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

Supplemental Study

Submitted To:
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Energy, Fleet & Facilities
Public Works
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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 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.

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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:

<u>General:</u>

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.

<u>Company A—HSR Fuel</u>

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)

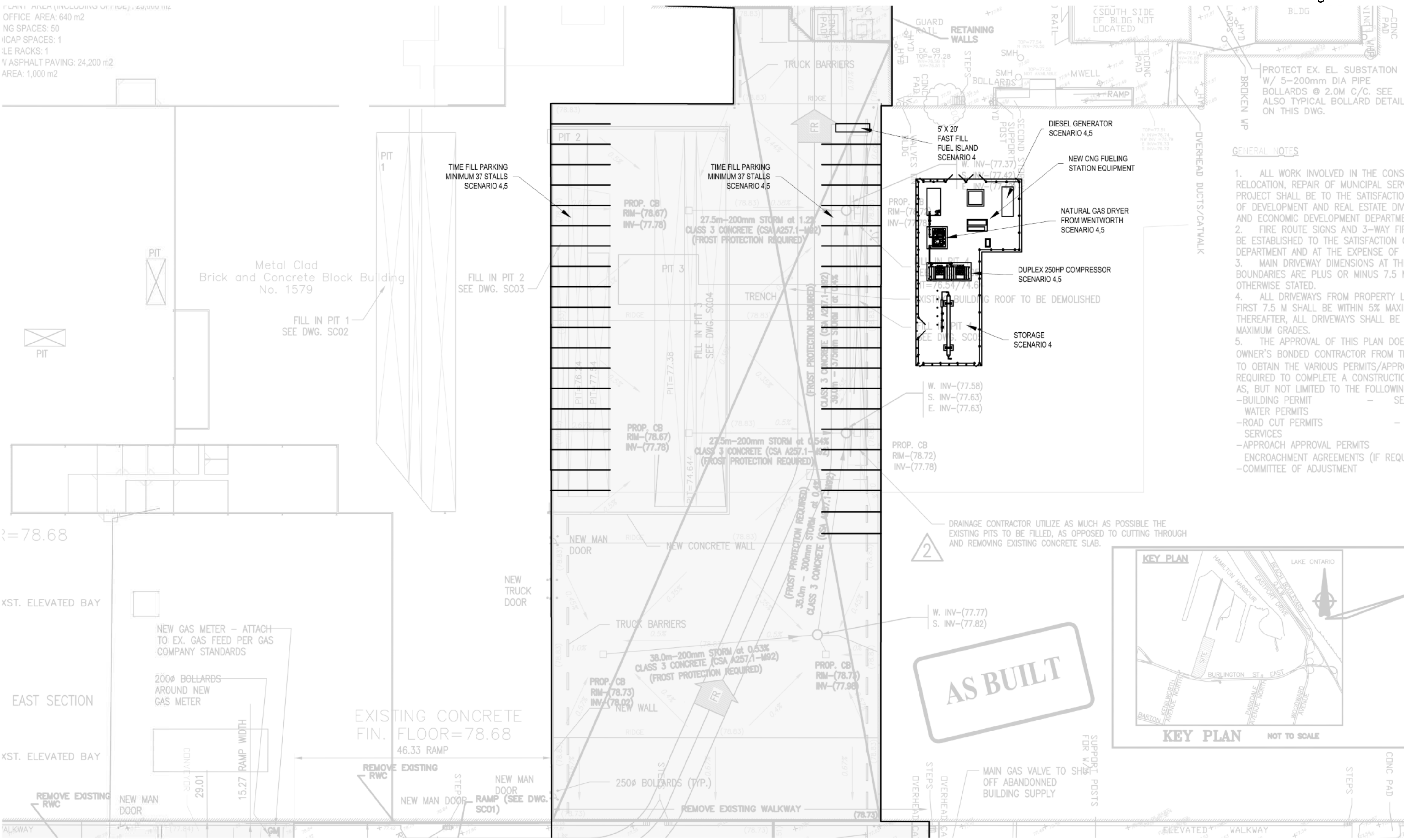
USG US Gallon

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:	
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

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?