2018/2019 HSR CNG station charges as provided by the City. Electricity costs were initially calculated based on the total load that the City attributes to the HSR CNG station.

14. GHG calculations are based on motor fuel data for the Canadian National Inventory Report (NIR) Table A6-12.

15. Trucks will continue to be serviced off site by third party maintenance shops, therefore no Hamilton shop upgrades for CNG are required or included.

16. No government grants or other incentives or subsidies are currently available or included in the cost estimates.

Approach/Methodology:

A 7-year life cycle cost analysis was built by Marathon Technical Services using inputs from a variety of sources (as previously outlined). Seven years was selected as it represents one truck life cycle for the sole group of 10 side loader packer trucks. It is assumed that if the City intends to continue with CNG after the seven-year period which may include having more than 10 trucks, it will renegotiate the contract with the contractor—this should lower the unit cost of fuel. If the City decides to transition away from CNG at the end of the seven years, the CNG station will be decommissioned and removed by the contractor.

The focus of this analysis was to identify and quantify those items that are differential costs for CNG compared to clean diesel—it should be stressed that there may be additional costs that are not identified in the analysis because they apply to both CNG and Diesel. These additional costs might include the base cost of a diesel truck (only the differential is used herein), end of life truck salvage value, packer truck maintenance costs (as previously noted), truck licensing costs, and truck driver costs as examples.

Two CNG station scenarios were conceived. Each scenario was then evaluated in the customized spreadsheet to determine the NPV over the seven years. Unlike the 2020 analysis, a payback year was not calculated since the payments are spread over the seven-year period with little to no upfront costs to pay back. Cash flow information is provided in the spreadsheets by cost category.

See Appendix B for concept level station layout drawing from the 2020 analysis. The layout for the concepts in this report will be similar to this layout but with fewer time fill locations and less compression equipment.

The Fuel as a Service contracting approach has the following benefits:

1. Little to no upfront cost.
2. No cost at end of contract.
3. No asset ownership.
4. Most costs including cost of capital are embedded in annual and/or throughput related charges. While this is beneficial to the City, the contractor will need to cover these costs so the City will be required to enter into a take-or-pay contract.

A brief description of the Fuel as a Service concept equipment and cost structure follows on Table 1 and 2 respectively.

Figure 1 provides photographs of equipment similar to Company A concept. Figure 2 provides photographs of equipment similar to Companies B concept.

Table 1-List of Equipment for Fuel as a Service

		Company A	Company B
Fuel Station Concept:		Trailer mounted compressor and storage (gas from HSR) gas dispensed to time fill manifold. No Fast Fill.	Conventional compressor station (gas from utility line) gas dispensed to time fill manifold. No Fast Fill.
Dryer:		None required as gas is already dry from HSR station.	Single Tower--PSB 10-2 DDP
Compressor(s):		One--trailer mounted hydraulic compressor. 1x75Hp	One duplex (two compressors in total) stationary compressor package. 2x30Hp
	Redundancy:	Exchanging compressor trailers if compressor fault cannot be rectified. Willing to accept a penalty for not fueling.	Second compressor to automatically start upon compressor fault.
	Equipment Age:	<5 years	New--conservative case
Storage:		Trailer Mounted	One 23' 5500psig tube with 345m^3 capacity
Time Fill Posts Included:		10	10
Electric Generator:		None--fueling will not occur with power outage.	None--fueling will not occur with power outage.

Table 2-List of Cost Structure for Fuel as a Service Contractors

		Company A	Company B
Assumed station annual throughput (m^3)		247,510	247,510
All In Fixed Cost:	Annual Cost: (based on a throughput charge of \$0.729/m^3)	None required as gas is already dry from HSR station.	
All In per m^3 Cost:	Year 1 to 3	$ 0.45	
	Year 4 to 5	$ 0.47	
	Year 6 to 7	$ 0.50	
Fixed plus Throughput Cost:	Annual Cost:		$ 395,739
	Per m^3 Cost:		$ 0.270
Annual Cost Escalation (percent):		As noted in throughput cost schedule.	Canadian CPI
Length of contract (years):		7	7
Initial Capital costs to City:		$ -	$ -
End of Term Costs to City:		$ -	$ -
Costs Included:			
All equipment costs for equipment in Equipment list.		Yes	Yes
All installation costs for station equipment and time fill except as excluded below.		Yes	Yes
All Equipment O&M		Yes	Yes
All Equipment Repairs		Yes	Yes
All costs to load fuel at HSR and truck to Burlington Street		Yes	N/A
Cost Exclusions:		Gas service not required	Cost of Gas Service
		Natural Gas Cost	Natural Gas Cost
		Cost of Electricity--this is added to Marathon Total Fuel Cost Estimate	Cost of Electricity--this is added to Marathon Total Fuel Cost Estimate
		Site lighting, bollards and curbstones--other minor installation costs. A \$100,000 contingency has been added to address this.	Site lighting, bollards and curbstones--other minor installation costs. A \$100,000 contingency has been added to address this.

Figure 1—Trailer mounted CNG Station (left) and time fill barricade (below).

Figure 2—Conventional CNG Station with CNG dryer (blue), two compressors for redundancy (silver enclosures), one storage tube (white tube with panel) (left).

Findings- Benefits of Time fill at the Burlington Street Location (abbreviated from the 2020 report):

Time fill in this location has several benefits:

1. Time fill of trucks takes place over a period of many hours. This additional fill time allows the heat generated during fueling to partially dissipate while fueling progresses and thus results in cooler, denser gas in truck tanks after fueling—this translates into a more complete fill and improved range.

2. Given that packer trucks are typically parked for 12 to 16 hours, time fill is well adapted to packer truck operations.

3. Time fill can significantly reduce the number of compressor starts and stops which leads to reduced wear and tear on station equipment. Time fill equipment is also simpler than fast fill dispensing equipment and thus is less prone to breakdown.

4. With much more time available for time filling, a (much) smaller compressor can be used than is used for fast fill.

5. The elimination of the need to drive trucks to another location for the sole purpose of fueling reduces unnecessary truck operating costs.

6. It is anticipated that there will be a reduction of personnel time required related to the use of time fill rather than fast fill fueling. This has not been included in the cost summary since a rework and extension of existing routes would be required to realize this time/labour reduction.

7. Fueling at Burlington Street consolidates the trucks to the location of dispatch, simplifying operations.

Findings-Quantitative

The primary means of quantitative evaluation for the project is the Net Present Value (NPV) of the costs and savings compared to Diesel trucks and operation (savings are calculated based on the cost of diesel that is displaced).

Costs are broken down as contractor costs, non-contractor City costs (such as power and gas), and the upcharge on the trucks have been used to offset the diesel expenditure that is displaced through the use of CNG.

Tables 3 through 6 on the next four pages provide the cost breakdown and totals as well as GHG emission savings.

Table 3--Company A--Trailer Concept using HSR Fuel				Year						
	NPV Calculations			0	1	2	3	4	5	6
Company A-using HSR Fuel	Contractor Costs	Assumed station annual throughput (m^3)		247,510	247,510	247,510	247,510	247,510	247,510	247,510
		All In per m^3 Contractor Cost:		$ 0.450	$ 0.450	$ 0.450	$ 0.470	$ 0.470	$ 0.500	$ 0.500
		Contingency for Lighting, Bollards, other minor site work.		$ 100,000						
		Total Annual Contractor Cost:		$ 211,380	$ 111,380	$ 111,380	$ 116,330	$ 116,330	$ 123,755	$ 123,755
		Discount Rate:	5.00%	$ 191,727	$ 96,214	$ 91,632	$ 91,147	$ 86,807	$ 87,950	$ 83,762
		NPV--Contractor Cost with net HST at 1.76% added:	**$ 742,075**							
	City Fuel Costs not Including Contractor Costs	Gas Commodity & Utility Cost based on HSR Data: (per m3)	2.50%	$ 0.243	$ 0.249	$ 0.255	$ 0.262	$ 0.268	$ 0.275	$ 0.282
		HSR Compression Electricity and Station Maintenance Costs:	3.00%	$ 0.104	$ 0.107	$ 0.110	$ 0.113	$ 0.117	$ 0.120	$ 0.124
		On-site Electrical Compression Costs based on HSR (per m3)	3.00%	$ 0.032	$ 0.033	$ 0.033	$ 0.034	$ 0.036	$ 0.037	$ 0.038
		Total City Costs Related to Fuel and not Covered in Contractor Costs:		$ 93,557	$ 96,063	$ 98,637	$ 101,280	$ 103,995	$ 106,783	$ 109,646
		Total City Costs Related to Fuel and not Covered in Contractor Costs discounted for Time:	5.00%	$ 84,859	$ 82,983	$ 81,149	$ 79,356	$ 77,603	$ 75,889	$ 74,213
		NPV--City Cost:	**$ 556,050**							
	Contractor Plus City Fuel Costs	Total Annual Fuel Cost including Contractor and City Costs:		$ 304,936	$ 207,442	$ 210,016	$ 217,610	$ 220,325	$ 230,538	$ 233,401
		Total Annual Fuel Cost including Contractor and City Costs Discounted for Time:	5.00%	$ 276,586	$ 179,197	$ 172,781	$ 170,503	$ 164,410	$ 163,839	$ 157,975
		NPV--Contractor+City Cost:	**$ 1,285,291**							
		Cost per Diesel Litre Equivalent (DLE):		$ 1.27	$ 0.86	$ 0.87	$ 0.91	$ 0.92	$ 0.96	$ 0.97
	Displaced Diesel Costs	Diesel+DEF Annual Cost (Total $)		$ 262,359	$ 270,230	$ 278,337	$ 286,687	$ 295,287	$ 304,146	$ 313,270
		Diesel+DEF Annual Cost (Total $) Discounted for Time	5.00%	$ 237,967	$ 233,435	$ 228,988	$ 224,626	$ 220,348	$ 216,151	$ 212,034
		NPV--Diesel+DEF Annual Cost (Total $)	**$ 1,573,549**							
	Truck Capital Cost Premium	**Differential Cost Premium for CNG vs Diesel Trucks (HST at 1.76% included in differential cost)**	**$ 505,458**							
	Net Project NPV	**Net Project NPV (-ve favours Diesel, +ve favours CNG)**	**$ (230,034)**							
Carbon Reduction-Tonnes CO2			**689.7**	98.5	98.5	98.5	98.5	98.5	98.5	98.5

Table 4--Company A--Trailer Concept using Contractor Fuel				Year						
	NPV Calculations			0	1	2	3	4	5	6
Company A-using Company Supplied CNG	Contractor Costs	Assumed station annual throughput (m^3)		247,510	247,510	247,510	247,510	247,510	247,510	247,510
		All In per m^3 Contractor Cost including Gas:		$ 0.750	$ 0.750	$ 0.750	$ 0.770	$ 0.770	$ 0.800	$ 0.800
		Contingency for Lighting, Bollards, other minor site work.		$ 100,000						
		Total Annual Contractor Cost:		$ 285,633	$ 185,633	$ 185,633	$ 190,583	$ 190,583	$ 198,008	$ 198,008
		Discount Rate:	5.00%	$ 259,077	$ 160,356	$ 152,720	$ 149,327	$ 142,216	$ 140,721	$ 134,020
		NPV--Contractor Cost with net HST at 1.76% added:	**$ 1,158,473**							
	City Fuel Costs not Including Contractor Costs	Gas Commodity & Utility Cost based on HSR Data: (per m3)	N/A							
		HSR Compression Electricity and Station Maintenance Costs:	N/A							
		On-site Electrical Compression Costs based on HSR (per m3)	3.00%	$ 0.032	$ 0.033	$ 0.033	$ 0.034	$ 0.036	$ 0.037	$ 0.038
		Total City Costs Related to Fuel and not Covered in Contractor Costs:		$ 7,810	$ 8,044	$ 8,286	$ 8,534	$ 8,790	$ 9,054	$ 9,326
		Total City Costs Related to Fuel and not Covered in Contractor Costs discounted for Time:	5.00%	$ 7,084	$ 6,949	$ 6,817	$ 6,687	$ 6,560	$ 6,435	$ 6,312
		NPV--City Cost:	**$ 46,843**							
	Contractor Plus City Fuel Costs	Total Annual Fuel Cost including Contractor and City Costs:		$ 293,443	$ 193,677	$ 193,918	$ 199,117	$ 199,373	$ 207,062	$ 207,334
		Total Annual Fuel Cost including Contractor and City Costs Discounted for Time:	5.00%	$ 266,161	$ 167,305	$ 159,537	$ 156,013	$ 148,775	$ 147,155	$ 140,332
		NPV--Contractor+City Cost:	**$ 1,185,279**							
		Cost per Diesel Litre Equivalent (DLE):		$ 1.22	$ 0.81	$ 0.81	$ 0.83	$ 0.83	$ 0.86	$ 0.86
	Displaced Diesel Costs	Diesel+DEF Annual Cost (Total $)		$ 262,359	$ 270,230	$ 278,337	$ 286,687	$ 295,287	$ 304,146	$ 313,270
		Diesel+DEF Annual Cost (Total $) Discounted for Time	5.00%	$ 237,967	$ 233,435	$ 228,988	$ 224,626	$ 220,348	$ 216,151	$ 212,034
		NPV--Diesel+DEF Annual Cost (Total $)	**$ 1,573,549**							
	Truck Capital Cost Premium	**Differential Cost Premium for CNG vs Diesel Trucks (HST at 1.76% included in differential cost)**	**$ 505,458**							
	Net Project NPV	**Net Project NPV (-ve favours Diesel, +ve favours CNG)**	**$ (137,225)**							
	Carbon Reduction-Tonnes CO2		**689.7**	98.5	98.5	98.5	98.5	98.5	98.5	98.5

Table 5--Company B--Conventional CNG Station Concept				Year						
	NPV Calculations			0	1	2	3	4	5	6
Company B	Contractor Costs	Assumed station annual throughput (m^3)		247,510	247,510	247,510	247,510	247,510	247,510	247,510
		Annual Contractor Cost (Capital Recovery):		$ 395,739	$ 395,739	$ 395,739	$ 395,739	$ 395,739	$ 395,739	$ 395,739
		Per m^3 Contractor O&M Cost:		$ 0.270						
		Annual Cost Escalation (percent):	2.50%	$ 0.28	$ 0.29	$ 0.30	$ 0.31	$ 0.31	$ 0.32	$ 0.33
		Contingency for Lighting, Bollards, other minor site work.		$ 100,000						
		Total Annual Contractor Cost:		$ 565,950	$ 467,705	$ 469,504	$ 471,349	$ 473,239	$ 475,176	$ 477,162
		Discount Rate:	5.00%	$ 513,333	$ 404,021	$ 386,262	$ 369,314	$ 353,138	$ 337,699	$ 322,962
		NPV--Contractor Cost with net HST at 1.76% added:	**$ 2,734,017**							
	City Fuel Costs not Including Contractor Costs	Gas Commodity & Utility Cost based on HSR Data: (per m3)	2.50%	$ 0.243	$ 0.249	$ 0.255	$ 0.262	$ 0.268	$ 0.275	$ 0.282
		On-site Electrical Compression Costs based on HSR (per m3)	3.00%	$ 0.032	$ 0.033	$ 0.033	$ 0.034	$ 0.036	$ 0.037	$ 0.038
		Total City Costs Related to Fuel and not Covered in Contractor Costs:		$ 67,915	$ 69,652	$ 71,434	$ 73,261	$ 75,135	$ 77,057	$ 79,029
		Total City Costs Related to Fuel and not Covered in Contractor Costs discounted for Time:	5.00%	$ 61,601	$ 60,168	$ 58,769	$ 57,402	$ 56,067	$ 54,763	$ 53,490
		NPV--City Cost:	**$ 402,260**							
	Contractor Plus City Fuel Costs	Total Annual Fuel Cost including Contractor and City Costs:		$ 633,865	$ 537,357	$ 540,938	$ 544,609	$ 548,374	$ 552,234	$ 556,191
		Total Annual Fuel Cost including Contractor and City Costs Discounted for Time:	5.00%	$ 574,934	$ 464,190	$ 445,031	$ 426,716	$ 409,205	$ 392,462	$ 376,452
		NPV--Contractor+City Cost:	**$ 3,088,990**							
		Cost per Diesel Litre Equivalent (DLE):		$ 2.64	$ 2.24	$ 2.25	$ 2.27	$ 2.28	$ 2.30	$ 2.31
	Displaced Diesel Costs	Diesel+DEF Annual Cost (Total $)		$ 262,359	$ 270,230	$ 278,337	$ 286,687	$ 295,287	$ 304,146	$ 313,270
		Diesel+DEF Annual Cost (Total $) Discounted for Time	5.00%	$ 237,967	$ 233,435	$ 228,988	$ 224,626	$ 220,348	$ 216,151	$ 212,034
		NPV--Diesel+DEF Annual Cost (Total $)	**$ 1,573,549**							
	Truck Capital Cost Premium	**Differential Cost Premium for CNG vs Diesel Trucks (HST at 1.76% included in differential cost)**	**$ 505,458**							
	Net Project NPV	**Net Project NPV (-ve favours Diesel, +ve favours CNG)**	**$ (2,068,186)**							
	Carbon Reduction-Tonnes CO2		689.7	98.5	98.5	98.5	98.5	98.5	98.5	98.5

Quantitative Findings-Summary Points:

A summary of the findings and additional considerations follows:

General:

1. None of the proposed approaches include standby power. This was eliminated to reduce cost. The City will need to deadhead the trucks to HSR for fuel in the event of a protracted power outage.

2. These alternatives are somewhat under-utilized with a fleet of 10 trucks. This provides an opportunity for the City to expand the number of trucks and/or extend the contract with a likely reduction in the overall per unit fuel cost. It is recommended that a procurement contract build in options to address these possibilities for future growth.

3. All of the alternatives studied appear to require a net investment by the City (ie the CNG total cost exceeds the diesel cost savings), however, this analysis does not include the very substantial impact of the upcoming rise in carbon fuel costs related to the federal government carbon tax escalations over the period of this project. This was not included in the analysis for four reasons:

   a) There could be a relaxation of these requirements due to public push-back or the installation of a new government.

   b) There will be some increase in both diesel and natural gas prices although it is expected that diesel price increases will be more pronounced.

   c) One purpose of a carbon tax is to reduce consumption so it is expected that market forces will reduce the non-tax portion of the fuel cost, making it difficult to predict final market prices.

   d) This report follows a 2020 report and to the extent possible, assumed prices and inflation rates used in the 2020 report have been carried forward on this report for consistency and to allow some comparison if desired.

Company A—HSR Fuel

1. Company A provided two concepts, the first being a trailer mounted CNG station (a compressor trailer plus a storage trailer) using gas compressed at the HSR station and delivered to the Burlington Street truck facility where trucks are time filled overnight. The HSR station is high capacity and the trailer filling will take place during the daytime when buses are not fueling. The use of the HSR station will increase the utilization of that existing asset.

2. Trucking CNG from a remote location introduces some risk to the project due to inclement weather, truck breakdowns, etc.

3. This scenario is the second lowest cost and is almost breakeven with the cost of diesel with a net cost of about $230,034 spread across seven years.

4. This approach was expected to be the fastest to deploy (along with Company A's alternative option), however, it was found that project time is equal to the conventional station proposal. This contractor has projected a 12-month time from contract award to fully permitted, operational station. This company is experiencing high demand for their mobile system and is gearing up to address this but is currently equipment limited. They anticipate improvement in this lead time in the future. This situation may have been resolved by 2023, improving the implementation time frame.

5. This approach (along with Company A's alternate option) requires less site work/improvements so the station will also be easy to decommission at contract completion.

6. Company A concepts include only one compressor on site. This means that in the event of a planned or unplanned protracted compressor outage, Company A will bring a "spare" compressor trailer to site and swap out with the existing compressor trailer.

7. This approach has been successfully used on similar fleets in Ontario and elsewhere.

Company A—Contractor Fuel

1. The second Company A approach is identical to the first except that the Contractor would supply the fuel rather than using fuel from HSR.

2. This scenario is the lowest cost and is almost breakeven with the cost of diesel with a net cost of about $137,225 spread across seven years.

3. See comments in previous bullets 4 to 7.

Company B—Utility Gas

1. Company B provided one concept with a conventional stationary CNG station with two 30 Hp compressors. The equipment as proposed is new equipment and the company indicated that they feel their estimated capital costs are very conservative, however, the capital cost recovery of a conventional station in only 7 years puts a heavy cost premium on this approach..

2. This scenario is the highest cost compared with the cost of diesel with a net cost of about $2,068,186. spread across seven years. This cost is much higher than the other concepts because the equipment is new, and the installation is more extensive than Company A’s installation due to the semi-permanent nature of this installation. This station is effectively a 20-year asset that is being depreciated over 7 years.

3. Gas is provided from a new utility service to the site.

4. Company B’s concept includes two compressors on site. The second compressor will automatically start in the event of a fault on the other compressor.

5. This approach is the typical station design across North America and is consistent with the general approach of the 2020 study although significantly scaled down to serve the smaller fleet and without some of the additional features (generator and fast fill) included in the 2020 study.

6. This contractor has projected a 6- to 18-month time from contract award to fully permitted, operational station.

Findings-Environmental:

The growing concern over climate change and the recent advancements in controlling toxic tailpipe emissions has caused a shift in focus toward greenhouse gases and most notably toward CO_2 reduction. Unlike other pollutants that can be reduced by exhaust treatment, CO_2 is simply a product of combustion—thus, if a hydrocarbon (HC) fuel is consumed, CO_2 is produced. In fact, there are basically three ways to reduce CO_2 emissions of a vehicle:

1. Reduce fuel consumption through greater engine or drive train efficiency (reduce weight, use a hybrid drive system, etc.).

2. Use a low carbon fuel such as CNG or Renewable Natural Gas (RNG).

3. Use an energy source that has no tailpipe emissions (Battery Electric or hydrogen) however, these technologies are not yet field proven or durable to the extent that diesel and CNG are, and these energy sources can emit as much GHG as CNG depending on how the hydrogen or electricity is produced.

The first point above is relatively straightforward, since CO_2 production is linked to fuel consumption, any improvement in fuel consumption will provide a similar reduction in CO_2 emissions.

The second point is not as obvious. The products of complete combustion of any hydrocarbon fuel are CO_2 and H_2O, thus if one uses a fuel that is inherently lower in carbon content per unit of energy output, there will be lower CO_2 emissions. This study has included an analysis of the annual and lifecycle GHG reduction associated with the transition from diesel to CNG trucks. In each of the alternatives studied, the 7-year project saving is projected to be 689.7 tonnes CO_2.

Findings-Operating Engineers:

As noted in the 2020 report, there has been some adjustment to the Technical Standards and Safety Authority (TSSA) operating engineer requirements. It is now possible to apply for and receive a waiver from the requirement to staff a site with more than 150 Horsepower of reciprocating compressor(s) in simultaneous operation. This waiver is subject to a review of a safety plan, and further de-regulation is forthcoming.

While these developments are positive and may help with large stations like HSR, with the scaling down of the packer truck project, we are now down to a station size that is under the 150 Horsepower threshold, so this de-regulation does not impact this project--note that Company A is proposing a single 75 horsepower compressor and Company B is proposing two 30 horsepower compressors, so these legacy requirements would not apply in any event.

Conclusions and Recommendations:

1. It is recommended that the City of Hamilton proceed with the CNG project using a Fuel as a Service contracting approach.

2. All of the identified scenarios are technically feasible. Marathon has considered the balance between qualitive and quantitative factors and based on a balanced approach between these two general criteria, Marathon has rank ordered the scenarios by overall desirability are as following:
    1) Company A—Contractor Fuel
    2) Company A—HSR Fuel
    3) Company B—Utility Gas

   The two Company A proposals feature easier deployment and lowest cost. In the case where Company A is contracting for fuel, the cost was lower and can be locked in for the duration of the contract, giving the City more price certainty. This trailer mounted station approach does involve higher operational risk than the other alternatives since the CNG must be trucked to site and there is no redundant compressor on site. Marathon believes that this risk can be mitigated contractually using performance penalties for failure to fuel trucks, combined with an emergency plan to fuel at HSR, if required.

   The Company B approach is in some ways the “best” and lowest risk approach since it includes new, modern, high-capacity equipment that can accommodate both some additional trucks and a longer project life. This station also includes full on-site compressor redundancy. The issue with this approach is its much higher cost.

3. Note that the lead time estimates ranged from 6- to 18-months with a typical/average lead time for the three vendors at 12-months. This was expected for the conventional station solution (Company B) but much longer than expected for the trailer solution (Company A). The reason for the longer lead time with the trailers relates to equipment availability.

4. Enbridge has indicated (during the 2020 study) that the Burlington Street location has ample gas supply, and they are currently proposing an 80-psig delivery pressure.

5. It is estimated that this project will create a savings of 689.7 tonnes CO_2 over the lifecycle of the project --projecting a “green” image for the City.

6. Hamilton’s interest in this “Fuel as a Service” approach is to minimize its infrastructure commitment given the evolving Battery Electric Truck (BET) propulsion technology is still very new and essentially unproven in this application; however, it is expected that BETs will evolve to meet the

operational challenges of a refuse collection fleet. It is unknown when this technology will be sufficiently proven to meet the City's needs, so Marathon strongly recommends that any "Fuel as a Service" RFP and contract be written to provide the City with flexibility in throughput and contract duration both from a capacity and cost perspective. This will allow the City to make additional CNG truck purchases if required.

7. To ensure competitive bidding, the Fuel as a Service RFP will need to be performance/outcome oriented and allow a range of solutions that meet the City's performance needs.

8. Further to the above recommendation, it is strongly recommended that the City include performance penalties on a per truck, per day basis for any trucks not fueled by a rollout deadline (perhaps 5:00 am).

Appendix A

Glossary of Terms

ACH	Air Changes per Hour
AHJ	Authority having Jurisdiction (the regulatory body with the authority to mandate design)
BET	Battery Electric Truck
CH_4	Methane—natural gas is about 90 to 95 percent methane.
CNG	Compressed Natural Gas
CO_2e	Carbon Dioxide Equivalent—a means of comparing other GHGs to CO_2 and also to combine the effects of multiple GHGs to a common unit for simplification of quantification.
DGE	Diesel Gallon Equivalent (the amount of CNG required to provide an amount of energy equal to one USG of diesel fuel).
Discount Rate	This is a percentage used to discount a future value back to a present value to be used in the calculation of the Net Present Value (NPV). The discount rate used is often the borrowing rate, however, it could also be the minimum acceptable rate of return also called the "hurdle rate". This should not be confused with the Internal Rate of Return (IRR) which is the rate at which the project has a net present value of zero—ie the rate at which the project is "breakeven".
ESD	Emergency Shut Down
F	Fahrenheit
GGE	Gasoline Gallon Equivalent (the amount of CNG required to provide an amount of energy equal to one USG of gasoline=5.66 pounds of CNG).
GHG	Greenhouse Gas—CO_2 (Carbon Dioxide), CH_4(methane) and N_2O (Nitrous Oxide) are the most common greenhouse gases.
HP or Hp	Horsepower
HSR	Hamilton Street Railway
HST	Harmonized Sales Tax—the sales tax in place in Ontario. At the time of this report, the City pays a net tax rate of 1.76 percent.
HVAC	Heating Ventilation and Air Conditioning

IR Infrared

LCA Life Cycle Analysis

LEL Lower Explosive Limit (this is 5 percent gas in air by volume—thus 20 percent LEL is 1 percent gas in air by volume)

LNG Liquefied Natural Gas

m^3 Cubic meter of natural gas

NG Natural Gas

NGV Natural Gas for Vehicles or Natural Gas Vehicle (depending on context)

NPV Net Present Value is the value of the project expressed in current dollars. It is calculated by “discounting” the future cost and savings back to current dollars using the “discount rate.”

Payback or Simple Payback is based on a cash flow analysis and is the time (expressed in years in this report) required for the income (or in this case the savings compared to a diesel fleet) to exceed the capital and operating expenditures. Future costs and savings are increased using inflation factors to their value in future years but there is no cost of money or “discount rate” applied) as this is not a Net Present Value. As with all analysis herein, the analysis is based on differential costs and savings only compared to the diesel baseline.

PSI Pounds per Square Inch

PSIG Pounds per Square Inch Gauge (Atmospheric pressure is 0 psig)

RNG Renewable Natural Gas—natural gas sourced from landfills or digesters.

SCF Standard Cubic Feet (the volume of gas within one cubic foot at atmospheric pressure and 60 F)

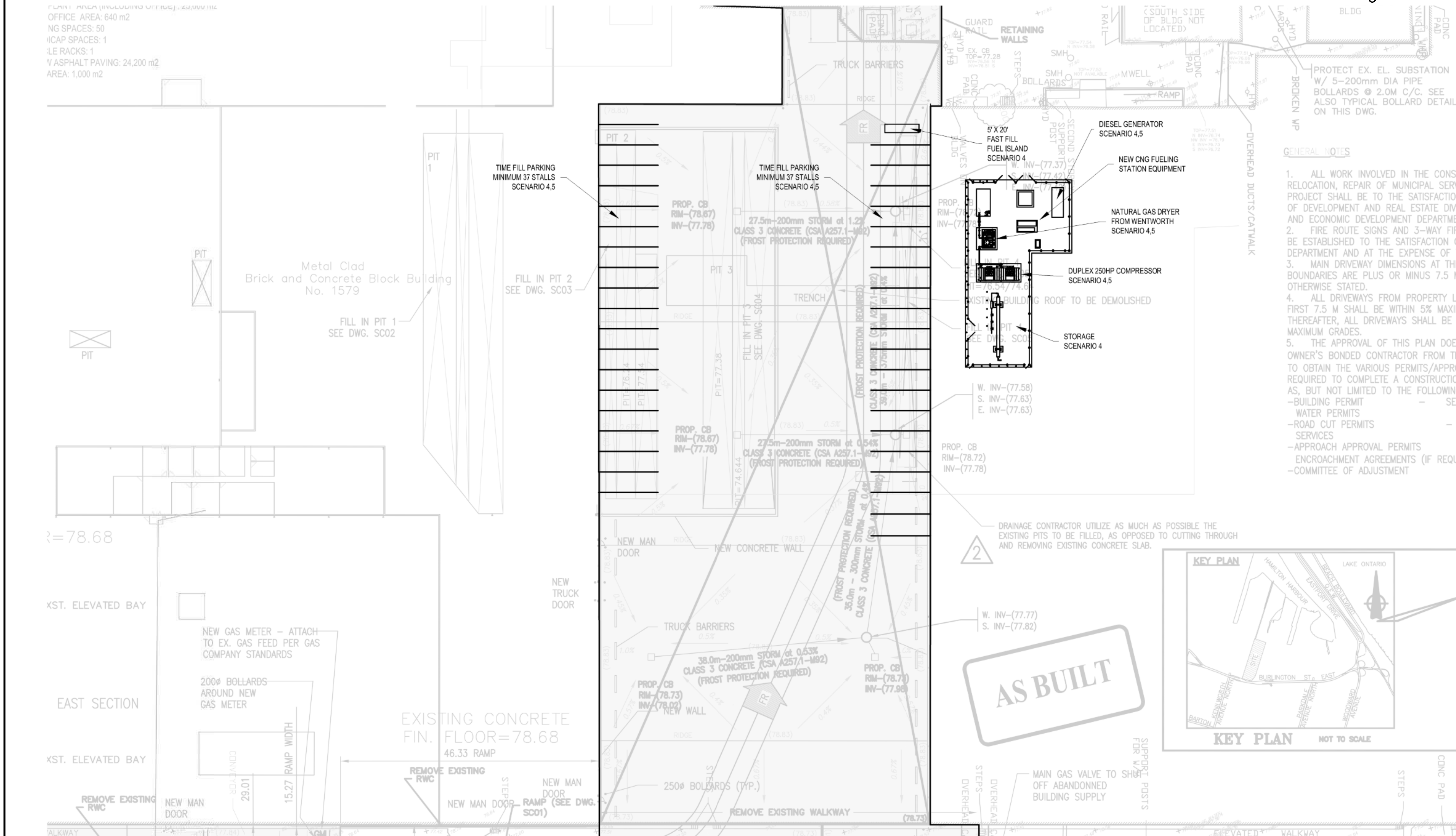
USG US Gallon

VFD Variable Frequency Drive—allows AC motors to operate at part speed.

Appendix B

Site Layout Drawings:

G-02 Hamilton Packer Truck CNG Concept Layout-1579 Burlington St., Hamilton ON



PROJECT ENGR./ARCH:	
DESIGNER:	Robert R. Adams
DRAWN BY:	KH
SCALE:	NTS
DATE:	12/10/2019
CHECKED BY:	
CHECKED/APPROVED BY:	

MarathonTechnical Services
6 Venus Crescent,
Heidelberg, Ontario,
N0B 2M1

REVISIONS

NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D

PROJECT: HAMILTON PACKER TRUCK CNG STATION CONCEPT LAYOUT

SHEET TITLE: 1579 BURLINGTON ST. HAMILTON, ONT.

WORK PROJECT NO.

G-02

Appendix C

Request for Information Provided to Contractors

RFI Excerpt for CNG Station "Fuel as a Service" Concepts:

We have been commissioned to study fueling options for the City of Hamilton. They are interested in exploring fueling strategies that minimize their capital commitment and are therefore looking at options that include compression as a service by a third party.

We are projecting the following project parameters:

1. 271,725 m3 annual throughput for a 7-year period—this is based on a 5-day work week and use 8 hours per day.
2. 80 psig utility pressure.
3. The Contractor would supply, install, permit, operate, maintain and own the station equipment.
4. The facility will/may be removed in 7 years—any costs associated with the removal of the equipment should be included below.
5. The City would prefer that all installation costs be included in the costs of the fuel, however, if there are costs that the City must bear, these should be identified.
6. Assume that sufficient power is available in a building approximately 250 feet from the required location.
7. Do not include any fast fill capability at this time.
8. The attached site drawing was based on a larger project scope—it is provided for general site information only. The site is located at 1579 Burlington Street, Hamilton, ON.

I would like to receive estimated costs by January 22, 2021. Please note that this is an estimate for analysis and budget purposes only. This is not a proposal, quotation or bid. Marathon will provide any information supplied to the City of Hamilton. Please provide the following information:

9. We are anticipating the City installing a 16 truck time fill barricade—is this something you can provide or do we need to supply this?
10. Please identify any capital cost items that the City will incur.
11. What are the infrastructure requirements and space/area required for your system? – please clarify any that are City furnished.
12. Please provide basic equipment specifications including horsepower, amps, scfm, make and model of compressors, dryer and other major equipment, scf of any storage.
13. Is equipment new or used at start of contract?
14. Compressor redundancy is required.
15. Please provide the cost per m3 for:
    a. New gas service from utility.
    b. Capital recovery.
    c. Operation and maintenance.
    d. Any licenses, permits or any other fees.
    e. The price should not include the natural gas commodity or transportation/distribution costs.
    f. The price should not include power costs, but please indicate the size of the motors.
16. What is the annual cost escalation over the seven-year period?

City of Hamilton Compressed Natural Gas (CNG) Packer Truck Funding Repayment

Lender	City of Hamilton
Borrower	City of Hamilton - Public Works (Energy Fleet & Facilities Management)
Purpose	To fund pruchase of CNG Waste Collection Trucks
Funding source	Energy Conservation Initatives (112272)
Report	

Principal Amount	$ 490,000.00
Annual Interest Rate	2.78 %
Loan Term (Year)	7
Debenture Date (mm/dd/yyyy)	12/01/2021
Maturity Date (mm/dd/yyyy)	12/01/2028
Payment Frequency	Annual
Loan Type	Serial

Payment Date	Total Payment	Principal Amount	Interest Amount	Principal Balance
12/01/2022	$ 83,622.00	$ 70,000.00	$ 13,622.00	$ 420,000.00
12/01/2023	$ 81,676.00	$ 70,000.00	$ 11,676.00	$ 350,000.00
12/01/2024	$ 79,730.00	$ 70,000.00	$ 9,730.00	$ 280,000.00
12/01/2025	$ 77,784.00	$ 70,000.00	$ 7,784.00	$ 210,000.00
12/01/2026	$ 75,838.00	$ 70,000.00	$ 5,838.00	$ 140,000.00
12/01/2027	$ 73,892.00	$ 70,000.00	$ 3,892.00	$ 70,000.00
12/01/2028	$ 71,946.00	$ 70,000.00	$ 1,946.00	$ 00.00
	$ 544,488.00	**$ 490,000.00**	**$ 54,488.00**	