Rapid Transit Implementation Working Group

Report

4th Meeting of the Rapid Transit Implementation Working Group
July 5, 2018
Council Chambers

Attendance

PRESENT: S. Rooth (Chair), Mayor M. Brown, Councillors J. Helmer, and H.L. Usher; D. Sheppard and E. Southern, and B. Westlake-Power (Acting Secretary).

ABSENT: Councillors P. Hubert , T. Park, M. van Holst and P. Squire.

ALSO PRESENT: A. Kemick, K. Paleczny, A. Rammeloo, J. Ramsay, M. Ribera, A. Rosebrugh and K. Scherr.

The meeting was called to order at 4:59 PM.

1. Call to Order

1.1 Disclosures of Pecuniary Interest

That it BE NOTED that no pecuniary interests were disclosed.

2. Scheduled Items

2.1 J. Ramsay, Project Director - Bus Rapid Transit Project Updates

That it BE NOTED that the Bus Rapid Transit Project Update presentation from J. Ramsay, Project Director, as included on the July 5, 2018 Rapid Transit Implementation Working Group Agenda, was received.

2.2 Josipa Petrunic - Executive Director and CEO of the Canadian Urban Transit Research and Innovation Consortium (CUTRIC)

That it BE NOTED that the attached presentation from J. Petrunic, Executive Director and CEO of the Canadian Urban Transit Research and Innovation Consortium (CUTRIC), with respect to the Pan-Canadian Electric Bus Demonstration and Integration Trial: Phase I, was received.

3. Consent

3.1 3rd Report of the Rapid Transit Implementation Working Group

That it BE NOTED that the 3rd Report of the Rapid Transit Implementation Work Group, from its meeting held on March 8, 2018, was received.

4. Items for Discussion

4.1 Briefing Package - Upcoming Public Consultation for London's Bus Rapid Transit System

That it BE NOTED that the Briefing Package with respect to the Upcoming Public Consultation for London's Bus Rapid Transit System, from J. Ramsay, Project Director, was received.

5. Deferred Matters/Additional Business

5.1 Update on Proposed Audit - Rapid Transit Project

That it BE NOTED that a verbal update from K. Scherr, Managing Director Environmental & Engineering Services and City Engineer, with respect to the rescheduling of the proposed internal audit of the Rapid Transit Project, on the recommendation of the outsourced internal auditor, was received; it being noted that the adjusted schedule is expected to better align to milestones the audit was originally matched to.

6. Adjournment

The meeting adjourned at 6:19 PM.

Pan-Canadian Electric Bus Demonstration and Integration Trial: Phase I

Dr. Josipa Petrunic
Canadian Urban Transit Research and Innovation Consortium (CUTRIC)
Consortium de Recherche et d'Innovation en Transport Urbain au Canada (CRITUC)

Pan-Canadian Electric Bus Demonstration & Integration Technology Trial: Outcomes Phases I, II, III

Phase I ($45 M)
- Standardization and Interoperability using OppCharge Protocol
- 3 Transit systems, 1 utility and 4 OEMs
- 18 electric bus and 7 450 kW electric chargers

Phase II ($110 M)
- 12 chargers (450-600 kW), 4+ energy storage devices, 60 E-buses, 8 new Transit systems
- Novel P3 funding options
- Integrating SAE J3105 opportunity standard and SAE J3068 depot charging

Phase III
- Automated charging of the vehicle
- Automated platooning of the vehicle to align with the electric charger
- Adding more Transit agencies

Pan-Canadian Electric Bus Demonstration and Integration Trial: Phase I: Project Planning and Launch **Video**

Project Partners: Phase I (2017 – 2020)

NEW FLYER, NOVA BUS Driven by your city, ABB, SIEMENS, TRANS LINK, BC Hydro, Newmarket Hydro, Brampton Transit, VIVA, GHG Reductions, Transit as Innovators, Jobs in Canada, St. Clair College, Canada NRC·CNRC, University of Ontario Institute of Technology, University of Victoria, UBC, UQTR, Centennial College, Conestoga, Brock University, Red River College

Pan-Canadian Electric Bus Demonstration & Integration Trial: Phase I


Green Car Congress

CUTRIC launches $40M Pan-Canadian electric bus trial

Technologies in Focus for E-Bus Phase II

Buses

Chargers

Energy storage media

Transit Partners for E-Bus Phase II

Prospective OEM and Utility Partners for Phase II

ecamion
BC Hydro
tm4 Electrodynamic Systems
alectra utilities
Nova Scotia POWER An Emera Company
NEW FLYER
ABB
NEWMARKET Hydro
Newmarket-Tay Power Distribution Ltd.
PROTERRA
VIRICITI
NOVA BUS
SIEMENS
STORNETIC The Energy Storage Company

Prospective Academic Partners for Phase II

St. Clair College
Centennial College
Conestoga
University of Victoria
University of Ontario Institute of Technology
SFU Simon Fraser University Engaging the World
University of Windsor
UQTR Université du Québec à Trois-Rivières
Brock University

Scope for E-Bus Phase II

Expansion
- At least eight new transit agencies
- Eight buses and two standardized overhead chargers per new agency

Technical Focus
- Higher power (450-600 kW) overhead chargers standardization
- Adoption of high power (150 kW) in-depot charging standard SAEJ3068
- Energy storage standardization and demonstration

Knowledge generation
- Addressing key skill gaps in training and academic programming
- Constituting academic advisory committee and elevating it to a Centre of Excellence

Techno-economic modelling of an electric bus demonstration project in London Ontario Fast Transit Route "7" & "L"

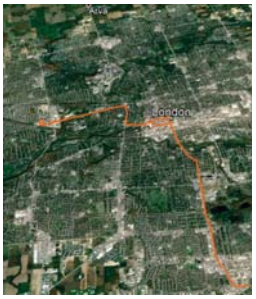
Anaissia Franca
Dr. Yutian Zhao
Dr. Garret Duffy
Dr. Anahita Jami
Dr. Josipa Petrunic
Canadian Urban Transit Research and Innovation Consortium (CUTRIC)
Consortium de recherche et d'innovation en transport urbain au Canada (CRITUC)
July 5th, 2018

Outline

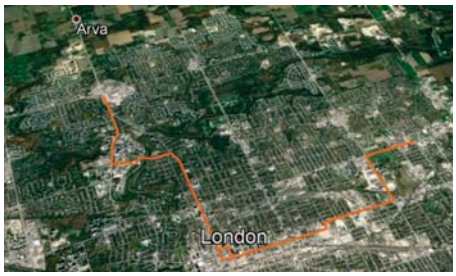
- Routes and duty cycles
- E-bus energy consumption and SOC calculations
- Charging infrastructure simulation
- Comparative simulation of diesel bus fuel consumption
- Electricity costs estimations, simulation results and emissions calculation for each route
- GHG emission savings

Routes and duty cycles

Route "7" map (28.6 km RT)



Route "L" map (29.2 km RT)



Route statistics

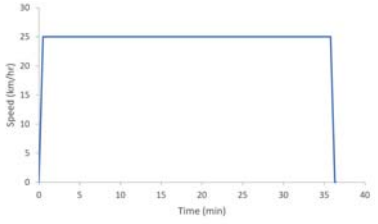
Name of route	Length of the route round trip (km)	Estimated time to complete the route round trip (min)
London route "7"	28.6	~ 70
London route "L"	29.2	~ 70

Model the route elevation profile & topography

- Used Google Earth to define the path (.kml files)
- Calculated the distances between the nodes
- Used a DEM (Digital Elevation Model) database to obtain the raw data for elevations
- Used filtration/smoothing to obtain realistic road grades (multiple steps of Savittzky-Golay filter)

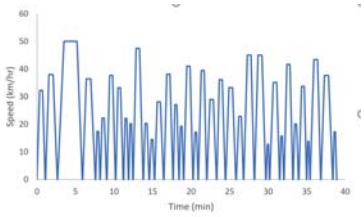
Route L (29.2 km RT) - Duty cycles development

- Light duty cycle (1 driver, no auxiliary load)
  - Constant velocity, no stop



Route L (29.2 km RT) - Duty cycles development

- Medium duty cycle (half full passenger load, half auxiliary load)
  - Stop for all scheduled (major) bus stops
  - Additional stops at 50 % of other stops: randomly selected from all the traffic lights, stops signs, passenger walks and other (unscheduled) bus stops



Route L (29.2 km RT) - Duty cycles development

- Heavy duty cycle (full passenger load, full auxiliary load)
  - Stop for all bus stops (scheduled/unscheduled), traffic lights, stop signs and additional stopping for pedestrians

E-bus energy consumption and SOC calculations

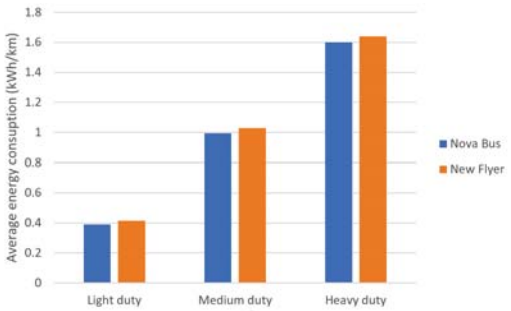
Key variables affecting the energy consumption

- Weight of the vehicle
- Auxiliary load
- Tire rolling coefficient
- Regenerative braking usage
- Gear ratio

Ebus energy consumption and charging power calculations

- Used in-house Matlab and Python code
- Physical characteristics of 12m New Flyer XE40 and a 12m Nova Bus LFSE
- Accounted for variation in topography
- Regenerative braking power split: 35%
- Constant accessory draw
  - Heavy duty cycle: 10,000 W
  - Medium duty cycle: 5,000 W
  - Light duty cycle: 0 W

Average energy consumption Route "7" (28.6 km RT) with Nova Bus (76 kWh) & New Flyer (200 kWh)



State of Charge (SOC) - Route “7” (28.6 km RT) with Nova Bus (76 kWh)

	South to West				West to South			
	kWh per km	Total kWh used	SOC at route end		kWh per km	Total kWh used	SOC at route end	
			5 % buffer	10% buffer			5 % buffer	10 % buffer
Light duty	0.4	5.79	87.0%	82.0%	0.38	5.45	87.5%	82.5%
Medium duty	0.99	14.29	75.2%	70.2%	1.0	14.3	75.2%	70.2%
Heavy duty	1.6	23.04	63.1%	58.1%	1.6	23.0	63.1%	58.1%

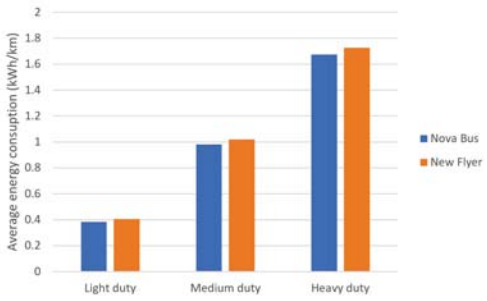
Note: Ideal battery initial SOC = 100%, 5 % buffer initial SOC = 95%, 10 % buffer initial SOC = 90 %

State of Charge (SOC) - Route “7” (28.6 km RT) with New Flyer (200 kWh)

	South to West				West to South			
	kWh per km	Total kWh used	SOC at route end		kWh per km	Total kWh used	SOC at route end	
			5 % buffer	10% buffer			5 % buffer	10 % buffer
Light duty	0.43	6.12	91.8%	86.8%	0.4	5.73	92.0%	87.0%
Medium duty	1.03	14.82	87.2%	82.2%	1.03	14.76	87.2%	82.2%
Heavy duty	1.64	23.63	82.6%	77.6%	1.64	23.58	82.6%	77.6%

Note: Ideal battery initial SOC = 100%, 5 % buffer initial SOC = 95%, 10 % buffer initial SOC = 90 %

Energy consumption Route “L” (29.2 km RT) with New Flyer (200 kWh)



State of Charge (SOC) - Route “L” (29.2 km RT) with Nova Bus (76 kWh)

	East to North direction				North to Easts direction			
	kWh per km	Total kWh used	SOC at route end		kWh per km	Total kWh used	SOC at route end	
			5 % buffer	10% buffer			5 % buffer	10 % buffer
Light duty	0.35	5.17	87.8%	82.8%	0.42	6.1	86.5%	81.5%
Medium duty	0.95	13.94	75.7%	70.7%	1.01	14.79	74.5%	69.5%
Heavy duty	1.66	24.19	61.5%	56.5%	1.69	24.74	60.7%	55.7%

Note: Ideal battery initial SOC = 100%, 5 % buffer initial SOC = 95%, 10 % buffer initial SOC = 90 %

State of Charge (SOC) - Route “L” (29.2 km RT) with New Flyer (200 kWh)

	East to North direction				North to Easts direction			
	kWh per km	Total kWh used	SOC at route end		kWh per km	Total kWh used	SOC at route end	
			5 % buffer	10% buffer			5 % buffer	10 % buffer
Light duty	0.37	5.45	92.1%	87.1%	0.44	6.45	91.6%	86.6%
Medium duty	0.99	14.41	87.4%	82.4%	1.05	15.27	87.0%	82.0%
Heavy duty	1.71	24.91	81.9%	76.9%	1.74	25.44	81.6%	76.6%

Note: Ideal battery initial SOC = 100%, 5 % buffer initial SOC = 95%, 10 % buffer initial SOC = 90 %

Charging infrastructure simulation

Electricity demand – Route “7” (28.6 km RT) Nova Bus (76 kWh) 450 kW charger

	South to West direction						West to South direction					
	Ideal charging 100 %		Typical efficiency 86 %		Worst case efficiency 71%		Ideal charging 100 %		Typical efficiency 86 %		Worst case efficiency 71%	
	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Endpoint charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)
Light duty	0.77	5.79	**0.89**	6.7	1.09	8.16	0.73	5.45	**0.84**	6.31	1.02	7.68
Medium duty	1.91	14.31	**2.21**	16.55	2.69	20.15	1.91	14.32	**2.21**	16.56	2.69	20.16
Heavy duty	3.08	23.07	**3.56**	26.68	4.33	32.49	3.07	23.02	**3.55**	26.63	4.32	32.43

Note: Ideal charging: the energy from the grid goes straight to the battery
Typical efficiency: 86% of the energy from the grid goes to the battery (91% charger efficiency, 95 % battery management system efficiency)
Worst case efficiency: 71% of the energy from the grid goes to the battery

Electricity demand – Route “7” (28.6 km RT) New Flyer (200 kWh) 450 kW charger

	South to West direction						West to South direction					
	Ideal charging 100 %		Typical efficiency 86 %		Worst case efficiency 71%		Ideal charging 100 %		Typical efficiency 86 %		Worst case efficiency 71%	
	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Endpoint charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)
Light duty	0.82	6.12	**0.94**	7.08	1.15	8.63	0.77	5.74	**0.89**	6.64	1.08	8.08
Medium duty	1.98	14.84	**2.29**	17.16	2.79	20.9	1.97	14.77	**2.28**	17.08	2.77	20.8
Heavy duty	3.15	23.65	**3.65**	27.36	4.44	33.31	3.15	23.61	**3.64**	27.31	4.43	33.25

Note: Ideal charging: the energy from the grid goes straight to the battery
Typical efficiency: 86% of the energy from the grid goes to the battery (91% charger efficiency, 95 % battery management system efficiency)
Worst case efficiency: 71% of the energy from the grid goes to the battery

Electricity demand – Route “L” (29.2 km RT) Nova Bus (76 kWh) 450 kW charger

	East to North direction						North to East direction					
	Ideal charging 100 %		Typical efficiency 86 %		Worst case efficiency 71%		Ideal charging 100 %		Typical efficiency 86 %		Worst case efficiency 71%	
	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Endpoint charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)
Light duty	0.69	5.17	**0.8**	5.98	0.97	7.28	0.81	6.11	**0.94**	7.06	1.15	8.6
Medium duty	1.86	13.96	**2.15**	16.15	2.62	19.66	1.97	14.8	**2.28**	17.13	2.78	20.85
Heavy duty	3.23	24.21	**3.73**	28.0	4.55	34.1	3.3	24.76	**3.82**	28.64	4.65	34.88

Note: Ideal charging: the energy from the grid goes straight to the battery
Typical efficiency: 86% of the energy from the grid goes to the battery (91% charger efficiency, 95 % battery management system efficiency)
Worst case efficiency: 71% of the energy from the grid goes to the battery

Electricity demand – Route “L” (29.2 km RT) New Flyer (200 kWh) 450 kW charger

	East to North direction						North to East direction					
	Ideal charging 100 %		Typical efficiency 86 %		Worst case efficiency 71%		Ideal charging 100 %		Typical efficiency 86 %		Worst case efficiency 71%	
	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Endpoint charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)	Charging time (min)	Energy from the grid (kWh)
Light duty	0.73	5.46	**0.84**	6.31	1.03	7.69	0.86	6.46	**1.0**	7.47	1.21	9.09
Medium duty	1.92	14.43	**2.23**	16.69	2.71	20.32	2.04	15.28	**2.36**	17.68	2.87	21.53
Heavy duty	3.32	24.93	**3.85**	28.84	4.68	35.12	3.4	25.47	**3.93**	29.46	4.78	35.87

Note: Ideal charging: the energy from the grid goes straight to the battery
Typical efficiency: 86% of the energy from the grid goes to the battery (91% charger efficiency, 95 % battery management system efficiency)
Worst case efficiency: 71% of the energy from the grid goes to the battery

Comparative simulation of diesel bus fuel consumption

Fuel consumption simulation – New Flyer 2013 XD35

- Used Python code developed in-house, based on work from [1]

Vehicle parameters	Value	Unit
Vehicle curb weight	11,113	kg
Mean passenger weight	75	kg
Maximum passengers	65	-
Engine maximum power	209	kW
Drivetrain efficiency	95	%
Rolling coefficient	Provided by OEM	-

Fuel parameters	Value	Unit
LHV of low sulfur diesel	42.6	MJ/kg
Diesel density	850	kg/m^3
CO_2 content of fuel *	2.630	kg CO_{2e}/L fuel

*Note: emission factors for mobile fuel combustion of diesel in heavy-duty vehicles, see [2]

[1] W. Edwardes and H. Rakha “Modeling Diesel and Hybrid Bus Fuel Consumption with Virginia Tech Comprehensive Power-Based Fuel Consumption: Model Enhancements and Calibration Issues Model”. Transportation Research Record: Journal of the Transportation Research Board, No. 2533
[2] BC Ministry of Environment “2016/17 B.C. Best practices Methodology for quantifying greenhouse gas emissions” Victoria, May 2016

Fuel consumption - Route "7" (28.6 km RT)

Runs (Round trips) per week to compare with fast charging: 744

	Light-Duty	Medium-Duty	Heavy-Duty
Fuel used per run (round trip) per bus (L)	6.4	10.9	16.1
Fuel efficiency of diesel equivalent (L/100km)	22.3	37.9	56.1
Emitted CO2e per year (kg)	656,227	1,114,254	1,646,306
Cost of diesel per year @$0.9116/L ($) *	$227,459	$386,218	$570,636

* Note: $0.9116/L based on London Transit's average fuel price over the last 10 years

Fuel consumption - Route "L" (29.2 km RT)

Runs (Round trips) per week to compare with fast charging: 1488

	Light-Duty	Medium-Duty	Heavy-Duty
Fuel used per run (round trip) per bus (L)	6.5	10.9	16.9
Fuel efficiency of diesel equivalent (L/100km)	22.2	37.4	58
Emitted CO2e per year (kg)	1,326,210	2,231,419	3,460,870
Cost of diesel per year @$0.9116/L ($) *	$459,686	$773,446	$1,199,593

* Note: $0.9116/L based on London Transit's average fuel price over the last 10 years

Electricity costs estimations, emission reduction and simulation results for each route

Assumptions on the schedule (revised)

Rapid Transit Operating Schedule Information

The "7" Corridor will operate on a 10 minute frequency during the following periods
Monday – Saturday from 6am to midnight **(18 hours of operation)**
Sunday & Stat Holidays from 7am to 11pm **(16 hours of operation)**

The "L" Corridor will operate on a 5 minute frequency during the following periods
Monday – Saturday from 6am to midnight **(18 hours of operation)**
Sunday & Stat Holidays from 7am to 11pm **(16 hours of operation)**

Stop at the terminal station: 5 min (maximum charging time is less than 4 min)

Sample route "7" weekday schedule

Total # round trips/day: Weekday: 108, Saturday: 108, Sunday: 96

West to South			South to West		
Wonderland & Oxford (starts)	White Oaks (arrive)	STOP time (min)	White Oaks (starts)	Wonderland & Oxford (arrive)	STOP time (min)
6:00	6:35	5	6:00	6:35	5
6:10	6:45	5	6:10	6:45	5
6:20	6:55	5	6:20	6:55	5
6:30	7:05	5	6:30	7:05	5
6:40	7:15	5	6:40	7:15	5
6:50	7:25	5	6:50	7:25	5
7:00	7:35	5	7:00	7:35	5
7:10	7:45	5	7:10	7:45	5
	....			...	

eBus B – 10 min frequency

eBus A – 10 min frequency

Sample route "L" weekday schedule

Total # round trips/day: Weekday: 216, Saturday: 216, Sunday: 192

West to South			South to West		
Wonderland & Oxford (starts)	White Oaks (arrive)	STOP time (min)	White Oaks (starts)	Wonderland & Oxford (arrive)	STOP time (min)
6:00	6:35	5	6:00	6:35	5
6:05	6:40	5	6:05	6:40	5
6:10	6:45	5	6:10	6:45	5
	...			...	
6:40	7:15	5	6:40	7:15	5
6:45	7:20	5	6:45	7:20	5
6:50	7:25	5	6:50	7:25	5
	....			...	

eBus B – 5min frequency

eBus A – 5 min frequency

Fully electrifying the route is possible

- According to the developed schedule, **8 buses are required for route "7", 16 buses are required for route "L",** therefore **24 electric buses** are needed
- Four chargers are required, at each North, East, West and South terminals
- Route "7" : Two buses charge in a 15min interval (used for demand charges calculations)
- Route "L": Three buses charge in a 15min interval (used for demand charges calculations)
- There is a possibility to refine the model to include longer stops and charging at the Central Transit Hub if this is a preferred strategy

Charging costs – Route "7" (28.6 km RT) Nova Bus (76 kWh)

Note:

Used London Hydro Rates: General Service, Greater Than 50 KW with no interval meter rates

	Light	Medium	Heavy
Yearly MWh estimated	507	1,290	2,077
Electricity cost (CAD $)	$59,258	$150,692	$242,669
Regulatory cost (CAD $)	$5,531	$14,062	$22,642
Delivery cost (CAD $)	$11,058	$21,625	$32,477
Total charging cost for a year (CAD $)	**$75,848**	**$186,378**	**$297,789**
Diesel cost for a year (CAD $)*	$227,459	$386,218	$570,636
Diesel cost for a year with cap & trade ($CAD)	$239,271	$406,275	$600,270
Benefits (CAD $)	**$151,611**	**$199,840**	**$272,847**
Benefits (CAD $) if cap & trade	**$163,423**	**$219,897**	**$302,481**

* at $0.9116/L based on London Transit's average fuel price over the last 10 years
** with a current carbon price of $18/TCO2e

Charging costs – Route "7" (28.6 km RT) New Flyer (200 kWh)

Note:

Used London Hydro Rates: General Service, Greater Than 50 KW with no interval meter rates

	Light	Medium	Heavy
Yearly MWh estimated	535	1,334	2,130
Electricity cost (CAD $)	$62,475	$155,913	$248,837
Regulatory cost (CAD $)	$5,832	$14,549	$23,218
Delivery cost (CAD $)	$11,468	$22,271	$33,210
Total charging cost for a year (CAD $)	**$79,775**	**$192,732**	**$305,264**
Diesel cost for a year (CAD $)*	$227,459	$386,218	$570,636
Diesel cost for a year with cap & trade ($CAD)	$239,271	$406,275	$600,270
Benefits (CAD $)	**$147,684**	**$193,486**	**$265,372**
Benefits (CAD $) if cap & trade	**$159,496**	**$213,543**	**$295,006**

* at $0.9116/L based on London Transit's average fuel price over the last 10 years
** with a current carbon price of $18/TCO2e

Charging costs – Route "L" (29.2 km RT) Nova Bus (76 kWh)

Note:

Used London Hydro Rates: General Service, Greater Than 50 KW with no interval meter rates

	Light	Medium	Heavy
Yearly MWh estimated	1,009	2,571	4,379
Electricity cost (CAD $)	$117,964	$300,735	$512,190
Regulatory cost (CAD $)	$10,998	$28,032	$47,739
Delivery cost (CAD $)	$15,230	$31,416	$49,948
Total charging cost for a year (CAD $)	**$144,192**	**$360,182**	**$609,876**
Diesel cost for a year (CAD $)*	$459,686	$773,446	$1,199,593
Diesel cost for a year with cap & trade ($CAD)	$483,557	$813,611	$1,261,889
Benefits (CAD $)	**$315,494**	**$413,264**	**$589,717**
Benefits (CAD $) if cap & trade	**$339,365**	**$453,429**	**$652,013**

* at $0.9116/L based on London Transit's average fuel price over the last 10 years
** with a current carbon price of $18/TCO2e

Charging costs – Route "L" (29.2 km RT) New Flyer (200 kWh)

Note:

Used London Hydro Rates: General Service, Greater Than 50 KW with no interval meter rates

	Light	Medium	Heavy
Yearly MWh estimated	1,065	2,656	4,507
Electricity cost (CAD $)	$124,558	$310,679	$527,054
Regulatory cost (CAD $)	$11,613	$28,959	$49,124
Delivery cost (CAD $)	$15,882	$32,310	$51,252
Total charging cost for a year (CAD $)	**$152,053**	**$371,947**	**$627,430**
Diesel cost for a year (CAD $)*	$459,686	$773,446	$1,199,593
Diesel cost for a year with cap & trade ($CAD)	$483,557	$813,611	$1,261,889
Benefits (CAD $)	**$307,633**	**$401,499**	**$572,163**
Benefits (CAD $) if cap & trade	**$331,504**	**$441,664**	**$634,459**

* at $0.9116/L based on London Transit's average fuel price over the last 10 years
** with a current carbon price of $18/TCO2e

Ontario 2015 Grid Emissions [2]

	Solar / Wind / Bioenergy	Natural Gas	Nuclear	Coal	Waterpower
Electricity production (TWh)	14.2	15.9	92.3	0	37.3
Percentage of the grid use (%)	8.89	9.96	57.80	0.00	23.36

- Total electricity production (2015): 159.7 TWh
- Total emission (2015): 7.1 MT CO_2e
- The emission is calculated as **0.044 Tonne CO_2e/MWh**

Emission reduction – Route “7” (28.6 km RT) Nova Bus (76 kWh)

	Light	Medium	Heavy
Yearly electricity estimated (MWh)	507	1290	2077
Yearly diesel use (L)	249,516	423,671	625,972
CO2e from electricity (Tonne)	22	57	91
CO2e from diesel (Tonne)*	656	1,114	1,646
CO2e reduction for a year (Tonne)	**634**	**1,057**	**1,555**

* : Mobile emission factor for mobile fuel combustion of diesel in heavy-duty vehicles is 2.63 kg CO2e/L

Emission reduction – Route “7” (28.6 km RT) New Flyer (200 kWh)

	Light	Medium	Heavy
Yearly electricity estimated (MWh)	535	1334	2130
Yearly diesel use (L)	249,516	423,671	625,972
CO2e from electricity (Tonne)	24	59	94
CO2e from diesel (Tonne)*	656	1,114	1,646
CO2e reduction for a year (Tonne)	**633**	**1,056**	**1,553**

* : Mobile emission factor for mobile fuel combustion of diesel in heavy-duty vehicles is 2.63 kg CO2e/L

Emission reduction – Route “L” (29.2 km RT) Nova Bus (76 kWh)

	Light	Medium	Heavy
Yearly electricity estimated (MWh)	1009	2571	4379
Yearly diesel use (L)	504,262	848,448	1,315,920
CO2e from electricity (Tonne)	44	113	193
CO2e from diesel (Tonne)*	1,326	2,231	3,461
CO2e reduction for a year (Tonne)	**1,282**	**2,118**	**3,268**

* : Mobile emission factor for mobile fuel combustion of diesel in heavy-duty vehicles is 2.63 kg CO2e/L

Emission reduction – Route “L” (29.2 km RT) New Flyer (200 kWh)

	Light	Medium	Heavy
Yearly electricity estimated (MWh)	1065	2656	4507
Yearly diesel use (L)	504,262	848,448	1,315,920
CO2e from electricity (Tonne)	47	117	198
CO2e from diesel (Tonne)*	1,326	2,231	3,461
CO2e reduction for a year (Tonne)	**1,279**	**2,115**	**3,263**

* : Mobile emission factor for mobile fuel combustion of diesel in heavy-duty vehicles is 2.63 kg CO2e/L

Thanks for your attention !