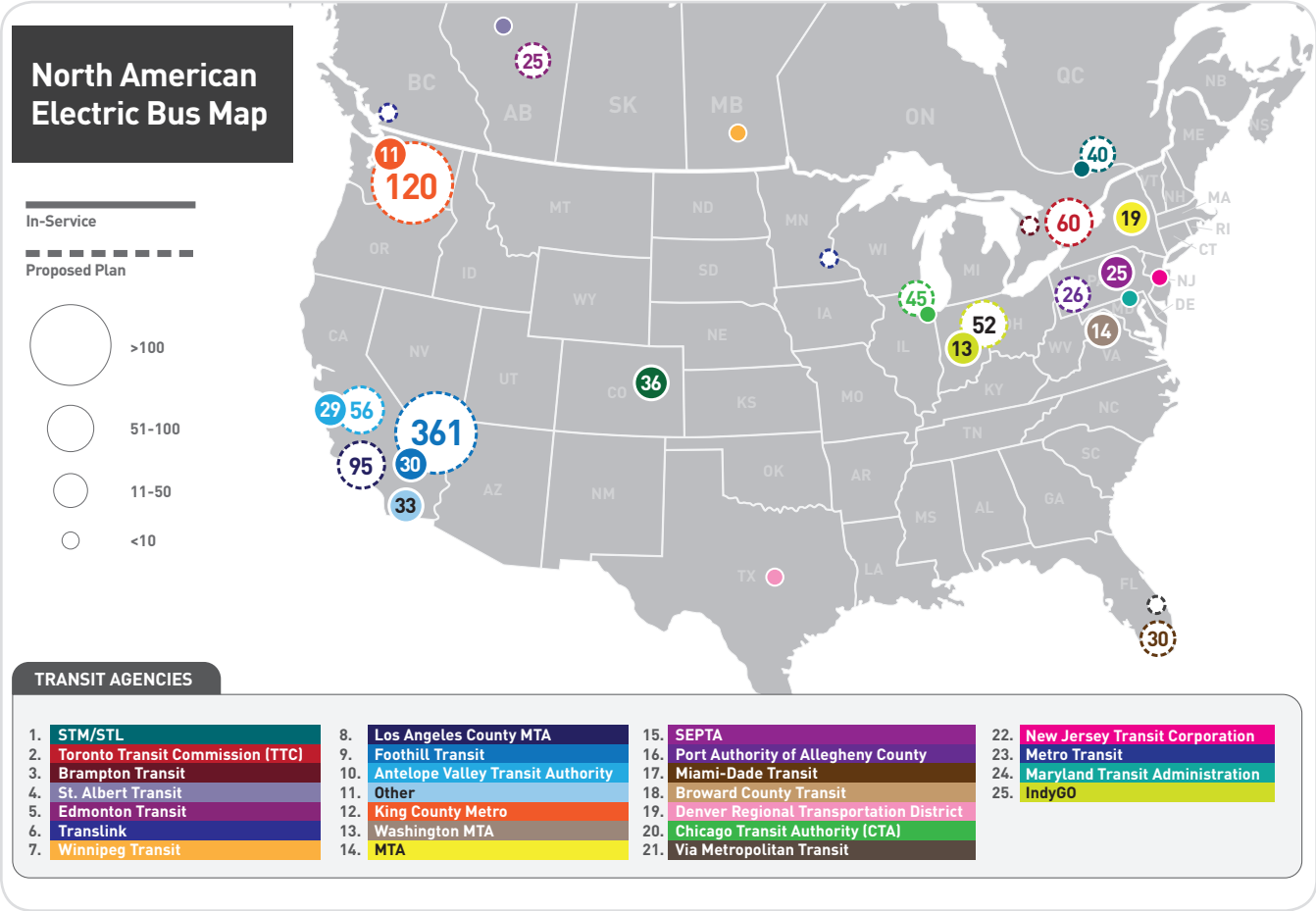
Electric Bus Deployment in North America

Electric bus technology has continued to advance and is being deployed in various scales throughout North America

- 233 battery electric in service across North America
- 936 battery electric bus procurement and expansion across North America



Key Points:

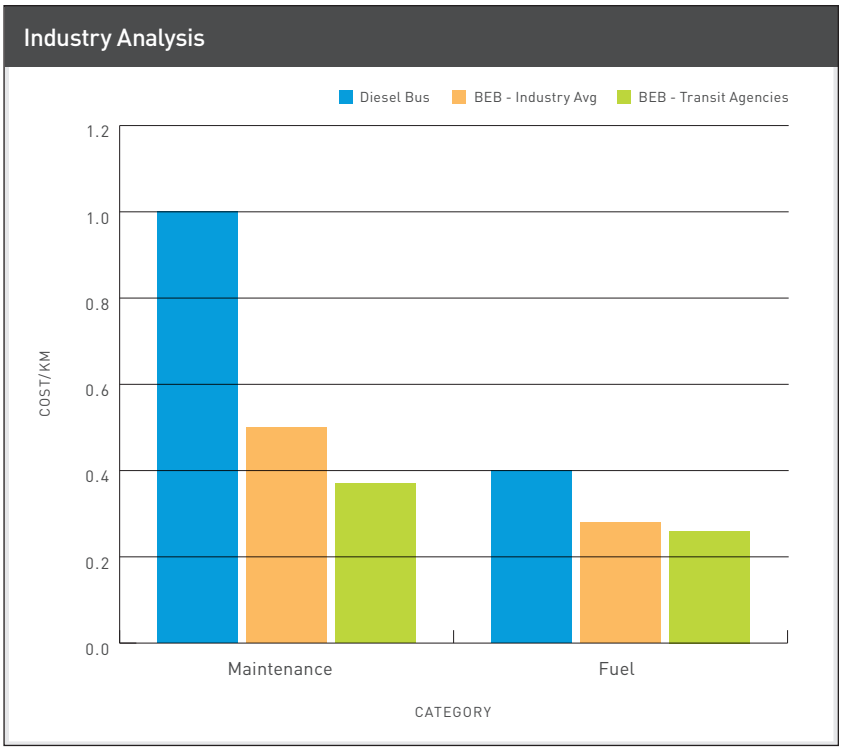
- The Toronto Transit Commission (TTC) has received board approval for procurement of only zero-emissions buses starting in 2025 and an all zero-emissions bus fleet by 2040.
  - Source: https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2018/June_12/Reports/27_Green_Bus_Technology_Plan_Update.pdf
- STL and STM (transit agencies) in Montreal, Quebec have committed to ordering only electric buses starting in 2023 and 2025, respectively
  - Source: https://www.newswire.ca/news-releases/montreal-and-laval-award-canadas-largest-ever-battery-electric-bus-contract-to-new-flyer-691671781.html
- Transit agencies such as Los Angeles County MTA, Foothill Transit and Antelope Valley Transit Authority in California have committed to become all-electric by 2030
  - Source: http://www.laist.com/2018/09/28/la_metro_is_already_buying_electric_buses_now_everyone_else_will_too.php

Industry analysis on maintenance and fueling costs

A reduction in maintenance and fueling costs has been demonstrated when comparing an electric bus to a conventional diesel bus.

The maintenance and fuel savings range of 30-50 per cent, provided in the report, is based on YRT and consultant research on the North American industry and data from specific transit agencies. Figure 1 depicts greater savings on maintenance and fuel; however, maintenance savings may be distorted by work covered under warranty and significant amount of on-site support provided by OEM's. In addition, fueling/electricity costs are dependent on the pricing structure for the specific city or agency.

Thus, the range provided is a realistic value for savings for YRT – without being overly optimistic – and leaving room for greater potential savings in the future.



YRT Route 55 Analysis

Operating and Maintenance Costs (Table 1)

Operating and Maintenance Cost	Electric Bus Per Bus	Diesel Bus Per Bus	Total Savings Per Bus
Energy/Fueling Cost	$19,269	$38,080	–
Maintenance	$15,000	$36,715	–
Capital Programs	$21,667	$15,556	–
Total Lifecycle (18 years)	$1,006,842	$1,626,310	38%

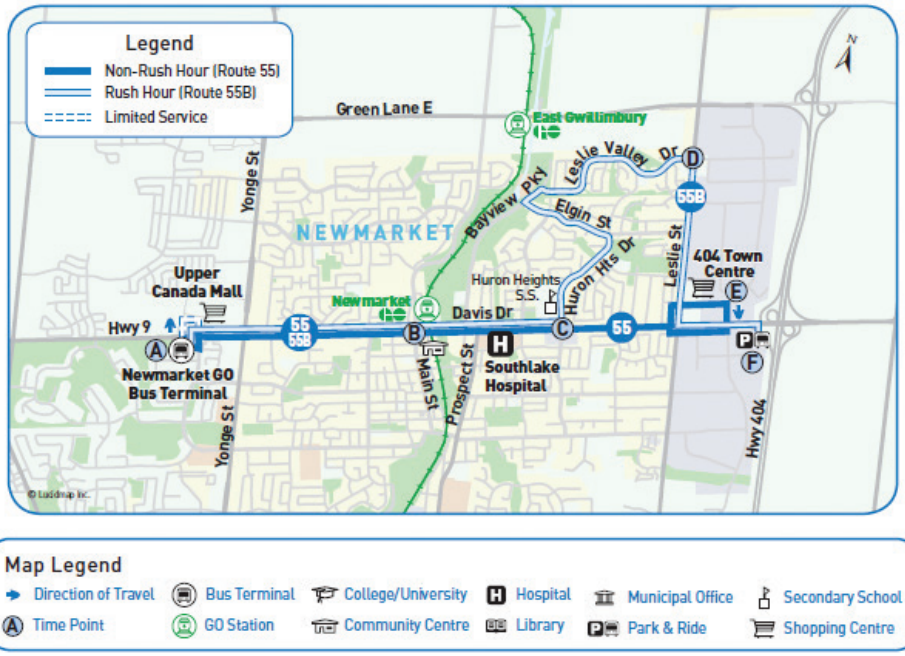
Energy/Fueling Cost

CUTRIC completed a modeling exercise of an electric bus specific to YRT Route 55 in September 2017. The energy/fueling costs identified in Table 1 were taken from this model using the medium duty cycle results. Some of the details used for the development of the model have been provided below:

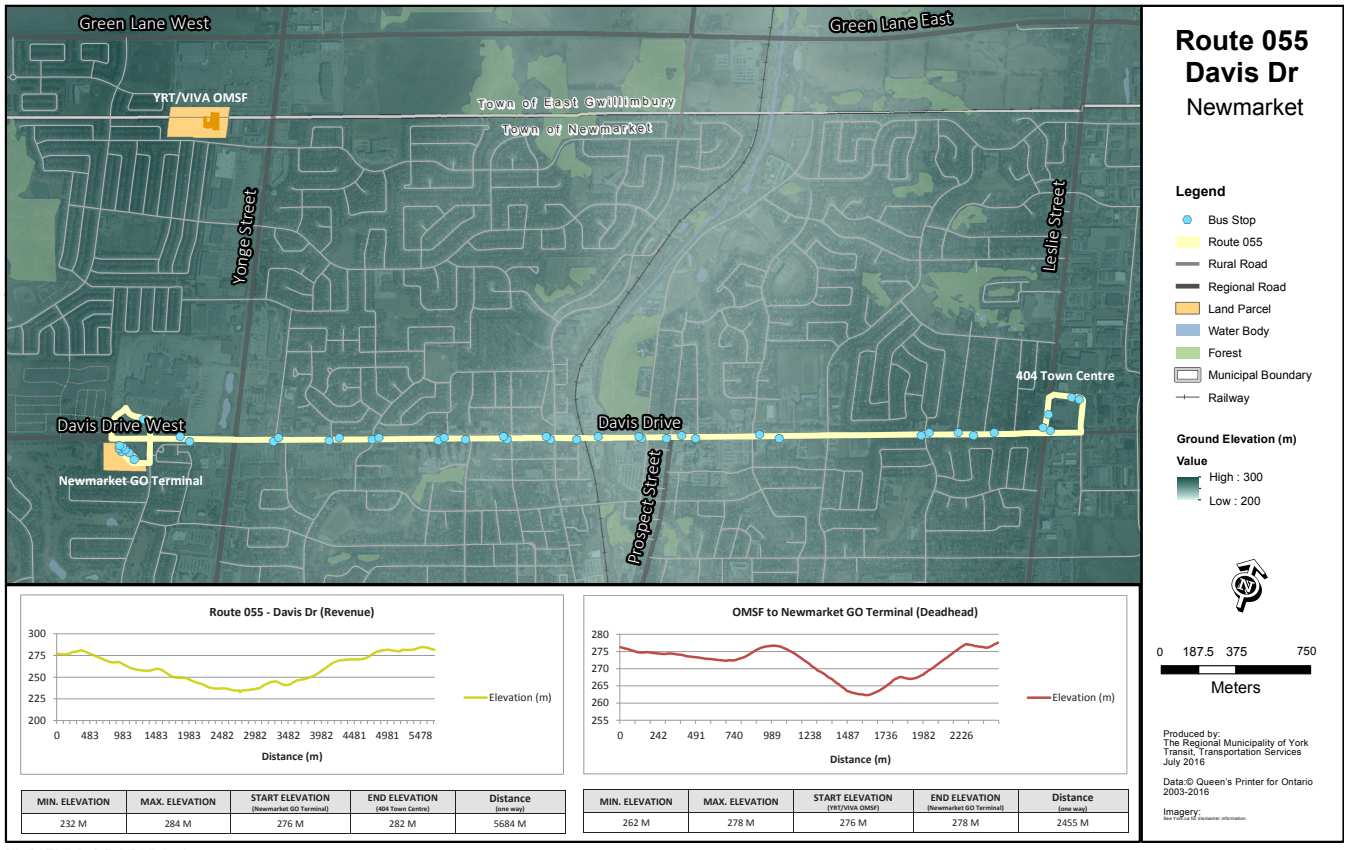
Medium Duty Cycle Parameters:

- Stop for all scheduled (major) bus stops
- Additional stops at 50 per cent of other stops: randomly selected from all the traffic lights, stop signs, passenger walks and other (unscheduled) bus stops

Route 55/55B



Route 55 Elevation Profile



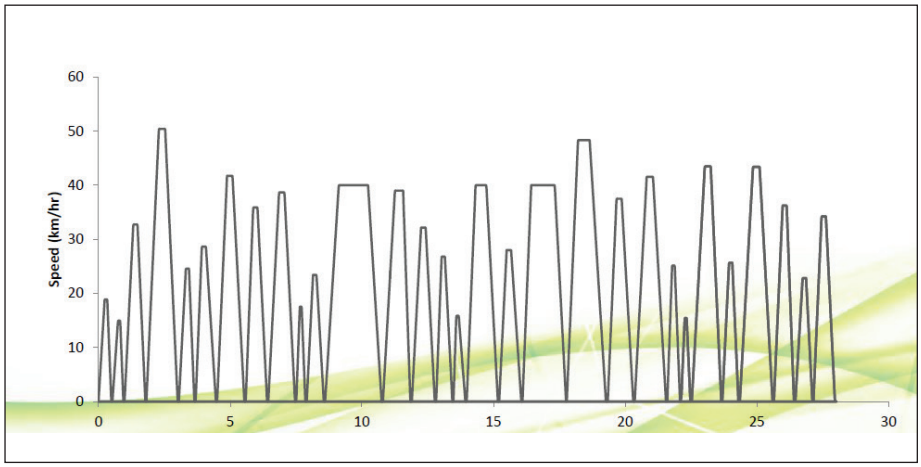
MIN. ELEVATION	MAX. ELEVATION	START ELEVATION (Newmarket GO Terminal)	END ELEVATION (404 Town Centre)	Distance (one way)
232 M	284 M	276 M	282 M	5684 M

MIN. ELEVATION	MAX. ELEVATION	START ELEVATION (YRT/VIVA OMSF)	END ELEVATION (Newmarket GO Terminal)	Distance (one way)
262 M	278 M	276 M	278 M	2455 M

Ebus Energy Consumption and Charging Calculations Method:

- CUTRIC in-house Matlab and Python code
- Physical characteristics of New Flyer and Nova Bus electric bus
- Topography
- Regerative braking power split: 35 per cent
- Constant accessory draw: 5,000W (medium duty cycle)

Duty Cycle Development



In summary, this modeling exercise considered route statistics, profile, vehicle parameters and Newmarket-Tay utility rates to simulate duty cycles and energy consumption. A comparative simulation of a diesel bus was completed to calculate fuel consumption and provide diesel costs ($1/L).

Energy/Fueling Costs (Table 2)

Medium Duty Cycle	Nova Bus	New Flyer	Average
Yearly MWh Estimated	77.4	79.3	–
Energy Cost	9,048	9,270	–
Regulatory Cost	989	1,013	–
Delivery Cost	9,038	9,179	–
Total Cost of Electricity	$19,075	$19,463	$19,269
Total Cost of Diesel	$38,080	$38,080	$38,080

The key variables that affect energy consumption are:

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

Maintenance

The maintenance cost for the electric bus was an estimated value provided by CUTRIC based on OEM and industry feedback received in early 2017. The costs were primarily attributed to the elimination of high impact components, such as the engine, exhaust and emissions system, transmission, hydraulic systems and running maintenance activities. Inspections and repairs for other components, such as the body, frame, steering and suspension, HVAC, lighting, air system, drive-shaft and wheels are expected to be similar to a diesel bus. The longevity of the electric propulsion components are unknown variables, although the technology is believed to be similar to highly reliable rail equipment.

Meanwhile, data for diesel buses was retrieved from the YRT Asset Management System (M5) — considering the labour, parts and commercial costs — for the buses in the North depot. The average maintenance costs were calculated based on the buses in their fleet for 2015 and 2016.

Maintenance costs are dependent on multiple variables, including vehicle age, duty cycle, topography, fleet maintenance practices and several other factors. In addition, operating and maintenance costs vary across fleets, bus types and operating environments. Comparisons of different technologies are most relevant if made on the same routes, average speeds and in the same fleet (California Air Resources Board, 2016).

Capital Programs

The capital programs for the electric bus consisted of battery refurbishment priced at $1250/kWh for the battery system and $140,000/bus for body overhaul over an 18-year bus life. Battery refurbishment costs was determined on a 200kWh configuration, with pricing based on CUTRIC and industry feedback received in 2016.

Meanwhile, YRT buses have regular midlife and overhaul programs budgeted for rebuilding or replacing major components within their mandated 18-year bus life. Therefore, based on budgeted programs as of 2017, a 40-foot diesel bus is scheduled to have three overhaul programs completed at a total cost of $280,000 over its operational life.

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