Vehicle-for-Hire Emissions Calculation and Modelling

Summary Report

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1. Introduction

The vehicle for hire industry (VFH), which consists of both taxi/limo brokerages and private transportation companies (PTCs) such as Lyft and Uber, represents an important transportation mode in the City of Toronto. The amount of greenhouse gas (GHG) emissions generated by Toronto's VFH industry is currently unknown, particularly in comparison to other transportation modes such as personal vehicles. Establishing a baseline for the industry's GHG emissions is critical to inform the design of policy options and initiatives that meet emission reduction targets and goals set out by Council in TransformTO[1]. Taking an evidence-based approach will also be important, as there are financial implications associated with emission reduction initiatives. In June 2022, the City of Toronto worked with the Transportation and Air Quality (TRAQ) research group at the University of Toronto to generate a baseline of the contribution of the VFH industry to the city's annual vehicle kilometres travelled (VKT) and GHG emissions. The study also used the baseline to evaluate the impact of future emission reduction initiatives. Three approaches were examined and evaluated in terms of their GHG reduction potential:

1. Reduction in kilometres travelled with no passenger on-board, also called deadheading;
2. Increase in pooled trips, which are trips that are shared with more than one passenger; and
3. Vehicle electrification in the VFH industry and implications for public charging.

2. Snapshot of the Vehicle for Hire Industry

The VFH industry in Toronto is a dynamic and highly regulated sector that includes taxis, limousines, and PTC services such as Lyft and Uber. The City of Toronto's municipal government regulates the industry to ensure passenger safety and fair competition among operators. Taxi and limousine services in Toronto are typically booked through a central dispatch service or hailed from designated stands, while PTC services operate through mobile apps. The industry has undergone significant changes in recent years, with the rise of PTCs within already established taxi and limousine services. Despite these changes, the VFH industry in Toronto remains an important growing component of the transportation system.

The City of Toronto's municipal licensing policies require PTCs and taxi/limo brokerages in the city to provide data on their operations. While PTC services share data on their operations using an established approach, the data collection process with taxi/limo brokerages is still being refined with limited detailed information on their operations available at this stage. For PTCs, the City of Toronto could accurately identify around 26,000 daily active drivers in 2019, with a drop to around 7,000 active daily drivers during the pandemic in 2020[2]. Due to limited data submitted by taxi/limo brokerages, an estimate of active drivers was generated based on the number of unique vehicles that were active at any point in 2019 and 2020, with no indication of how often each individual

[1] City of Toronto (2021). TransformTO Net Zero Strategy. A climate action pathway to 2030 and beyond. Retrieved from: https://www.toronto.ca/legdocs/mmis/2021/ie/bgrd/backgroundfile-173758.pdf
[2] City of Toronto (2021). The Transportation Impacts of Vehicle-for-Hire in the City of Toronto: October 2018 to July 2021. Retrieved from: https://www.toronto.ca/wp-content/uploads/2021/11/98cd-VFHTransportationImpacts2021-11-23.pdf

driver was operating within those years. A total of 5,586 and 4,870 taxi/limo vehicles had active licenses for 2019 and 2020 respectively based on the data provided.

3. Contribution to Vehicle Kilometers Travelled and Greenhouse Gas Emissions

The total VKT associated with the transportation sector (on-road vehicles including trucks and public transportation) was estimated for 2019 and 2020. The VFH industry contributed 4.6% and 3.0% of total VKT in the City of Toronto in 2019 and 2020 respectively (Figure 1). On average, a PTC and taxi/limo vehicle drove 126 km and 182 km per day respectively in 2019. PTCs such as Lyft and Uber represent around 70% of VFH VKT with the remaining 30% travelled by taxis/limo brokerages. The contribution of the VFH industry was expectedly lower during the pandemic than prior to the pandemic.

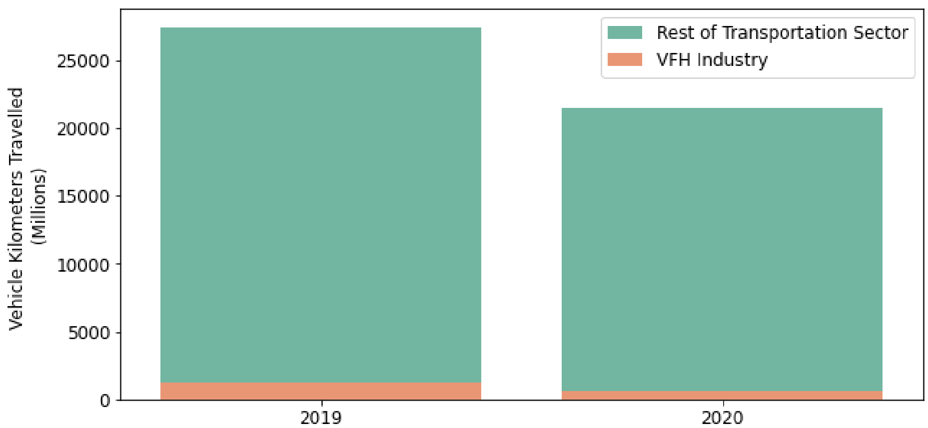


Figure 1: VFH industry contribution to transportation VKT in Toronto

When translated to GHG emissions, the VFH industry is estimated to contribute 5.8% and 3.6% of total transportation GHG emissions in the City of Toronto in 2019 and 2020 respectively (Figure 2).

Figure 2: VFH industry contribution to transportation GHG emissions in Toronto

3.1 Comparison of GHG Intensities Between Different Trip and Vehicle Powertrain Types

An emission intensity in gCO2eq/km was estimated based on the data collected to compare the emissions associated with each PTC service. Emission intensity was not quantified for taxis/limos, due to the limited detailed trip level data. Figure 3 presents the median emission intensity in gCO2eq/km of PTC services by distinguishing the contribution of deadheading (when a driver is looking for but without a customer) and the portion of a trip with a passenger on-board. The figure compares emission intensities for pooled and non-pooled ride-hailing trips by segmenting among internal combustion engine (ICE), battery electric vehicles (BEV) and plug in hybrid electric vehicles (PHEV) powertrain technologies. The comparison is only focused on operational GHG emissions and does not include lifecycle GHG emissions along with the implications of vehicle ownership on parking requirements and congestion. This analysis also assumes an equal number of passengers per trip (i.e. one occupant per private vehicle trip and one passenger for each trip for PTCs).

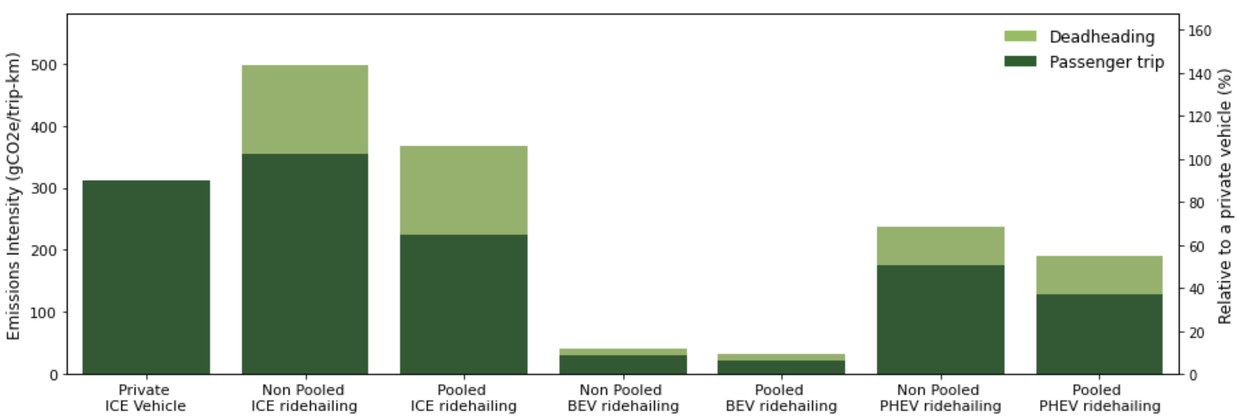


Figure 3: Median emission intensities of PTC services and comparison with a private ICE vehicle

The median emission intensity of all trips performed by private passenger vehicles in Toronto is presented as the first column (310 gCO_{2eq}/km). Non-pooled ICE ride-hailing trips have an emission intensity that is 59% higher than using a private ICE vehicle. The passenger contribution of a non-pooled trip is 13% higher than a private vehicle due to the contribution of the distance travelled by a PTC driver to reach a passenger after accepting a trip. The additional 46% are due to deadheading events that occur throughout a day of driving. While a non-pooled ICE PTC trip has higher operational GHG emissions than a consumer using their own private vehicle, PTCs along with taxi services play a role in allowing individuals that live in urban areas to reduce private car ownership and use these services as part of a group of transportation modes, including active modes and public transit. In other words, these findings do not necessarily indicate that PTC services always promote higher emissions at the scale of an urban transportation system.

Pooled ICE ride-hailing trips have an emission intensity that is also higher than private ICE vehicles but less pronounced with 18% more emissions per passenger kilometre. While the passenger contribution of pooled ICE trips is 28% lower than a private ICE vehicle due to the scaling of emissions by the number of passengers in a vehicle, the deadheading contribution results in a higher emission intensity overall. These findings reflect a low penetration of pooled trips conducted prior to the pandemic. Theoretically, a PTC driver that conducts pooled trips for a full day should be spending less time deadheading as the pooling increases the number of chained trips. However, the evaluation of deadheading events from drivers did not reveal differences across drivers that pool and those who do not pool, indicating that the prevalence of pooling had not reached levels that would result in reduced deadheading for drivers. Higher demand for pooling services should result in a lower deadheading contribution that could lower the emission intensity of pooled trips relative to private ICE vehicles.

Lastly, non-pooled and pooled BEV ride-hailing services result in significant emission intensity reductions of 87% and 90% relative to private ICE vehicle. These findings are due to the low carbon intensity of the Ontario electricity grid. Non pooled and pooled PHEV ride-hailing services result in an emission intensity reduction of 24% and 39% relative to a private ICE vehicle as PHEV use smaller batteries than BEVs.

4. Exploring Emission Reduction Initiatives

4.1 Role of Deadheading

Deadheading occurs when a vehicle driver is operating without customers, either in between passenger pickups or when driving to a more favorable location for new ride requests. Analysis was conducted only on PTCs, because their data is granular enough to distinguish different portions of a trip including: the portion where the driver is driving without a passenger on-board and is eligible to accept a trip (deadhead p1), the portion of a trip where the driver is en-route to pick up a passenger (en-route p2), and the portion of a trip with a passenger on-board going to their destination (trip passenger p3). Figure 1 presents the contribution of each PTC trip portion to overall VKT, vehicle hours travelled (VHT), GHG, nitrogen oxides (NO_x) and fine particulate matter ($PM_{2.5}$) emitted during the week of February 3-8, 2020. Deadheading (p1) contributes 33% of total GHG emissions from PTCs.

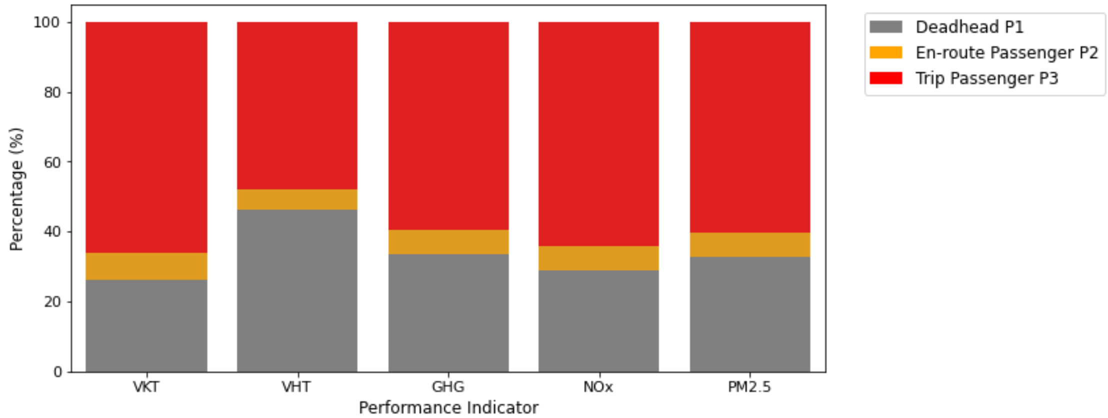


Figure 4: Contribution of each PTC trip portion to VKT, VHT and emissions on the week of February 3-8, 2020

Travel trends of full-time and part-time drivers were further explored to identify approaches to mitigate deadheading GHG emissions. Full-time drivers are designated as drivers that are active for more than 4 distinct hours on the evaluated day while part-time drivers are active 4 hours or less. This distinction is based on the assumption that a full-time driver works 8 hours a day and a part-time driver half of that.

For each vehicle, deadheading (p1), enroute to passenger (p2) and trip passenger (p3) events were aggregated over the full day and an emission factor for GHG emitted from deadheading (p1) per kilometer of distance travelled with a passenger on-board (p3) was estimated. Figure 4 presents boxplots of vehicle level deadheading (p1) GHG emissions per kilometer with a passenger on-board (p3) segmented by full-time and part-time drivers.

Full- and part-time drivers exhibit median emission factors of 137 and 157 gCO2eq/km respectively. In other words, full-time drivers generate less emissions while waiting to accept a trip than part-time drivers relative to the total distance they travel with a passenger on-board over a given day. Additionally, full-time drivers exhibit significantly less variability across drivers than part-time drivers. Fifty percent of full-time drivers emit between 100 and 190 gCO2eq/km on the evaluated day. On the other hand, fifty percent of part-time drivers emit between 90 and 300 gCO2eq/km on the evaluated day. Further research will be required to identify the reasons behind the higher deadheading observed for part-time drivers, and what initiatives can be put in place to minimize it.

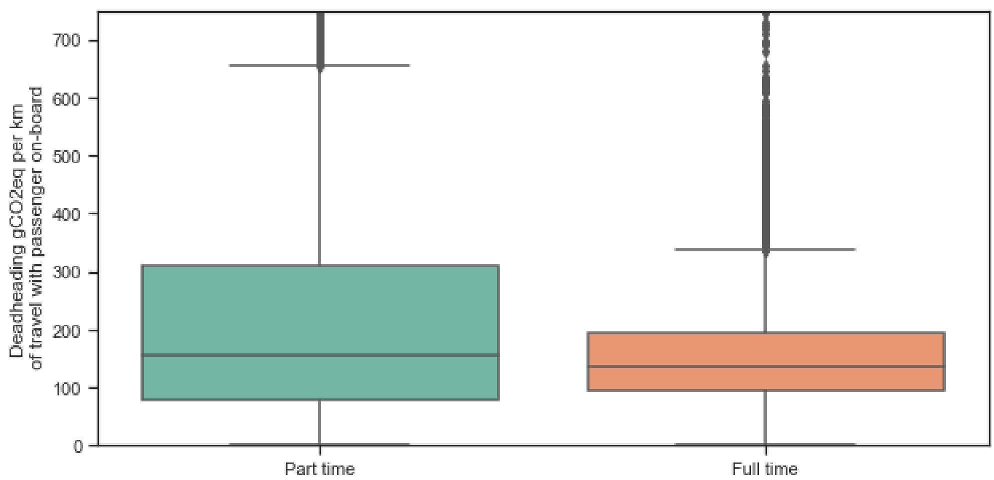


Figure 5: Distribution of vehicle level p1 GHG emissions emitted per kilometer of p3 segmented by full-time and part-time drivers

4.2 Role of Pooled trips

PTCs uniquely offer ride pooling services that allow passengers to share their ride with other passengers for a reduced fee. These pooling services were halted during the pandemic and have since resumed in some Canadian cities including Toronto since February 2023. Pooled trips provide an opportunity for emission reductions by reducing low occupancy trips—though currently data collected from PTCs do not indicate the number of passengers on board.

Based on the data collected, pooled trips were identified as a PTC service that was not widely utilized by consumers prior to the pandemic. During the evaluated week, only 10% of total trips were classified as pooled, and just 27% of those resulted in multiple passengers sharing a vehicle on the same route. In other words, only 27% of consumers who requested a pooled trip were matched with another passenger to share the ride. There was insufficient demand at the prices established for the service to effectively match rides in a way that resulted in multiple passengers sharing a trip. Further research is needed to identify effective strategies for incentivizing pooling, particularly in replacing single-auto commuting trips to and from the City of Toronto.

4.3 Role of Electrification

Recent cost reduction developments in battery technology have increased the viability of vehicle electrification as a solution to limit GHG associated with the ride-hailing sector. Ontario boasts one of the cleanest grids in the world, leading to substantial reductions in operational GHG emissions through vehicle electrification[3]. The study quantified the emission reduction potential that could be achieved with electric vehicles (EVs), accounting for both battery electric vehicles (BEVs) and plug in hybrid electric vehicles (PHEVs).

[3] Pereira, L., Posen, I.D., 2020. Lifecycle greenhouse gas emissions from electricity in the province of Ontario at different temporal resolutions. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.122514

The City of Toronto's electric vehicle strategy goals project a penetration of 5%, 30%, 80% and 100% of registered electric vehicles by 2025, 2030, 2040 and 2050 respectively. Figure 2 presents the yearly GHG savings that would be achieved for the VFH industry (taxis, limos, and PTCs) under each of the established City of Toronto goals with BEVs and PHEVs assuming 2019 trip activity. The transition of 5% of the VFH fleet by 2025 would result in yearly savings of 8.1 and 16.8 kt CO_{2eq} with PHEVs and BEVs respectively. The GHG savings would increase to 162 and 335 kt CO_{2eq} with PHEVs and BEVs respectively at a penetration of 100%. In other words, transitioning the VFH industry fleet to BEVs would result in a reduction in the City of Toronto's yearly transportation GHG emissions by around 5.3% based on the City of Toronto's 2019 traffic emission inventory generated by the University of Toronto's Traffic Emission Prediction Scheme (TEPs) model.

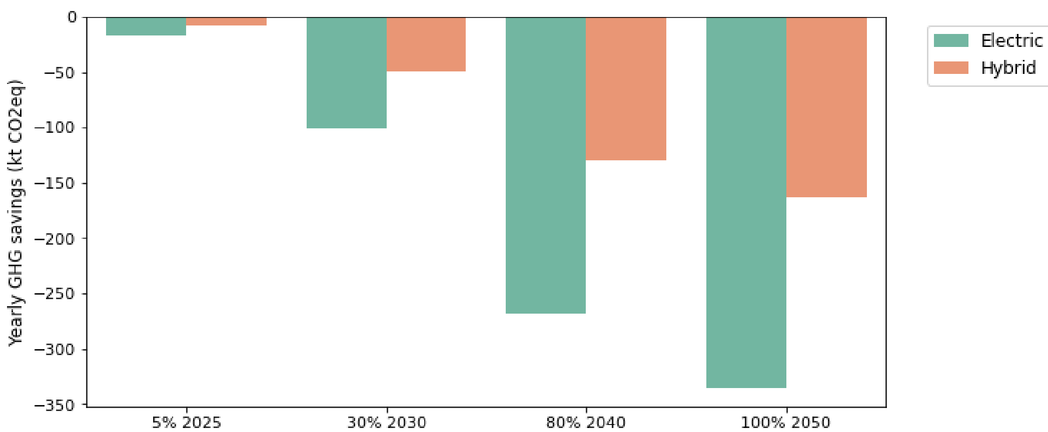
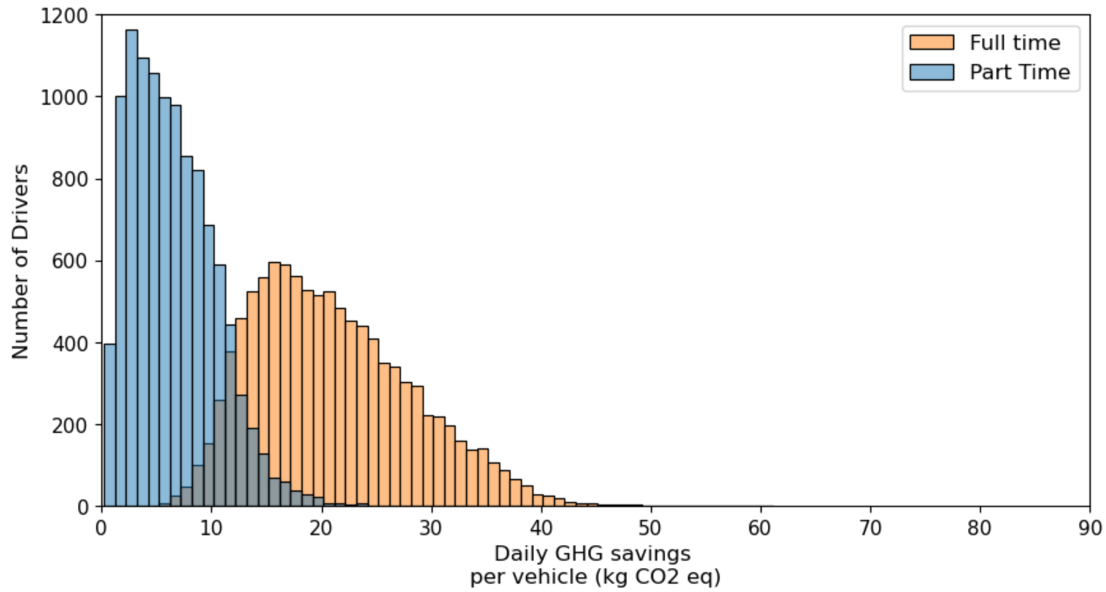


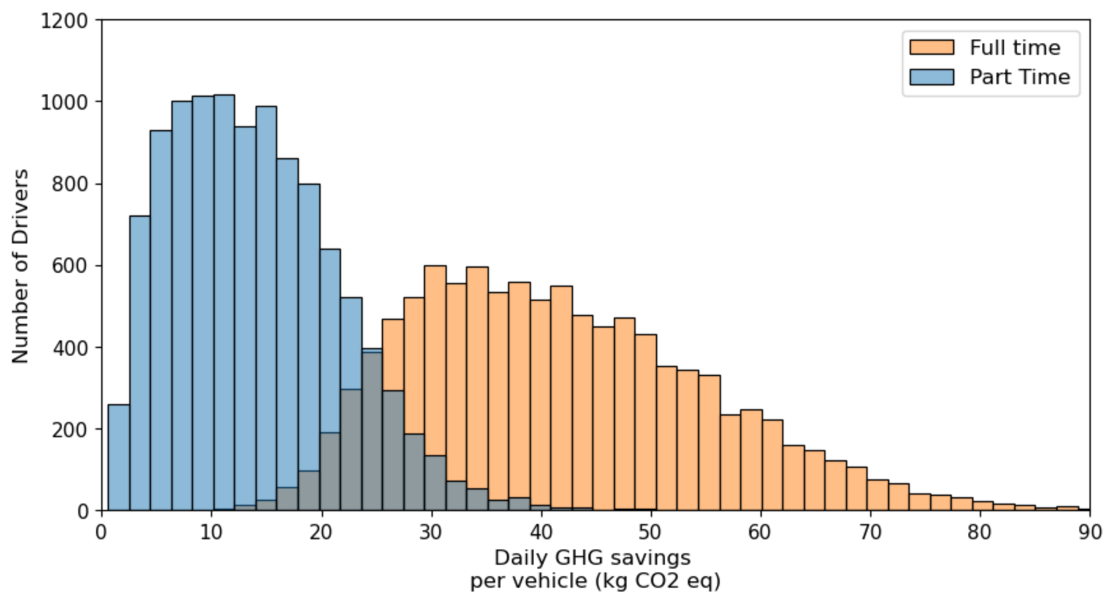
Figure 6: VFH yearly GHG savings achieved from PHEV and BEV scenarios with 5%, 30%, 80% and 100% penetration (percent reductions are compared to a base case scenario with GHG emissions for the VFH industry equal to 392 kt CO_2eq in 2019)

The GHG savings achieved with electrification were further explored at the driver level by distinguishing part- and full-time drivers. Full-time drivers are designated as drivers that are active for more than 4 distinct hours on the evaluated day while part-time drivers are active 4 hours or less. With this definition, full- and part-time drivers are estimated to travel 40,560 km and 14,560 km annually.

Figures 3 (a and b) present the distribution of daily GHG savings per vehicle using a) PHEVs and b) BEVs segmented by full- and part-time drivers. A similar trend can be observed across both figures, with full-time drivers achieving more than twice as much GHG emission savings relative to part-time drivers due the higher distance travelled by their vehicles per day.



a) Daily GHG savings per vehicle achieved with PHEVs



b) Daily GHG savings per vehicle achieved with BEVs

Figure 7: Distribution of daily GHG savings achieved with a) PHEVs b) BEVs by segmenting drivers in terms of full and part-time status

5. VFH Electrification Key Considerations

5.1 Charging infrastructure

Public charging infrastructure is essential to improving the uptake of BEVs. VFH drivers, particularly full-time VFH drivers who drive daily distances that are close to battery capacity limits, will require direct current (DC) fast public charging infrastructure to limit any lost revenue, which occur while charging, driving to, or queuing at charging stations. The collected data shows that 4% of part-time drivers and a 66% of full-time PTC drivers would require charging during their PTC shift using the lowest range vehicle (40-kWh battery capacity Nissan Leaf BEV). In this context, it is important to adequately plan and design the required charging infrastructure that enables the electrification of the VFH industry.

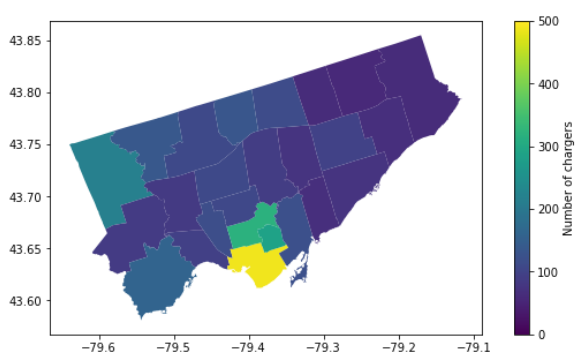
The estimated total energy consumption for all vehicles-for-hire on a typical, winter, pre-pandemic day with a Nissan Leaf is 827,625 kWh at full electrification. Based on these needs, the number of needed chargers can vary based on a multitude of factors including the utilization of stations in each geographic location, access of VFH drivers to home charging, the charging power of the stations and the vehicle battery capacities and charging capabilities.

Charging infrastructure needs were estimated for a fully electrified VFH fleet based on two scenarios:

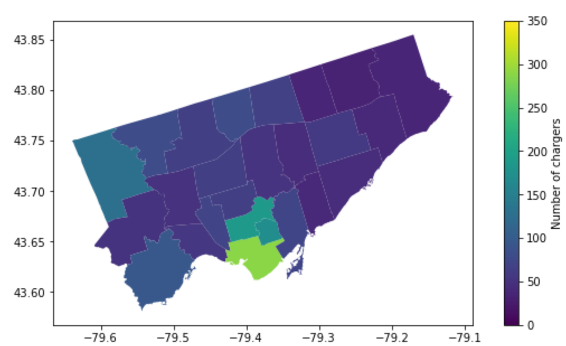
1. VFH drivers relying exclusively on public charging; and
2. 40% of VFH drivers relying on home charging.

Under 100% BEV penetration, a total of 3,449 and 2,040 DC fast chargers with a power level of 60 kW are required for each scenario, assuming the 60-kW charging stations are used by VFH drivers for four hours per day. The 60-kW power level was chosen to offer a balance between the typical hardware charging speed restrictions of existing BEVs on the market, the impact of charging time on driver revenue, the cost of charging infrastructure, and the limitations of existing transmission electricity grids.

Significant technological developments are occurring in the automotive sector to increase the charging rate capacity of new BEVs to accept a power output of at least 150 kW. This would reduce the number of chargers estimated in this study by at least a factor of two. Figure 8 presents the distribution and number of DC fast chargers across the City of Toronto’s 25 wards under the two scenarios, noting the gradient scale differences between the two maps.



Scenario 1: VFH sector relies exclusively on public level 3 charging stations



Scenario 2: VFH sector relies on public level 3 charging stations and home level/on-street charging stations that are available to 40% of drivers

Figure 8: Distribution of DC 60 kW public chargers across the City of Toronto assuming a BEV penetration of 100%

5.2 Cost of ownership

The economics of electric vehicles entail a higher capital cost for the purchase of a vehicle that is followed by operational savings throughout the lifetime of the vehicle. These operational cost savings are achieved through maintenance and fuel cost savings that result in a lower overall total cost of ownership relative to ICE vehicles after a certain number of years. This study examined the economics of owning BEVs for drivers in the VFH industry, by analyzing the differences between part- and full-time drivers, who have varying annual distance travelled and thus differing ownership costs. The analysis included various scenarios, such as relying solely on public charging infrastructure or utilizing low overnight charging rates available in Ontario.

Due to the early stage of development with electric vehicles and evolving policies that support its use, it is difficult to precisely predict the amount of time to reach cost parity. A sensitivity analysis was conducted to identify different charging scenarios (home versus public charging), charging rates, and the inclusion of the $5,000 federal incentive for the purchase of electric vehicles. Figure 8 summarizes the number of years to reach parity between a benchmark Toyota Camry ICE vehicle with a Kia Soul EV6 BEV.

	25,000 km Yearly Distance Approx median distance travelled for a part-time VFH driver		50,000 km Yearly Distance Approx median distance travelled for a full-time VFH driver	
	With Federal Incentive	Without Federal Incentive	With Federal Incentive	Without Federal Incentive
Exclusively Home Charging				
At $0.025 per kWh	3.4 years	4.8 years	1.7 years	2.4 years
At $0.08 per kWh	3.7 years	5.2 years	1.9 years	2.6 years
Exclusively Public Charging				
At $0.15 per kWh	3.7 years	5.4 years	1.9 years	2.7 years
At $0.30 per kWh	4.9 years	7.0 years	2.4 years	3.5 years
At $0.40 per kWh	6.1 years	8.8 years	3.1 years	4.4 years

Figure 9: Number of years required to break even with a BEV (Kia Soul EV6) relative to ICE (Toyota Camry) vehicle based on yearly distance travelled

As shown in Figure 9, the economics of owning a BEV are more favourable for full-time drivers due to their high annual mileage. Drivers who are able to take advantage of lower home charging rates will reach cost parity much faster than relying solely on public charging. With the diverse profile of VFH drivers in the City, it is expected that a majority of drivers will require a combination of both home and public charging to sustain their operation on a given day. Part-time drivers will reach parity between 3.4 to 8.8 years, while full-time drivers will reach the same point within 1.7 to 4.4 years.

Additional research could be undertaken to assess a broader range of vehicle models and driver travel distance profiles, with the aim of more accurately determining the proportion of VFH drivers for whom vehicle electrification is financially feasible.

6. Conclusion

This study established the contribution of the VFH sector to transportation GHG emissions in the City of Toronto. The study takes an evidence-based approach to investigate the effectiveness of three widely promoted methods—deadheading, pooling and electrification—for reducing GHG emissions from vehicles-for-hire in the Toronto context.

Deadheading contributes 33% of PTC GHG emissions and deadheading increases the emission intensity of a non-pooled ride relative to driving a personal vehicle by 59%, due to the additional distance travelled from the drivers enroute to pick up a passenger and the distance travelled prior to accepting a trip. The analysis is however focused on operational GHG savings and does not consider potential GHG savings achieved from reduced vehicle ownership. Additionally, part-time drivers exhibit more deadheading, with the reasons for this difference still unclear. A hypothesis to test is that part-time drivers indicate availability on ride-hailing apps with less conviction to accept a trip than full-time drivers, resulting in a higher proportion of deadheading. Further research will be focused on approaches to minimize driver deadheading with no passenger on-board.

Before the pandemic, consumers did not significantly utilize pooled trips as a PTC service. In the evaluated week, only 10% of total trips were pooled trips, and of those, just 27% resulted in more than one passenger on board. In other words, only 27% of consumers who requested a pooled trip were matched with another passenger by the algorithm to share the ride. The emission intensity for a pooled ICE ride-hailing trip is 18% higher than that of driving one's own car. While the portion of the GHG emission intensity with passengers on-board is lower than a using a private vehicle due to the higher number of passengers in the vehicle, the contribution of deadheading results in a higher overall GHG intensity. This is because the demand for pooled trips is not high enough to achieve lower deadheading from chained trips. Despite this, pooling remains critical in reducing PTC GHG emissions, particularly for long-distance commuter trips. Suggested future research could focus on developing incentives to encourage consumers to use pooling services and identifying the most effective types of pooled trips based on consumer travel patterns.

Transitioning the VFH industry fleet to BEVs would result in a reduction in the City of Toronto's yearly transportation GHG emissions by around 5.3%. A comparison between full- and part-time drivers reveals that full-time drivers achieve three times the GHG savings of their part-time counterparts making them an impactful target for electrification policies. Moreover, the high mileage travelled by full-time drivers makes BEV ownership economically viable, as the cost savings from reduced fuel and maintenance expenses offset the higher capital cost of purchasing an electric vehicle. This is true regardless of whether full-time drivers take advantage of Ontario's overnight low-cost electricity charging or rely on more expensive public charging infrastructure. However, significant investments are necessary to build the charging infrastructure required to support the VFH fleet. Under 100% BEV penetration, over 3,000 DC fast chargers would be needed, a significant increase from the current 170 DC fast chargers in the City of Toronto. This number could be reduced by increasing the power level of the chargers or having a significant portion of drivers rely on home charging.