ELECTRIFYING BUS RAPID TRANSIT SYSTEM: A CANADIAN CASE STUDY

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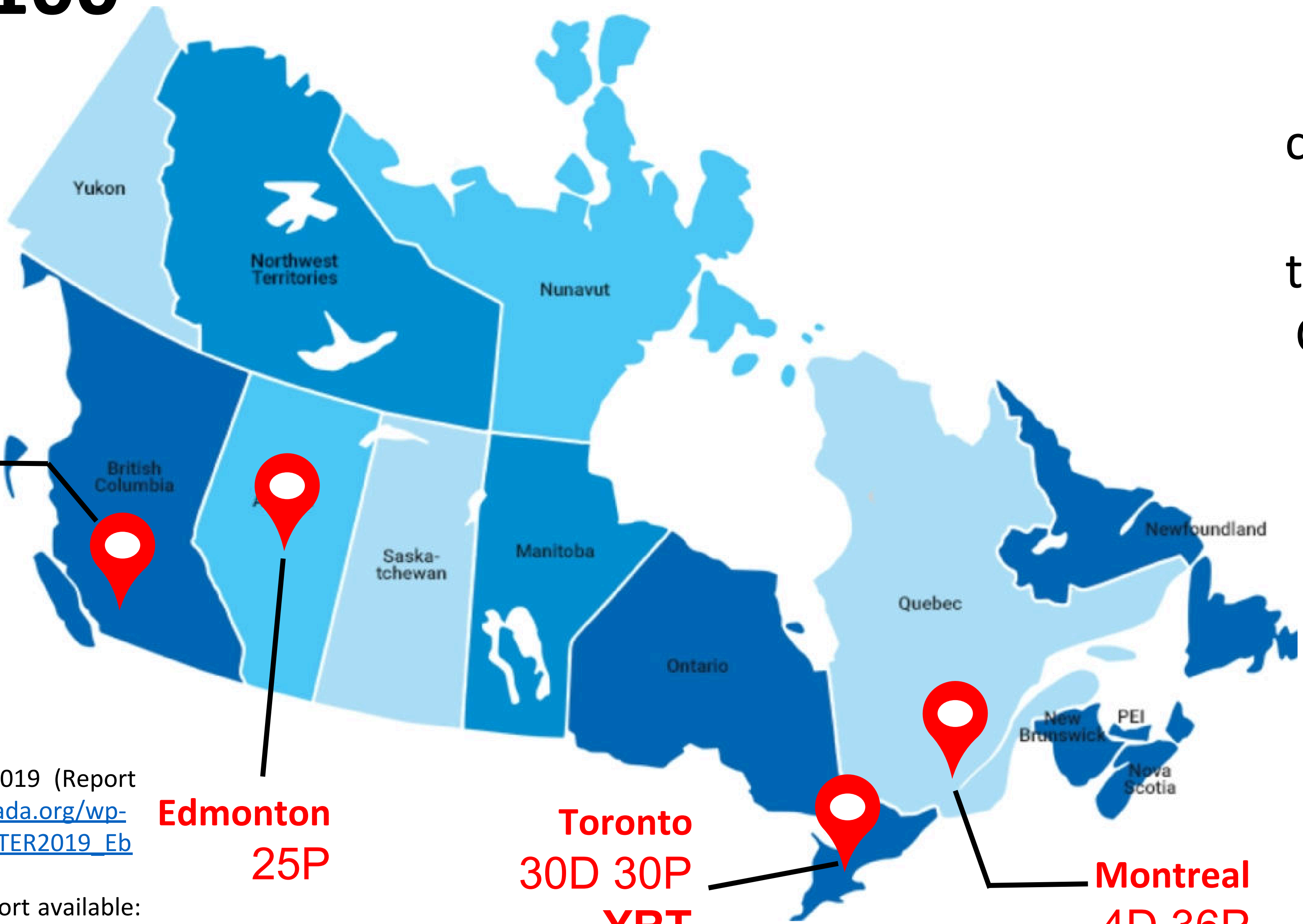
Canadian Landscape – Battery Electric Bus Deployment by 2025 < 100



Vancouver 4D

Edmonton 25P

Toronto 30D 30P
YRT 4P

Montreal 4D 36P

Percentage of commuters who used public transit: **12.0%** in Canada in 2011

Source:
1) Clean Energy Canada March 2019 (Report available : http://cleanenergycanada.org/wp-content/uploads/2019/03/Report_TER2019_Ebuses_20190329_v4_FINAL.pdf)
2) Statistics Canada July 2018 (Report available: https://www12.statcan.gc.ca/nhs-enm/2011/as-sa/99-012-x/99-012-x2011003_1-eng.cfm)

Areas of Activity

Project Management

Commercialization Projects -
Technology Readiness Level (TRL) 7-9

Funding

Co-funding for projects in Ontario -
TRL 2-6

Applied Industrial Research

Predictive Feasibility Energy, Emissions, and Economic Modelling; National and Global Industry Overviews; EVSE Siting

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Pan-Canadian Electric Bus Demonstration & Integration Trial – Phase 1 ($45M)

Standardization

Interoperability

OppCharge Protocol

3 Transit: TransLink, Brampton, YRT

18 electric buses

7 overhead 450kW chargers

5 routes

Utility business innovation

Charger cybersecurity

OEM Partners: ABB, Siemens, New Flyer, Nova Bus

Utility partners: New Market Tay Power, BC Hydro

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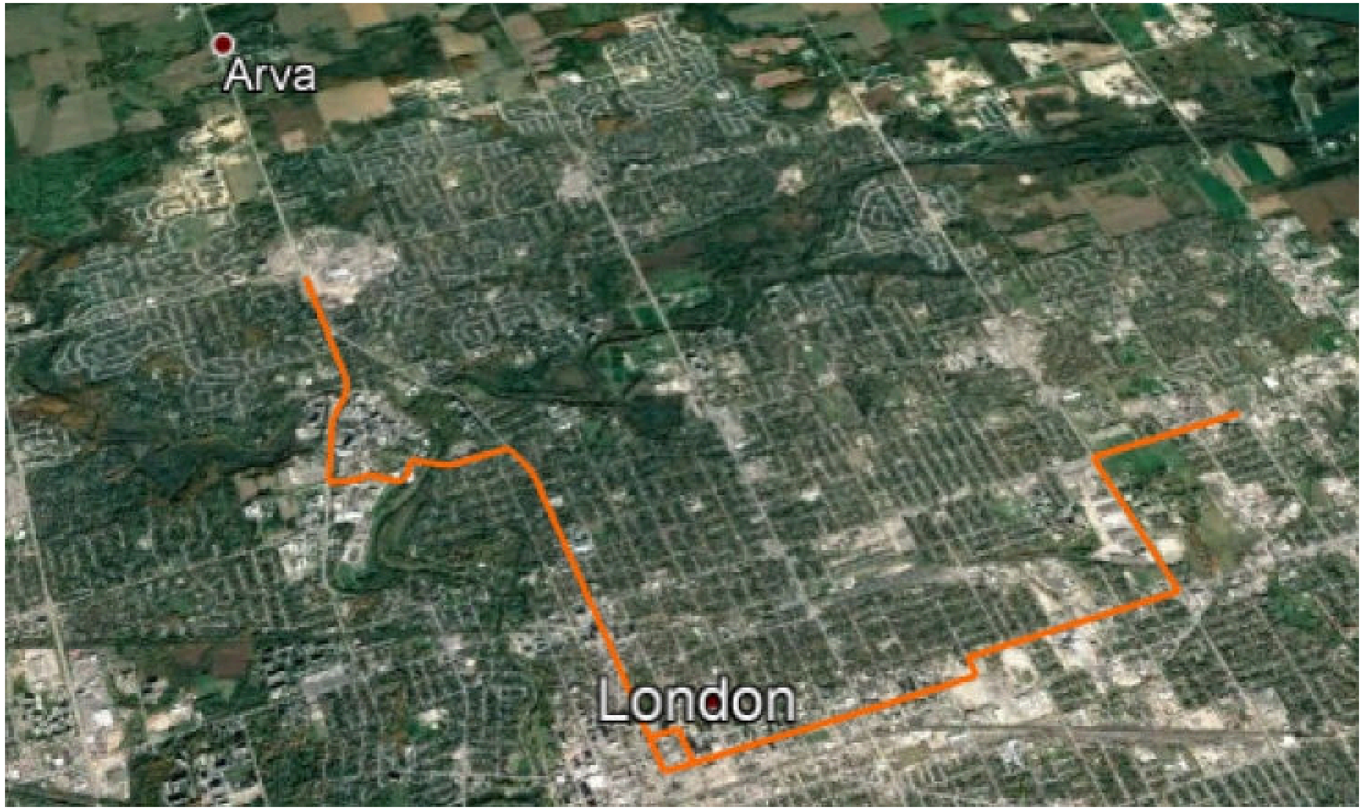
Feasibility on route “L” – London Transit (ON)



- High frequency / Rapid Transit (construction in 2025)
- 60 ft (articulated) deployed
- 29.2 km round trip
- 5 minutes of downtime scheduled at the terminal stations
- ~70 minutes round trip

TRiPSIM © on route “L” – London Transit

1. Find the route topography

2. Use the route GTFS data to find information related to the schedule of the buses (including interlining), so called “block” modelling

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
	….			…	

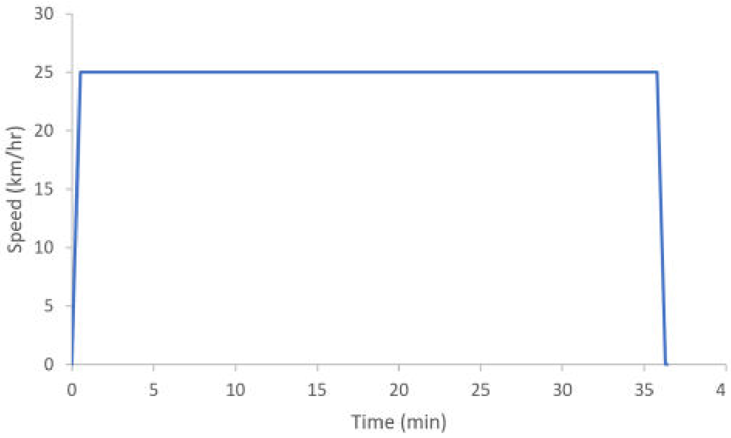
eBus B – 5min frequency

eBus A – 5 min frequency

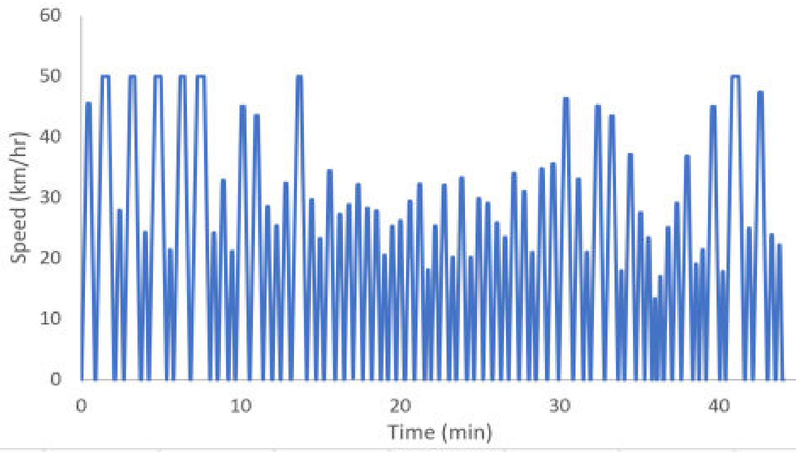
TRiPSIM © on route “L” – London Transit

3. Get the traffic impediment information from the city
4. Model three duty cycles:

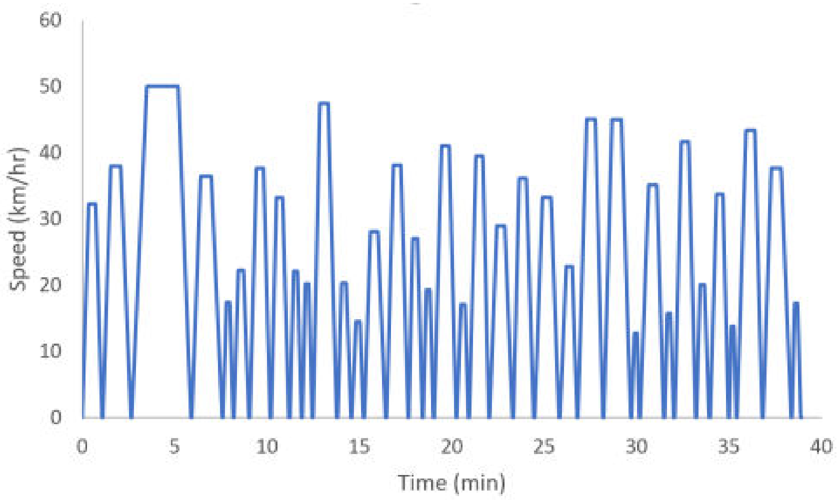
BASELINE SCENARIO



WORST-CASE SCENARIO



AVERAGE SCENARIO



TRiPSIM © Inputs

Operating conditions:
- Speed profile, second-by-second
- Topography (road grade), second-by-second
- Regenerative braking allowed
- Passenger load
- Auxiliary usage (including diesel heaters in winter)

Vehicle side (Provided by the OEMs):
- Powertrain characteristics (efficiencies of the motor, converters, transmission, maximum torque and RPM allowed…)
- Aerodynamic characteristics (drag coefficient, frontal area…)
- Physical characteristics (CW, battery capacity)

Systems constraints (Provided by the utility and transit agencies):
- Schedule and distance to depot
- Local jurisdiction rates and emissions

Charger side (Provided by the OEMs):
- Efficiencies of the charger and connection time
- Rated power

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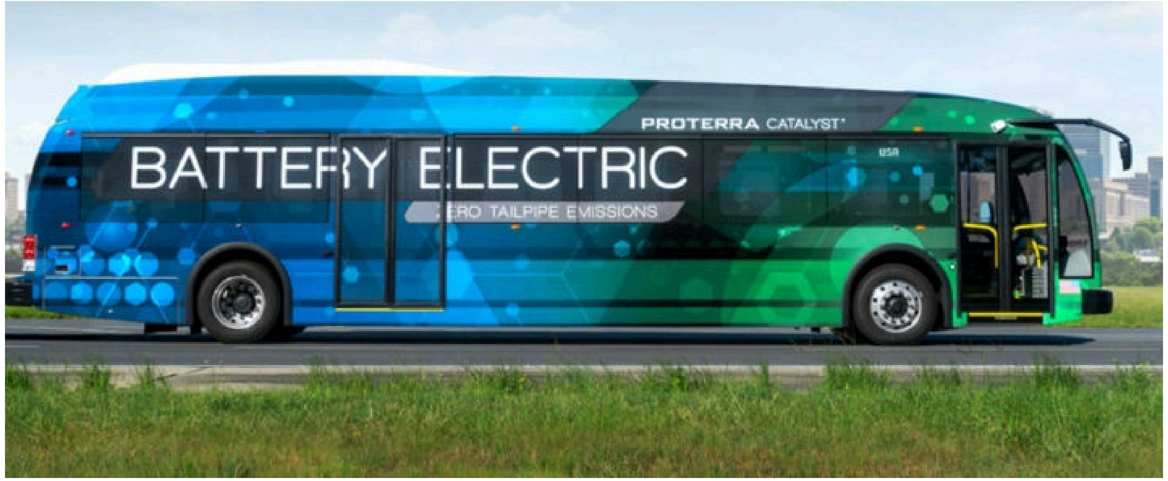
TRiPSIM © Inputs – OEM part of this study

New Flyer XE60 – 60 ft – 640 kWh (Depot charging capabilities – may have overhead fast charging capacities in the future)



Proterra– 60 ft – 660 kWh (overhead fast charging capability dominant, plugin in depot available)

TRiPSIM © Energy Consumption Results on Route “L” (29.2 km RT) – OEM X

	East to North direction				North to East direction			
			SOC at route end				SOC at route end	
	kWh per km	Total kWh used	Ideal	10% buffer	kWh per km	Total kWh used	Ideal	10 % buffer
Baseline	0.52	7.59	93.8%	88.8%	0.61	8.9	93.5%	88.5%
Average	1.73	25.19	90.9%	85.9%	1.78	26.04	90.7%	85.7%
Worst-case	3.35	48.91	87.0%	82.0%	3.47	50.61	86.7%	81.7%

TRiPSIM © Charging Time Results on Route "L" (29.2 km RT) – OEM X

With a 150 kW fast charger at the depot (including losses)

	OEM X			
	Number of runs (roundtrips) without charging	Overnight/at-garage charging time (hours)	Energy from the grid (kWh)	Number of 60 ft required to electrify the route
Baseline	31	4.2	568.0	16
Average	10	4.2	569.2	22
Worst-case	5	4.1	552.9	42

Minimum required for the schedule, 1 to 1 diesel replacement

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TRiPSIM © Charging Time Results on Route "L" (29.2 km RT) – OEM X

With a 600 kW fast charger at the terminal stations (including losses)

	East to North direction				North to East direction			
	Ideal charging 100 %		Typical efficiency		Ideal charging 100 %		Typical efficiency	
	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)
Baseline	0.84	8.4	0.97	7.29	0.8	8.04	0.93	6.97
Average	2.53	25.31	2.93	21.96	2.55	25.49	2.95	22.12
Worst-case	4.72	47.21	5.46	40.96	4.62	46.22	5.35	40.1

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TRiPSIM © Charging Time Results on Route "L" (29.2 km RT) – OEM X

With a 600 kW fast charger at the terminal stations (including losses)

	Number of 60 ft required to electrify the route
	OEM X
Baseline	16
Average	16
Worst-case	27

Minimum required for the schedule, 1 to 1 diesel replacement

- Note, routes **will not operate continuously on a heavy duty cycle mode**
- Two chargers are required, one at each terminal
- 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

TRiPSIM © Charging Costs Results on on Route "L" (29.2 km RT) – OEM X – Full Fleet

2,268,069.12km per year on this route

s	Baseline	Average	Worst-case
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
Benefits (CAD $)	**$307,633**	**$401,499**	**$572,163**
Benefits with Carbon price (CAD $)	**$311,302**	**$409,574**	**$585,539**

(1) Electricity costs assuming London Hydro's electricity rates large general service customers
(2) Two chargers are required to fully electrify the route
(3) Demand charges are almost maximized
(4) Carbon tax: $50/Tonnes CO2e
(5) Diesel at $0.9116/L based on London Transit's average fuel price over the last 10 years

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TRiPSIM © Emissions Reduction Results on Route 100 (30 km RT) – OEM X – Full Fleet

	Baseline	Average	Worst-case
Yearly electricity estimated (MWh)	1,065	2,656	4,507
Yearly diesel use (L)	504,262	848,448	1,315,920
CO2e from electricity (Tonne) (1)	47	117	198
CO2e from diesel (Tonne) (2)	1,326	2,231	3,461
Yearly CO2e reduction (Tonne)	1,279	2,115	3,263
Yearly CO2e reduction (%)	**94%**	**94%**	**94%**

(1) ON's electricity grid emission factor is 0.044 Tonne CO2e/MWh (2015)

(2) Mobile emissions factor for mobile fuel combustion of diesel in heavy-duty vehicles is 2.63 kg CO2e/L

BC Ministry of Environment "2016/17 B.C. Best practices Methodology for quantifying greenhouse gas emissions" Victoria, May 2016

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Conclusion

For every Ebus project:

- Perform a feasibility analysis (preferably route based and capturing climatic variations)
- Ensure your system is standardized – such as J3105
- Different technologies may work best for your system i.e Fast Charging, Slow Charging, Hydrogen, With or Without Energy Storage
- We still welcome new champions to join our Pan Canadian Ebus Phase II project

Next steps for us:

- Validate our tool with ViriCity loggers
- Create a robust modelling tool integrating energy storage to calculate the benefits it can generate

Contact Information

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