2014

Efficiency of Automated Collection and Performance of Compressed Natural Gas Vehicles CIF Project No. 548.11

Submitted by: City of Toronto

Submitted to: Waste Diversion Ontario, Continuous Improvement Fund

Contents

Background

In 2005, Toronto was completing the implementation of its Green Bin program for single family dwellings as well as adding new materials to the recycling program. During this period it became obvious that the former dual stream, blue and grey box system no longer provided enough recycling capacity for residential City customers. Pilot projects were conducted to test different methods to provide additional capacity to residents. The City of Toronto received funding from the Waste Diversion Organization through the Effectiveness and Efficiency Fund program which was the precursor to the Continuous Improvement Fund program (Effectiveness and Efficiency Project #60 – Recycling Container Capacity Pilot).

Four collection routes in the eastern section of the City were used to test a variety of methods of providing extra recycling capacity. The pilot project tested carts (250 litre), weekly collection (single stream recycling was collected bi-weekly prior to the pilot, and co-collected with green bin material), and the provision of clear blue plastic bags. A fourth route acted as the control group. Based on the results of the pilot, staff recommended going forward with a cart system. Through 2007-2008, the City of Toronto replaced the blue and grey recycling boxes with carts for approximately 454,000 single family households. Residents were offered a choice of four size options: small - 75 litres, medium - 130 litres, large - 250 litres and extra large - 360 litres.

In the spring of 2010, CIF issued an REOI identifying various priority projects designated for Best Practice grants including automated collection and large curbside containers. Toronto submitted a request to CIF for automated collection vehicles and additional carts in order to test fully automated natural gas vehicles. CIF approved the City of Toronto funding requests for the purchase of 10,000 recycling bins for ongoing needs for new residents; and the purchase of 46 automated side loading vehicles including 3 natural gas vehicles. The total cost of this initiative was $11.7M with CIF contributing $1.4M.

Project Goal

There were two main project goals:

1. To determine how efficient automated collection of blue bin recyclables is compared to semi-automated collection.
2. To determine how well compressed natural gas (CNG) recycling vehicles perform compared to new diesel vehicles.

Findings

1. Semi-Automated vs. Fully Automated Collection Vehicles

The City of Toronto is organized into four collection districts. Districts 1 and 2 (West of Yonge St.) are collected by "Green For Life" on contract to the City. Districts 3 and 4 are collected by municipal staff.

This project was undertaken in Districts 3 and 4. A total of 21 semi-automated side-loading vehicles were replaced with fully automated side-loading vehicles. Fully automated vehicles cost approximately $70,000 more per vehicle than semi-automated vehicles.

In Toronto, semi-automated vehicles are operated by two staff and fully automated collection vehicles are operated by one staff. The switch from semi to fully automated vehicles was estimated by Operations Management staff to result in an overall efficiency of one staff reduction per route as noted below.

When the City of Toronto implemented its curbside green bin source separated organics (SSO) program (between 2002, and 2005) it moved to a single stream recyclable material stream in order to co-collect two products with one vehicle. Recyclables are collected on alternating weeks with garbage. Thus, recyclables and green bin materials are co-collected one week in a split vehicle, and garbage is co-collected with green bin materials the following week.

In 2008, when the City of Toronto replaced residents' blue boxes with carts, semi-automated split vehicles were used to collect the routes. The single stream recyclables' collection was semi-automated, while the green bins were still emptied manually. (The present generation of green bins are too small to be collected with automation.)

The City's semi-automated vehicles require two staff in order to collect two materials. Toronto estimates indicate that a semi automated vehicle is able to collect from approximately 700 households per route, while a fully automated vehicle is able to collect from approximately 1,300 households per route. However, the routes collected by fully automated vehicles require a second vehicle to pick up the secondary material (green bin SSO) material. Thus for every two routes, a reduction of 2 staff can be achieved. A total staff reduction of 19 was achieved in Districts 3 and 4 due to the use of fully automated vehicles, resulting in an approximate overall operational savings of $1,425,000 annually.

The City purchased vehicles through two separate tenders. This resulted in two different lifters being used on the vehicles purchased by the City. One lifter is manufactured by Labrie and can extend 12 feet in length and is powered via electricity. The other lifter is manufactured by McNeilus and can extend nine feet in length and is powered via an air-over hydraulics system. Staff feedback and experience indicates that the electrically powered lifters operate more smoothly than the air over hydraulic powered lifters.

Figure 1: McNeilus lifter

A table comparing fuel and maintenance costs for semi and fully automated vehicles can be found below in Table 1: Semi Automated vs. Fully Automated Vehicle Comparison.

Table 1: Semi Automated vs. Fully Automated Vehicle

Variable	Semi-Automated Vehicle	Fully Automated Vehicle
Recycling route size	700 hhs	1,300 hhs
Capital cost	$188,835	$262,000
Repair and maintenance costs	$20,160	$32,200
Vehicle volume	25 cy	27 cy
Fuel cost average per year	$201,352	$142,455

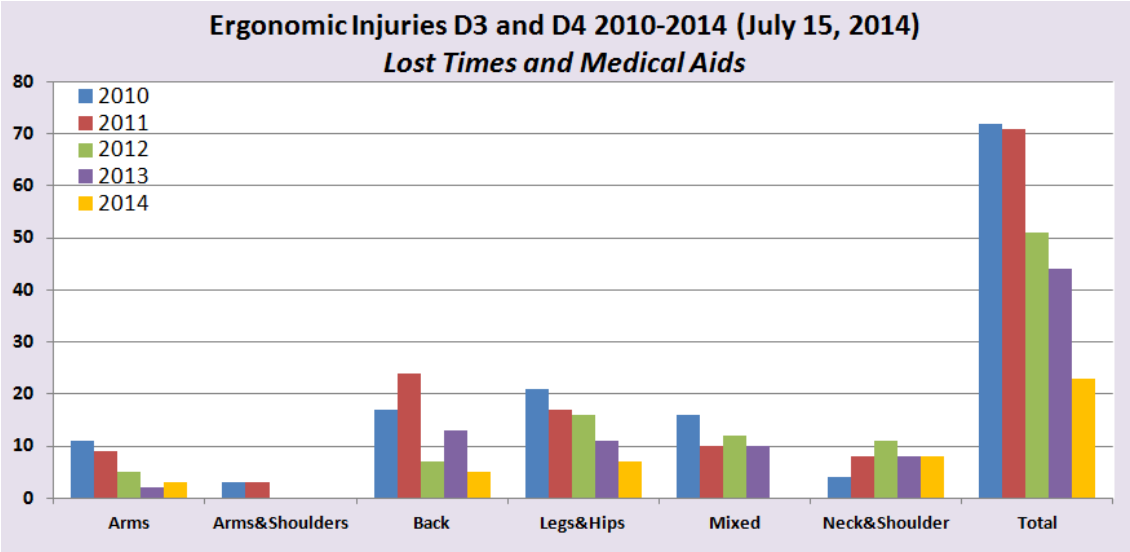
Operator preference between the semi automated and fully automated vehicles was more a factor of individual staff inclinations rather than operational factors to do with the vehicles. For example, some staff prefer to work on their own, some prefer to be more active, some don't like to do a lot of lifting and lastly some staff prefer operating the fully operated vehicles.

Health and Safety

Staff injury reports are not tracked by vehicle number by the City of Toronto. This prevents the City from being able to identify any trends related injuries on fully automated vs. semi automated vehicles as they were added to the fleet.

Automated vehicles eliminate the need for workers to manually empty garbage bins. This reduces a significant amount of the manual-material-handling ergonomic risk from the job activities of residential curbside collection. Since the introduction of automated vehicles in 2011, there has been a steady decrease in ergonomic related injuries in D3 and D4. This validates the overall ergonomic injury risk reducing benefits of automated vehicles.

Chart 2: Ergonomic Injuries in D3 and D4 (2010 – 2014) July 15, 2014



Compressed Natural Gas (CNG) Vehicles vs. Diesel Vehicles

Compressed natural gas is methane stored at high pressure which can be used in place of gasoline or diesel. CNG combustion produces fewer undesirable gases than gas or diesel.

The number of vehicles in the world using CNG has grown steadily (30 percent by year) (Wikipedia). The growth in use of CNG vehicles will result in the reduction of costs for the fuel storage tanks. Fueling issues will be discussed later in the report.

Some of the advantages of CNG:

- CNG does not contain lead
- CNG powered vehicles have lower maintenance costs than other hydrocarbon-fuel-powered vehicles
- CNG fuel systems are sealed- preventing fuel losses from spills
- Increased life of lubricating oils (CNG does not contaminate and dilute crankcase oil)
- Less pollution and more efficiency: CNG emits significantly fewer pollutants such as carbon dioxide, unburned hydrocarbons, carbon monoxide, nitrogen oxides, sulfur oxides and particulate matter
- An engine running on gasoline for 100 km emits 22 kg CO2 while the CNG engine emits only 16.3 kilograms of CO2 - thus switching to CNG can help reduce greenhouse gas emissions.

CNG vehicles require a greater amount of space for fuel storage than conventional gasoline powered vehicles. This means the vehicles are larger and can be harder to manoeuvre.

CNG vehicles cost approximately $25,000 more than diesel vehicles. According to the City's Fleet Services, it takes 1.5 to 2 years of fuel cost savings to recover the premium cost of the CNG vehicles.

For the purposes of comparison, statistics from 2 similar vehicles are shown in Table 2 below.

Table 3: CNG vs. Diesel Vehicle

Factor	Diesel - Unit #237117 (28,944km)	CNG - Unit #237118 (32,772km)
Fuel Cost	$22,490 (see note 1)	$17,290 (see note 1)
Time to Fuel	5 min to pump	1 hr/day (20 min fuel, 20 min travel (see note 2)
Fuel Capacity	189 liters/50 US gallons	3 tanks equal to 75 gallons
Fueling Frequency	Once a day	Could be more than 1/day
Fuel Availability	available	Pending legal agreement
Frequency of filter changes	Once per year	Once per year
Operating Costs	Total maintenance cost $66,434.60 (see note 3)	Total maintenance cost $51,270.67
Operating Efficiencies	No significant difference	No significant difference
Issues	both vehicles operate slower in cold weather	both vehicles operate slower in cold weather
Vehicle Cost	$262,000	$ 330,000

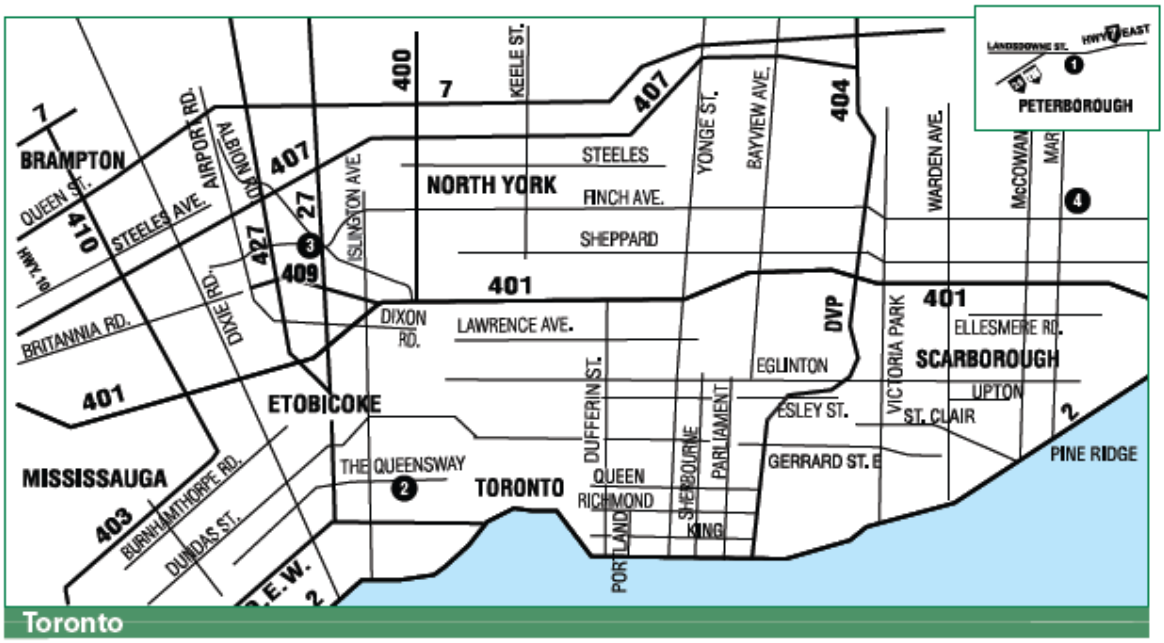
Notes:

1. Diesel fuel at 1.01/litre or 1.73/km based on 13,000 km/year in 2011, CNG fuel at 0.49 per cubic meter or $1.33/km based on 13,000 km/year in 2011.
2. Once SWMS has its own fueling station, the vehicles can be "slow fueled" overnight, which will eliminate the fueling delays.
3. This includes the cost of maintaining the Diesel Emission Fluid (DEF) regeneration system.

It was found that there were no significant operating issues or differences in operating efficiencies between the diesel and CNG vehicles. The capacity and horsepower are the same for both and the main maintenance issue for both vehicles are with the lifting arms. The lifting arms are the main cause of unscheduled maintenance.

The main challenge the City of Toronto experienced with the CNG vehicles was one of fuel availability and fueling time. In May of 2011, Shell closed 13 natural gas fueling locations in the GTA. Presently, there are a limited number of fueling stations, see map below:

Figure 2: Enbridge Ontario Natural Gas Public Refueling Stations



Greater Toronto Area

1 Kiff Auto
Hwy 7 East
Peterborough, Ontario
4 km East of Peterborough (Hwy 115) on Hwy 7
705-749-1805
Hrs. of Operation: Mon-Fri 8-5, Sat 8-12, Closed Sundays
24 hr. Card Lock access
NGV Conversion/Service Station

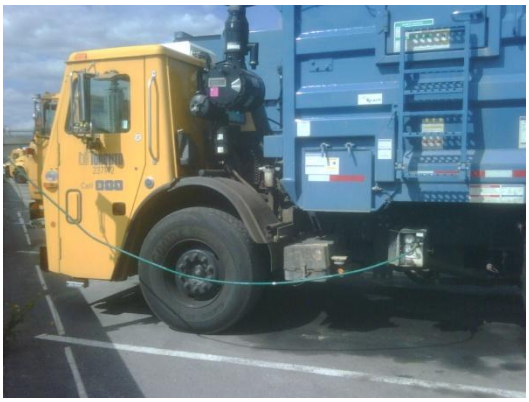
2 OLCO Queensway Car Wash
875 The Queensway
Etobicoke, Ontario
East of Islington on South side of The Queensway
Exit #142 off QEW, North onto Islington
416-251-4712
Hrs. of Operation: Mon-Fri 7-9, Sat 7:30-8, Sun 8-6

3 Shell
1765 Albion Road
Etobicoke, Ontario
Southeast corner of Albion Road and Hwy 27
Exit Hwy 427 at Finch Ave., East to Hwy 27, North to Albion Rd.
416-674-8665
Hrs. of Operation:
Mon-Sat 5:30-10, Sun 7:30-10

4 KMC
2671 Markham Road
Scarborough, Ontario
½ km North of Finch Avenue on the East side
Exit #383 off Hwy 401, North onto Markham Rd.
416-754-2658
Hrs. of Operation: Mon-Fri 7-6, Sat 8-12, Closed Sunday
24 hr. Card Lock access
Sea NG Fill ups

City of Toronto CNG vehicles are fueling at KMC Vehicle Scale and Fuels at 2671 Markham Road. To improve fueling and operating efficiencies, Solid Waste Management Services undertook the installation of a CNG fueling station at its Ellesmere Yard (Ellesmere Road and Midland Avenue, Collection District 4). The fueling station was completed in February of 2013. Since February 2013, the City of Toronto has been in the process of finalizing an agreement with Enbridge Gas Distribution Inc. and the fueling station has not been activated to date. The agreement has recently been signed on June 19, 2014. At the writing of this report, it is anticipated that the fueling station will be activated sometime in August of this year.

Figure 3: Solid Waste Management Vehicles Fueling at KMC



Once the fueling station at Ellesmere is activated and becomes operational, huge time savings in refueling will be realized. Currently, the CNG vehicles fuel up at KMC using the "Fast-Fill" system. However, this only allows the tank to fill to 60% of its capacity, as it is set up to fuel vehicles and quickly get them back on the road. By having a fueling station in a City yard, the vehicles will be able to use the "Slow-Fill" overnight fueling, which allows for 100% fuel capacity. The vehicles are then ready to go on the road in the morning and do not need refueling again during the day. Fueling will then no longer take up regular operational time. The Enbridge fuel rental station will cost approximately $4,000 per year.

Figure 4: Ellesmere Yard CNG Fuelling Station

Thus, it has been a lengthy process from the time discussions were initiated regarding the installation of a fueling station at one of the Solid Waste Management yards, to the signing of the agreement with Enbridge, and finally to the activation of the fueling station.

Based on discussions with Enbridge staff, the City of Toronto is one of the first municipalities to undertake the installation of a CNG fueling station at one of its works yards. Based on the work with City of Toronto, Enbridge now has a standard agreement that will ensure that other municipalities moving forward to install CNG fuel stations will not have the same time delays. Enbridge staff has indicated that it should now take only 8 months from time of order to installation and activation of a CNG fuelling station.

Summary and Conclusions

Fully Automated Vehicles

Fully automated vehicles cost approximately $73,000 more per vehicle than semi-automated vehicles. With Toronto's collection methodology (recyclables and green bin organics on the same day one week, garbage and green bin organics on the same day on alternating weeks) collection operations was able to achieve an overall efficiency of two staff reductions for every two routes amounting to a savings of $1,425,000 annually. To purchase 46 fully automated vehicles cost $3,358,000 more than purchasing 46 semi-automated vehicles, thus with the staff savings of $1,425,000 annually, the payback is a period of 2.4 years.

Repair and maintenance costs were modestly higher for fully automated vehicles, whereas fuel costs were less. The most significant saving, however, was realized due to reductions in staff.

Since the introduction of automated vehicles in 2011, there has been a steady decrease in ergonomic related injuries in D3 and D4. This validates the overall ergonomic injury risk reducing benefits of automated vehicles.

As Solid Waste Management Services replaces collection vehicles in its fleet, fully automated vehicles will replace semi-automated vehicles in those areas of the City where fully automated vehicles can be used. Older areas of the city closer to the downtown core will stay on semi-automated collection due to collection challenges such as narrow streets, on-street permit parking, one-way streets, and alley and rear laneway collection.

Compressed Natural Gas Vehicles

While compressed natural gas vehicles currently cost more than diesel, the cost can be recovered within 1.5 to 2 years due to savings in fueling costs. Other than significant gains in reduced fueling costs, no major differences in operating cost and operating efficiencies were found. Due to the need for larger fuel storage space versus conventional vehicles, the compressed natural gas vehicles can be larger and harder to manoeuvre.

Compressed natural gas has many environmental benefits including less pollution, and reduced greenhouse gasses. The main disadvantage experienced was due to a lack of fueling stations and the time required to fuel. Once the compressed natural gas fueling station at Ellesmere Yard is operational, fueling time delays will no longer be an issue.

The City of Toronto currently operates three compressed natural gas vehicles and is in the process of purchasing two more this year. There are plans to purchase three more compressed natural gas vehicles in 2015, and each year we will continue to purchase a percentage of compressed natural gas vehicles to add to our fleet.