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

Submitted To:
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Energy, Fleet & Facilities
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FINAL REPORT

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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.

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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.

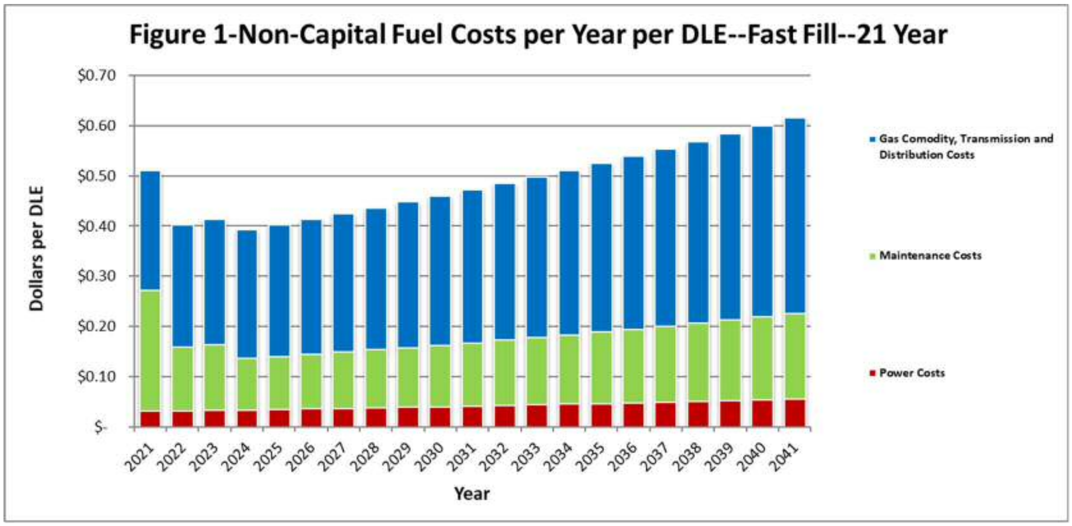
    Marathon has considered the trailer use approach and has developed a lower cost option. To investigate this approach, Marathon proposes to install the new permanent packer truck CNG fast fueling equipment (CNG storage and two new high flow dispensers as well as controls and ancillary equipment) at Wentworth 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 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 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

		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	$ 11,154,085	$ 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

	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	$ 11,734,773	$ 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

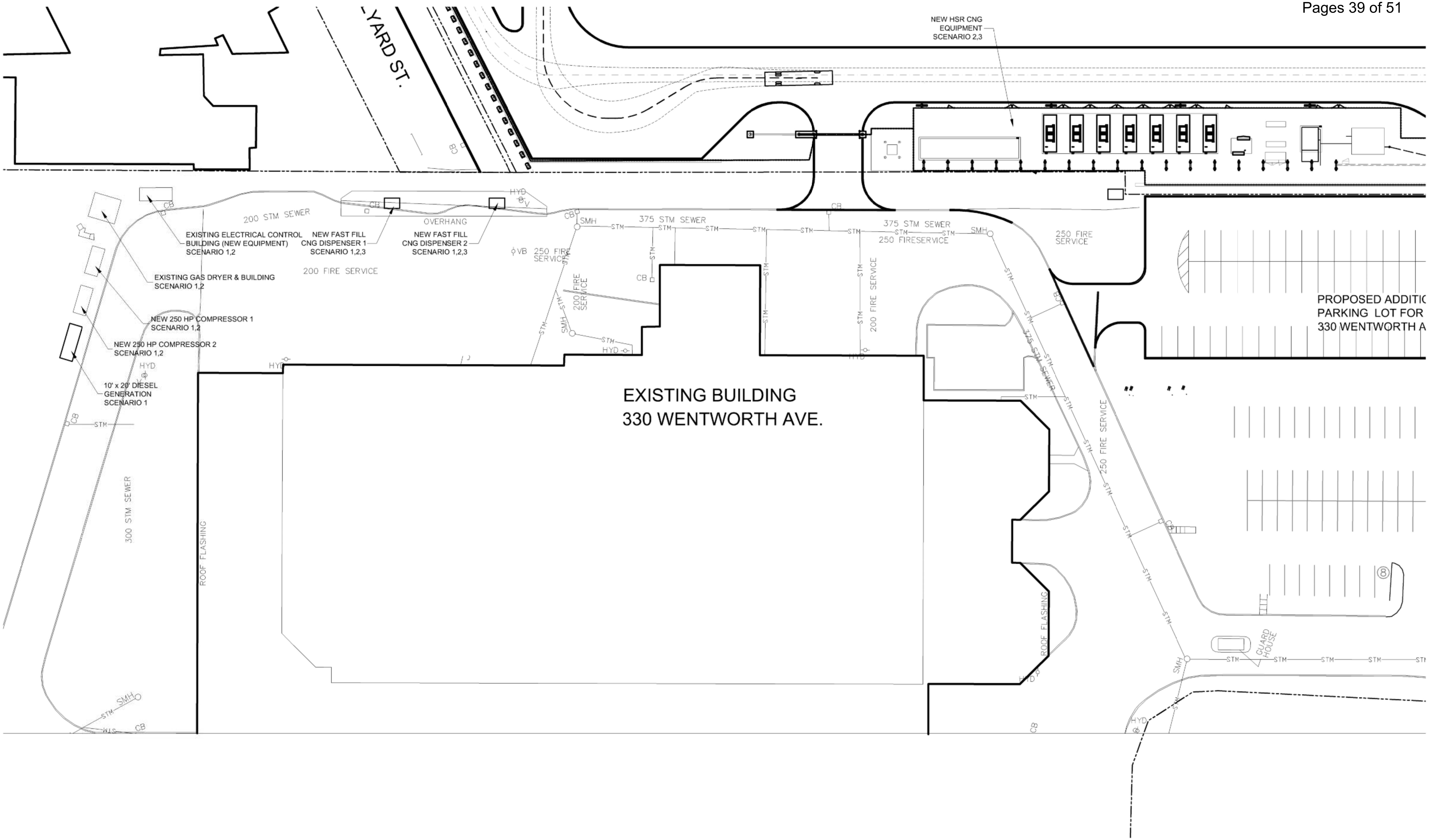
VFD Variable Frequency Drive—allows AC motors to operate at part speed.

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:	

Marathon Technical Services
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Heidelberg, Ontario,
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REVISIONS

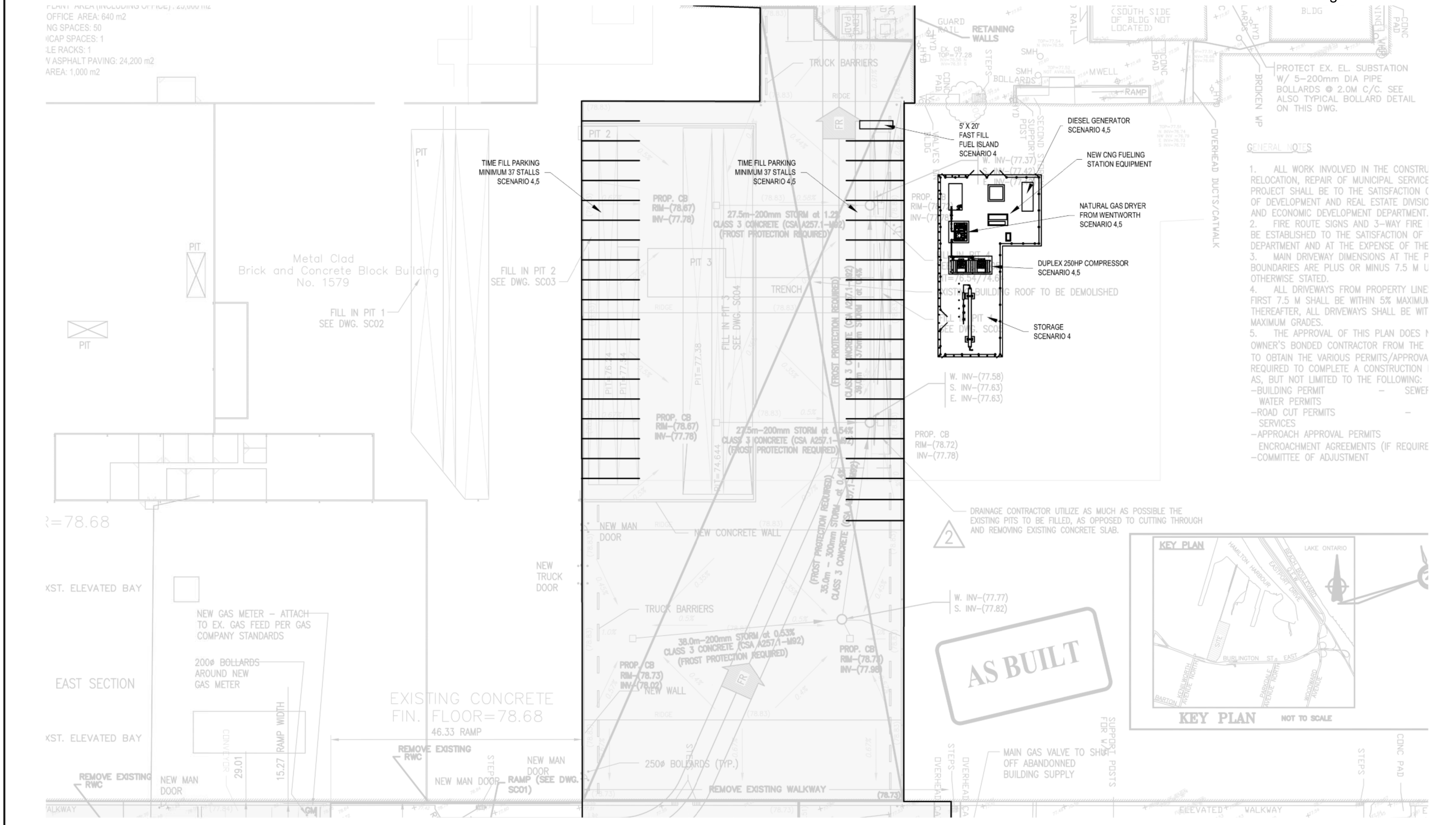
NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D

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:		

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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

Calculation of Vehicle Differential Cost

	Vehicle Purchase and Retirement Schedule	NPV of Vehicle Premium	Vehicle CNG Differential Cost	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	0	0	0	0	0	0	16	0	0	0	0	0	0	16	0	0	0	0	0	0
	Classification 78--Vehicles Retired			0	0	0	0	0	0	0	16	0	0	0	0	0	0	16	0	0	0	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	$ 61,585	$ 63,125	$ 64,703	$ 66,320	$ 67,978	$ 69,678	$ 71,420	$ 73,205	$ 75,036	$ 76,911
	Total Differential Cost			$ 750,989	$ -	$ -	$ -	$ -	$ -	$ -	$ 892,690	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,061,128	$ -	$ -	$ -	$ -	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	**$ 1,921,348**		**$ 750,989**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 634,418**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 535,942**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**
	Classification 157--Vehicles Purchased			0	10	0	0	0	0	0	0	10	0	0	0	0	0	0	10	0	0	0	0	0
	Classification 157--Vehicles Retired			0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	10	0	0	0	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	$ 61,585	$ 63,125	$ 64,703	$ 66,320	$ 67,978	$ 69,678	$ 71,420	$ 73,205	$ 75,036	$ 76,911
	Total Differential Cost			$ -	$ 481,102	$ -	$ -	$ -	$ -	$ -	$ -	$ 571,879	$ -	$ -	$ -	$ -	$ -	$ -	$ 679,785	$ -	$ -	$ -	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	**$ 1,172,251**		**$ -**	**$ 458,193**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 387,070**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 326,988**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**
	Classification 157A--Vehicles Purchased			0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0
	Classification 157A--Vehicles Retired			0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	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	$ 41,057	$ 42,083	$ 43,135	$ 44,214	$ 45,319	$ 46,452	$ 47,613	$ 48,804	$ 50,024	$ 51,274
	Total Differential Cost			$ -	$ 64,147	$ -	$ -	$ -	$ -	$ -	$ -	$ 76,251	$ -	$ -	$ -	$ -	$ -	$ -	$ 90,638	$ -	$ -	$ -	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	**$ 156,300**		**$ -**	**$ 61,092**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 51,609**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 43,598**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**
	Classification 170A--Vehicles Purchased			0	0	0	9	0	0	0	0	0	0	9	0	0	0	0	0	0	9	0	0	0
	Classification 170A--Vehicles Retired			0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	9	0	0	0
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	$ 61,585	$ 63,125	$ 64,703	$ 66,320	$ 67,978	$ 69,678	$ 71,420	$ 73,205	$ 75,036	$ 76,911
	Total Differential Cost			$ -	$ -	$ -	$ 454,912	$ -	$ -	$ -	$ -	$ -	$ -	$ 540,748	$ -	$ -	$ -	$ -	$ -	$ -	$ 642,779	$ -	$ -	$ -
	Cost Differential Recapture on Retirement--assumed $0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	NPV of Total Vehicle Differential Cost	**$ 1,005,385**		**$ -**	**$ -**	**$ -**	**$ 392,970**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 331,972**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 280,442**	**$ -**	**$ -**	**$ -**
	Packer Fleet Total Vehicle Differential Cost			**$ 750,989**	**$ 545,249**	**$ -**	**$ 454,912**	**$ -**	**$ -**	**$ -**	**$ 892,690**	**$ 648,130**	**$ -**	**$ 540,748**	**$ -**	**$ -**	**$ -**	**$ 1,061,128**	**$ 770,423**	**$ -**	**$ 642,779**	**$ -**	**$ -**	**$ -**
	NPV Packer Fleet Total Vehicle Differential Cost			**$ 750,989**	**$ 519,285**	**$ -**	**$ 392,970**	**$ -**	**$ -**	**$ -**	**$ 634,418**	**$ 438,680**	**$ -**	**$ 331,972**	**$ -**	**$ -**	**$ -**	**$ 535,942**	**$ 370,587**	**$ -**	**$ 280,442**	**$ -**	**$ -**	**$ -**
	NPV of Vehicle Cost Differential:	**$ 4,255,284**																						

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

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																					