



Lisa (Elisabeth) DeMarco
Senior Partner
Bay Adelaide Centre
333 Bay Street, Suite 625
Toronto, ON M5H 2R2
TEL +1.647.991.1190
FAX +1.888.734.9459
lisa@demarcoallan.com

March 20, 2019

Kirsten Walli
Board Secretary
Ontario Energy Board
P.O. Box 2319, 27th Floor
2300 Yonge Street
Toronto, ON M4P 1E4

Dear Ms. Walli:

Re: Toronto Hydro-Electric System Limited
Application for order or orders approving or fixing just and reasonable distribution
rates and other charges, effective January 1, 2020 to December 31, 2024
Board File No. EB-2018-0165

We are counsel to the Distributed Resource Coalition (**DRC**) in the above-referenced proceeding (the **Proceeding**). Please find enclosed the expert evidence of Dr. Josipa Petrunic, submitted on behalf of DRC in the Proceeding, further to the Board's Decision on the Filing of Expert Evidence (dated February 14, 2019) and Procedural Order No. 6 (dated March 14, 2019).

Sincerely,

A handwritten signature in black ink, consisting of a stylized 'L' followed by a long, sweeping horizontal stroke that ends in an arrowhead.

Lisa (Elisabeth) DeMarco

c. Charles Keizer, Torys LLP
Andrew Sasso and Daliana Coban, Toronto Hydro
Distributed Resource Coalition

Electrified Transportation Systems in the Context of Utility Planning: Light-Duty and Heavy-Duty Applications

Evidence prepared by
Canadian Urban Transit Research & Innovation Consortium (CUTRIC)
for Distributed Resource Coalition

EB-2018-0165

March 20, 2019

Author:

Josipa Petrunic, PhD, Executive Director and CEO, CUTRIC

Supporting Authors:

Anahita Jami, PhD, Research and National R&D Manager, CUTRIC

Abhishek Raj, PhD, Lead Electric Bus Program, Research and Project Development Officer,
CUTRIC

Anaïssia Franca, Research Strategy Manager, CUTRIC

**CUTRIC Evidence on Electrified Transportation Systems in the Context of Utility Planning:
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Executive Summary: Objectives and Goals

Toronto Hydro-Electric System Limited (Toronto Hydro) filed a five-year Custom Incentive Rate-setting (IR) application with the Ontario Energy Board (OEB) on August 15, 2018 (updated September 14, 2018) seeking approval for changes to its distribution rates for a five-year period from January 1, 2020 to December 31, 2024. During that period, we anticipate that significant electricity distribution efficiencies from electric vehicles (EVs) and the distributed energy resources (DERs) associated with them can and should be achieved and incorporated into any five-year distribution plan. This evidence highlights potential efficiencies and enhanced reliability for customers and Toronto Hydro (capital expenditures and operations and maintenance) related to EVs and associated DERs. This evidence is provided by the Canadian Urban Transit Research & Innovation Consortium (CUTRIC), a leading organization focused on electrification of transportation, and was commissioned by the Distributed Resource Coalition (DRC), which has intervened in this proceeding in support of EV and related DER resources to facilitate efficiency and distribution system optimization.

CUTRIC's mission is to support the commercialization of technologies through industry-led collaborative research, development, demonstration, and integration projects that bring innovative design to Canada's low-carbon smart mobility ecosystem. It has been retained by DRC to consider:

- 1. Customer efficiencies that may be effected through progressive integration of EVs and related DER charging infrastructure into electricity distribution systems.**
- 2. Electric buses, EV, and related DER charging infrastructure as a reliability resource for electricity distribution systems.¹**
- 3. Integration of battery electric buses (BEBs) and EVs and related charging infrastructure into local electricity distribution system planning, and related operations and maintenance considerations; and**
- 4. BEB and EV related considerations for distribution rate base design.**

The evidence is organized as follows: (i) summary findings, (ii) general introduction to the topic, of heavy- and light-duty EV technologies; (iii) review of the predictive modelling work performed by CUTRIC using the TRiPSIM® modelling tool for BEBs² and predictive analytical outcomes provided by the EV (car) literature.

The evidence provides key considerations regarding long-term savings and revenue generation opportunities for Toronto Hydro based on current opportunities associated with the development, integration and intelligent management of charging system hubs and networks for

¹ Electric truck technologies are being designed to support interoperable charging infrastructure, i.e., potentially interoperable with buses and coach charging infrastructure at the municipal level in the future. Thus, the discussion of battery electric buses (BEBs) here will serve as a stand in for analogous considerations allied to battery electric trucks that would require charging infrastructure for both long-distance freight trucks and return-to-base delivery vehicles. A thorough separate study would be required for a full assessment of the impacts and considerations that need to be taken into account vis-a-vis truck electrification.

² We note that the BEB modelling referred to in this evidence is based on analysis of Brampton Transit's bus electrification needs. Similar and more refined modelling outputs are currently being produced for the TTC, which falls primarily within the service area of Toronto Hydro. This latter modelling will be more directly relevant to Toronto Hydro's rates, but it is not yet in the public domain. CUTRIC recommends that the OEB and Toronto Hydro consider the outcomes of the TTC modelling before finalizing a five-year rate structure. The data provides an interim analysis of potential opportunities associated with electrification goals within the territory of Alectra Utilities. This is meant to facilitate the OEB's and Toronto Hydro's consideration of the potential impact and savings that are likely to arise from EVs during the Planning Period.

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high-powered and low-powered charging infrastructure, as well as associated integrated energy storage devices. Each of these elements form an important part of the EV landscape and are relevant to demand management, DERs, and potential operational efficiencies.

We note that on March 19, 2019, the federal government has announced significant new EV incentives for customers and municipalities that are likely to enhance the related utility efficiencies and customer savings that are outlined in this evidence.

Summary Conclusions

There are a number of customer³ savings and utility efficiencies opportunities that may be realized by actively incorporating EVs, BEBs, and related charging infrastructure into Toronto Hydro's distribution planning over the 2020-2024 period. They include:

1. Customer efficiencies resulting from the progressive integration of heavy-duty and light-duty EVs based on intelligently controlled and managed fleets of chargers and allied storage devices given the cheapness of electricity as a propulsion fuel over gasoline and diesel in all instances in Toronto. This may also result in:
 - a. reduced greenhouse gas (GHG) emissions from the transportation sector across Toronto; and
 - b. increased distribution asset lifecycles, and decreased operations, maintenance and administration (OM&A) costs (due to improved grid management based on charging and storage devices, which enable long-term grid reliability and provide customer choice and savings through charging systems).
2. Improved electricity reliability through the integration and use of BEBs, EVs and storage devices as grid resources in order to capture and optimize surplus baseload power and intermittent renewable power and provide the "fuel" for existing and future transportation propulsion systems (particularly in light of the recently proposed federal EV penetration targets and incentives). Specifically, this may include:
 - a. Optimization of the distribution network through the use of BEBs, EVs, and allied storage devices, as a reliability and backup resource for electricity distribution systems through an artificially intelligent (AI) network of instantaneously deployed DERs to fuel the grid in times of peak requirements or to manage grid-wide variabilities in demand across Toronto Hydro's network throughout any given 24-hour period.
3. Long- and short-term OM&A savings that may emanate from the improved system-wide management of optimized cycling of both onboard batteries in EVs and offboard batteries in stationary devices at the site of chargers, which may minimize grid impacts associated with new transportation electrification demands, and to manage existing industrial and residential loads on the grid.
4. Distribution system efficiencies that may result from dedicated and/or newly established rate structures or tariffs established for heavy-duty applications, municipally-owned BEBs, and heavy-duty vehicles owned by Toronto Hydro and/or its primary shareholder, the City of Toronto (the City) (including the Toronto Transit Commission (TTC) and City vehicle fleet). City-wide savings may also be achieved through displacing imported diesel and gasoline fuels used for the City fleet with clean, Ontario-produced electricity.

³ Note that the term "customer" in these discussions includes both the City of Toronto (and TTC as a division of the city) as well as individual residential electricity customers across Toronto.

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This broad range of potential opportunities and efficiencies that are likely to result from active integration of EVs, BEBs, and charging infrastructure into the distribution system plan for 2020-2024 are significant, but difficult to quantify in the absence of specific plans.

The below sections set out new revenue possibilities for Toronto Hydro from electrification in the context of the TTC and EV penetration:

Potential New Revenues from Electric Bus Charging: TTC & Toronto Hydro

If Toronto Hydro or other entities were to support investments in EV charging infrastructure and/or customer benefits plans allied with charging demand management, the following new revenue sources could arise:

- In the City of Toronto, based on early estimations emanating from CUTRIC TRiPSIM© based modelling, approximately 30% of electric bus charging may occur overnight with the other 70% occurring during the day. For the purposes of evidence presented here, CUTRIC has estimated that 50% of daytime charging occurs during the peak periods and 50% occurs during non-peak periods.
- With no energy storage integrated into the system to offset peak demand, the 30:35:35 division of off-peak: mid-peak: peak charging hours would create estimated new revenues for Toronto Hydro from the City of Toronto equal to approximately \$20,015,800 if the full TTC fleet were electrified.
 - According to TTC's Staff Report entitled "Green Bus Technology Plan", the TTC has recommended procuring only zero-emissions buses starting in 2025 to achieve a 100% zero-emissions bus fleet by 2040 (TTC, 2017). To achieve this goal, the TTC must commence purchasing and integrating zero-emissions BEBs immediately, and it has already done so with an initial procurement of 30 electric buses starting in 2018.
 - Thus, by 2025, it is reasonable to assume TTC's fleet of buses would need to be at least 30% electrified to achieve the transit agency's goal of zero-emissions by 2040, which would result in new revenues to Toronto Hydro of approximately \$6 million per annum by 2025.
 - These calculations are based on Toronto Hydro's current residential rates of 13.2 cents/kWh at peak, 9.4 cents/kWh at mid-peak, and 6.5 cents/kWh off-peak (Toronto Hydro, 2019).
- These revenues could be distributed across the customer base in the form of savings or utilized to offset the costs of utility-owned, operated and maintained EV charging networks of infrastructure.

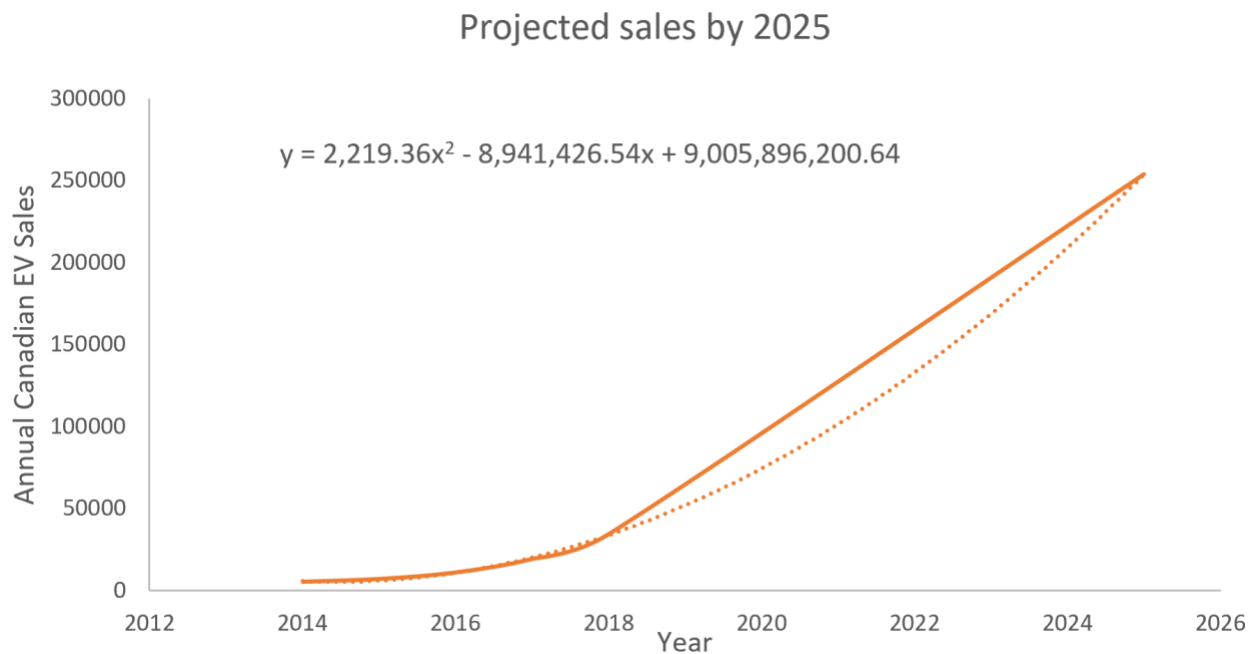
Potential New Revenues for Electric Car Charging: Toronto EV drivers & Toronto Hydro

- With regards to EV charging among individual passenger car owners, CUTRIC estimates that 50% charging occurs overnight (i.e., off peak), 25% during peak hours and 25% at mid-peak (taking into account a future in which not all EV owners will be home owners with access to nighttime charging in all cases).
- With no energy storage integrated into the system to offset peak demand, the 50:25:25 division of off-peak: mid-peak: peak charging hours for EVs creates estimated new revenues for Toronto Hydro from EV electricity customers can be estimated.

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- To generate reasonable potential estimations of EV penetration rates in Toronto by 2025, CUTRIC expanded the curve describing national sales of EVs from 2013 to 2018 (including plug-in hybrids and fully battery EVs), as cited by IHS (formerly R.L. Polk & Company) registration data (Fleetcarma, 2018). This extrapolation curve utilized a second order polynomial (as opposed to third order trend line) to suggest a total EV sales outlook of approximately 254,000 EVs across Canada by 2025, which constitutes approximately 12.7% of all car sales in Canada assuming a constant sales figure of approximately 2 million cars sold in Canada per annum (Autonews, 2018).
- Based on these figures, it is reasonable to assume a penetration rate of 5% of all cars in Toronto being EVs (a combination of battery electric and plug-in-hybrids), which could result in new revenues for Toronto Hydro of approximately \$18 million per annum by 2025.

Image 1.0 Extended growth curve predicting EV sales in Canada based on past sales data



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Table 1.0 Summary table of new revenues per annum

	TTC's (ebus) electrification (100% of fleet by 2040)	TTC's (ebus) electrification (30% of fleet by 2025)	Toronto's EV (car) electrification (5% by 2025)
Total GWh	203	61	189
\$	\$20,015,800	\$6,004,740	\$18,635,400

Operations & Maintenance Considerations: Efficiency Savings E-Buses & EVs

- The revenues noted above may be lessened by increased off-peak charging which, in the case of electric buses specifically, would be enabled by the integration of energy storage devices. The loss in new revenues from lower off-peak periods to Toronto Hydro may be compensated by virtue of the savings due to reliability of grid services emanating from optimized demand management and delayed grid-side infrastructure investments required to manage the delivery of mid-peak and peak hour electrical services to the City of Toronto as an e-bus electricity customer.
- Similarly, the integration of energy storage at the side of EV charging network “hubs” that Toronto Hydro may own and operate in the future could help to achieve similar systems-wide savings in terms of demand management for grid health and asset life cycle extension or diminished grid-side investments in infrastructure upgrades to manage peak requirements of EVs.
- These savings would need to be more precisely calculated against the costs of the capital investment associated with charging systems integration.

We have attempted above to provide rough estimates of the potential new revenues generated by Toronto Hydro from EV customers, which could be passed back to the general rate base in the form of rate base reductions across the entire network.

These estimates and the evidence do not presume or advocate for a specific model of ownership of EV, BEB, or charging infrastructure and we expressly note that customer savings, utility efficiencies, and new revenue streams may be achieved regardless of whether the utility pursues a regulated or unregulated EV charging business model.

CUTRIC is of the view that the potential customer savings and distribution efficiencies are real and may be realized if electrification of transportation is actively integrated into the distribution system plan during the 2020-2024 period.

It is also integral for Toronto Hydro to ensure a prudent approach to EV, BEB, and charging infrastructure investment through prudent planning that ensures that such DERs are not installed in an ad hoc manner absent of broader grid planning considerations and likely to result in stranded assets.

In summary, CUTRIC urges the OEB to facilitate Toronto Hydro’s integration of EVs, BEBs, and charging infrastructure into its 2020-2024 distribution system plan and revenue requirement, and thereby avoid unnecessary costs, stranded assets, and lost efficiencies from failing to incorporate the rapid electrification of the transportation system into its proposed five-year rates.

Introduction

Over the past several years, Canada has made an international commitment under the Paris Agreement to reduce its GHG emissions by 30% from 2005 levels by 2030. Currently, Canada's GHG emissions from the transportation sector have increased from 122 Mt CO₂e in 1990 to 173 Mt CO₂e in 2016 — an increase of almost 42% (ECCC, 2018).

Similarly, Ontario has recently revised its GHG emission targets and is committed to reducing its GHG emissions by 30% from 2005 levels by 2030. Ontario's GHG emissions from the transportation sector have also increased from 41.6 Mt CO₂e in 1990 to 55.8 Mt CO₂e in 2016 — an increase of over 14% (ECCC, 2018).

The transportation sector is therefore a prime focus for emission reductions in order to meet both the federal and Ontario GHG emission reduction targets and electrification of transportation is a key strategy to achieve such reductions. This will necessitate a transition from diesel and gasoline-based propulsion to electricity-based propulsion through battery EVs (hybrids, plug-in hybrids and fully electric vehicles) and hydrogen electric propulsion systems. The recently announced 2019 federal budget includes at least \$500 million in related incentives.

Appendix A to this evidence provides background information on electric vehicle supply equipment (EVSE) ownership and tariff models for utilities, the electrification of heavy-duty and light-duty vehicles to support our views on the relevance and efficiency of transportation electrification in the context of Toronto Hydro's 2020-2024 distribution rates.

Discussion

1. Potential Customer Savings and Distribution System Efficiencies through EVs and Associated DERs

All types of heavy-duty and light-duty EVs, EV charging infrastructure, and related distributed electricity storage may contribute to significant customer savings and distribution system efficiencies over the long term.

Heavy-Duty Vehicles

Heavy-duty vehicle electrification, including a transition to electric buses, may result in a number of efficiencies for a number of stakeholders. Specifically, each and all of Toronto Hydro's customers, the transit agency, the municipal and provincial taxpayer, may benefit from bus and other heavy vehicle electrification. Within Toronto Hydro's service area, both the TTC and York Region Transit (YRT) may benefit from high-powered ("fast") and low-powered ("slow") charging electrification systems integration. Toronto Hydro may wish to develop rates and services for electrified heavy-duty vehicles in order to facilitate systems integration, installation, operation, maintenance and control of high- and low-powered charging systems for BEBs, municipal trucks, and integrated energy storage resources. We envision that this could be done directly as the utility or through an affiliate or competitive entity for the benefit of distribution customers. Toronto Hydro may, either directly or indirectly, also wish to consider providing related services to surrounding communities with local distribution companies that do not have the scope or scale to provide related charging infrastructure installation and services.

Currently, CUTRIC is delivering a full-fleet feasibility study for the TTC to assess the costs, environmental benefits and systems integration requirements associated with electrifying the entire TTC bus route system (which is composed of approximately 175 routes serviced by thousands of vehicles). One of the main outcomes of this feasibility study will be to provide recommendations on a strategic electrification plan which incorporates a refined calculation of the yearly electricity demand and related requirements and identifies the optimal mechanism by which electric loads will need to be distributed across the jurisdiction. As of the date of this submission (March 20, 2019), these results are not yet public. It may be possible, however, for these results to be made public, with the City's consent, during the time period that the Toronto Hydro application is being considered by the Board.

It is worthwhile to consider the high-level opportunities associated with TTC's electrification here. In 2016, the TTC used a total of 88,618,955 L of diesel.⁴ The equivalent energy density of diesel is 10kWh/L. The CUTRIC modelling package TRiPSIM©, has been used to perform an analysis of approximately 50 transit routes across Ontario, and an electric bus is approximately 77% more energy efficient than a diesel bus. Applying this average, the TTC's current diesel fuel consumption expressed as electricity consumption would be approximately 203 GWh of energy if the entire fleet were electrified in 2016. Data indicate the TTC already consumed a total of 428 GWh of electrical energy in 2016 to operate its subways and streetcars primarily. Therefore, the electrification of TTC's bus fleet (as of 2016) would increase the City's transit-related electricity consumption by almost 50%.⁵ As TTC's fleet has continued to grow, this figure is anticipated to be higher in 2019. CUTRIC submits that Toronto Hydro's distribution system plan and resulting rates should incorporate at least a portion of the significant electricity load growth that can reasonably be anticipated from electrification of buses. The plan should also

⁴ Based on data derived from the Ontario Urban Transit Fact Book: 2016 Operating Data, as prepared for the Ontario Ministry of Transportation by the Canadian Urban Transit Association (CUTA),

⁵ See note 4, above.

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expressly consider that some of the associated peak demand will be concentrated at depots (when buses return for top-up charging) and at highly congested traffic locations with on route “fast” chargers that will need to operate, at times, for 24 hours a day and during periods that may include peak demand periods.

It is crucial to use a route-based modelling tool in order to assess the benefits resulting from electrifying transit to the TTC and Toronto Hydro customers that are also taxpayers, as differing returns on investment emerge based on the application of the vehicles. For example, electrification of buses along routes that are short distance, with low frequency of service, low ridership, and relatively light loads will cost more overtime compared to electrification of routes that are longer with high frequency, high ridership and therefore heavy loads. The results show that generally, where diesel performs the worst, electrification may perform best from an energy efficiency and emissions perspective. Therefore heavy-loaded routes that engage in stopping and starting, frequent acceleration and deceleration, and full passenger loads (which consume large quantities of diesel) will generally demonstrate result in the greatest savings when electrified but will also result on greater electricity demand. In these instances, the return on upfront capital investments is also quicker when compared to lower consumption routes based on savings over diesel costs. It is also possible for transit agencies to optimize how they electrify in order to maximize relative efficiencies by choosing where in their fleet/jurisdiction they electrify first. By doing so they may gain maximum return on investment (ROI) in the initial years when capital costs are higher (given that capital costs of e-buses, storage devices and chargers are expected to fall over time as mass production gets underway in the heavy-duty landscape). Electricity consumers may benefit from greater demand over the same distance of distribution wire assets, thereby rationalizing costs for all.

Similarly, it is possible to assess the ROI and total cost of ownership of high- and low-powered EV chargers by performing an economic analysis of full fleet electrification. CUTRIC anticipates that this information as it applies to the TTC will be available in the next several months.

In the interim, we provide an overview of the methodology used and a summary of outcomes associated with a similar feasibility and economic modelling analysis performed for Brampton Transit, for a single, high density, 30 km route. The outcome of both the feasibility and economic study for Brampton Transit Route 23 are available upon request.⁶

Light-Duty Vehicles

The electrification of light-duty vehicles will induce a significant load growth on Toronto Hydro's grid. Using the 2009 average distance travelled for light duty vehicles, the average number of cars per household and the average fuel consumption in Ontario (NRCan, 2011), along with the number of associated households in Toronto (City of Toronto, 2017), the total fuel consumption of 2009 for cars in Toronto was estimated. The energy density of 1L of gasoline is 11 kWh. We assume that electric cars are on average 80% more efficient than their internal combustion engine (ICE) counterpart, the total energy consumption per year if the entire GTA would be around 3,780 GWh. In 2017, Toronto Hydro delivered 24,381 GWh of power (Toronto Hydro, 2017). We anticipate electrification of light vehicles to increase significantly as a function of shifts in OEM vehicle fleets offered during the 2020-2024 period covered in the application. The recently announced federal EV incentives are likely to further accelerate EV adoption and ICE turnover to EVs in the GTA. It is therefore prudent for Toronto Hydro to plan for at least a portion of this potential load growth attributable to light-duty EVs.

⁶ CUTRIC. Techno-economic modelling of an electric bus demonstration project Brampton Route #23. July 20, 2018. (available upon request).

Customer Efficiencies

Cost Savings: Heavy-Duty Vehicles

Heavy duty EVs, including the electrification of buses, are likely to result in cost and rate savings to large transit customers of Toronto Hydro, and taxpayers that are also ratepayers of Toronto Hydro. This savings results in part from the high efficiency of electric motors and electricity as a propulsion fuel in a heavy-duty powertrain system as compared to the low efficiency of diesel engines and diesel as a propulsion fuel in a heavy-duty powertrain system. It also increases electricity demand and distributes related distribution costs over a greater number of diverse customers that may facilitate system benefits through their different load profiles. The Brampton analysis⁷ shows a savings of 76-82% per year compared to the status quo baseline scenario (with diesel fuel propulsion) for the City of Brampton. We anticipate analogous results for cities like Toronto.

The CUTRIC full fleet electrification analysis for TTC will help in assessing the City's ROI in electrifying all of its routes. In this regard, the analysis will demonstrate the utilization rate of chargers and e-buses required to ensure savings over time for the entire electric mobility system installation in Toronto compared to legacy diesel mobility systems. These figures will help Toronto Hydro and the City of Toronto determine the best pathway for capital and O&M investments in the future, a factor which should feed into considerations of the rate base as an opportunity for long-term revenue generation through O&M contracts by Toronto Hydro in partnership with TTC, as well as long-term energy consumption stabilization, demand management and grid management that emanates from Toronto Hydro's, or another entity's, potential ownership, operation and maintenance of chargers and allied storage devices over the long-term.

Cost Savings: Light-Duty Vehicles

Many electricity distribution customers will benefit from the progressive integration of EVs as a result of the increase in demand and decrease in OM&A per customer. On a total bill perspective, electricity is a much more efficient transportation fuel that has overall system benefits for electricity customers. A kWh in Toronto has an average delivered cost of 12.15 cent/kWh (Toronto Sun, 2016) and the price of gasoline is approximately 118.9 cents/L. One liter of gasoline is equivalent to 11 kWh in terms of energy density, but electric cars are much more efficient than their gasoline counterparts therefore cost savings on the operation will be achieved by EV users. Additionally, Toronto Hydro would financially benefit from electrifying its own vehicle fleet as it would reduce the utility's own overall OM&A expenses (Toronto Hydro, 2018). Additionally, the TCO for electric cars, when factoring in maintenance, is cheaper than traditional light duty vehicles. In a study performed by Palmer et al., the maintenance costs of EVs are shown to be 23% cheaper than gasoline cars (Palmer, 2018).

Though CUTRIC does not have in-house modelling with quantitative figures for EV, other studies have shown that EVs can convert up to 62% of the energy they get from charging to propel the vehicle (i.e., grid to wheel) while gasoline cars can only convert up to 21% of energy (i.e., tank to wheel). From an energy use standpoint, electric cars are significantly more efficient than gasoline or diesel cars (Cleantechnica, 2018).

Finally, the Toronto Hydro distribution grid may benefit significantly by optimizing EV and charging assets in a manner that responds to customer demand and flexibility requirements. This, in turn, is likely to result in distribution savings from pacing wires investments and related

⁷ CUTRIC. Techno-economic modelling of an electric bus demonstration project Brampton Route #23. July 20, 2018. (available upon request)

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capital expenditures through the flexibility that may be harnessed from EVs and charging infrastructure on the distribution system. Specifically, incentives for EVs to charge at night, like those implemented by Alectra, may result in both system and Toronto Hydro customer benefits. Further, EV battery assets may be used as an effective distributed energy resource at times of peak demand or compromised reliability.

Environmental Efficiencies

There are also significant GHG benefits resulting from electrification of the transportation sector. CUTRIC's TRiPSIM® tool estimates that up to 98% of Ontario's GHG emissions from the transit sector can be eliminated upon full vehicle fleet electrification. This will also improve local air quality. We recognize that full electrification during the 2020-2024 period is unlikely but anticipate that between up to 30% of new buses adopted in the GTA during that period could be BEBs.

Similar GHG reductions can be anticipated from the ongoing electrification of light-duty EVs. The Conference Board of Canada indicates that plug-in electric cars could reduce GHG emissions across Canada by 1,394MT assuming a minimum potential scenario of 10% share of new vehicle sales. Current EV incentives, along with OEM fleet commitments to provide 100% EVs (BMW, Audi, Volvo, GM), and country-wide bans of sales of new ICE vehicles (Norway, India, announced, UK, France, Germany, China, considering) are anticipated to greatly accelerate the penetration of EVs and new EV sales. (The Conference Board of Canada, 2015).

2. EVs and Charging Infrastructure as a Reliability Resource for Electricity Distribution Systems

BEBs and EVs, particularly when coupled with charging infrastructure that includes energy storage, may offer a significant reliability resource for local distribution grids. There is potential for the bi-directional flow of electricity between BEBs and EVs and the use of BEBs, EVs and related charging/storage infrastructure to offer reliability benefits and improvements to the system overall. This may defer related "wires" investments addressing peak demand and result in further system-wide savings.

Light-Duty Vehicles

Though electric cars do not operate on a fixed route and schedule like BEBs, driving patterns can be recognized and help inform charger localization. For instance, workers coming from outside Toronto and parking at specific locations offer "low hanging fruit" to electrify. Several arguments offered above in the heavy-duty domain have analogous arguments in the light-duty realm when trying to assess how electric cars and chargers can serve as reliable resource for electricity distribution systems.

First, charging electric cars can serve as stationary power sources with vehicle-to-grid (V2G) capacities and the charging rate can be monitored and controlled remotely and digitally. Therefore, if Toronto Hydro were to put in place Demand Response programs with incentives for users, charging electric cars could serve to buffer the grid load fluctuations.

Additionally, energy storage devices can be paired with existing charging infrastructure for additional flexibility and to accommodate unpredictable power variations, such as when electricity is generated from wind power. It would allow for a higher integration of these power sources into the grid, leading to greater greenhouse gas emissions reductions.

3. Integration of Electric Buses and Related Distributed Charging Infrastructure into Local Electricity Distribution Systems Planning and Related O&M Considerations

As noted above, the integration of electric buses and charging infrastructure opens the door to new business opportunities for utilities. Most transit agencies usually lack the personnel required to maintain and operate the chargers and/or storage devices, especially with relation to high power charging (450 kW+) which utilize overhead pantograph systems. This is remedied if the local utility takes over the operation and maintenance for the chargers through an innovative P3 ownership model in partnership with transit, or a direct “fee for service” model of asset and service delivery.

In this section, we will provide an example of how this has played out in the first phase of the Pan Canadian Electric Bus Demonstration and Integration Trial (2016-2022), as led by CUTRIC with champion agencies Brampton Transit, YRT and TransLink (Vancouver). E-buses and e-chargers are currently on route and will be installed and operational in Vancouver by May/June 2019 while the e-buses and e-chargers for YRT and Brampton will arrive later this year and into next year as a phased procurement process is underway. Once launched, all e-buses and e-chargers will carry data loggers on board for real-time data analysis.

In York Region, a unique business model has been adopted wherein the overhead charging system will be owned, operated and maintained by Newmarket-Tay Power Distribution Limited (NTPDL) for the purpose of rapid charging of the electric buses of YRT. As noted above, NTPDL is actively seeking new business models for shared and distributed electric charger ownership between utilities and transit agencies.

In the case of Brampton Transit, a different business model is emerging due to a lack of interest or capability by Alectra (as a utility partner in the jurisdiction) to develop a similar prototypical or demonstration business model; in this instance, while Brampton is intending to own the charger (and eventual storage) assets, it is actively seeking — with the assistance of the CUTRIC team — a 3rd party provider or set of 3rd party providers who can form a consortium of operations, maintenance and service delivery support on a fee-for-service basis.

In Vancouver, TransLink has partnered with BC Hydro which has provided support for the integration of the chargers and which is a keen data collection partner; however, TransLink operates heavy-duty electric rail as part of its SkyTrain network and therefore is developing capacity in house to own, operate, maintain the charger network. This may or may not change based on operational efficiencies gained and lessons learned in the future from the operations and maintenance of high-powered charging equipment that may — in future — be used by fleets other than TransLink itself.

These three business models have created an ideal testing and learning ground that will enable the customers of electricity (as transit agencies) and their shareholders (as taxpayers) to determine which one or many business pathways make feasible sense over the long-term.

In the case of TTC’s electrification, there is a business case for Toronto Hydro to be made in terms of contracting the latter to operate and maintain in the interests both of transit and the grid a widespread network of chargers and storage devices in the future. It is not feasible to expect transit agencies that choose to own, operate and maintain these systems — as TTC may decide to do — to digitally manage the DER in a manner that accommodates or supports the grid, however. If and when transit owns, operates and maintains these distributed resources it will be in the sole interest of transit system operation, and not of the grid, unless or until significant incentives for integrating other considerations come into play. Thus, there is an urgency to be

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noted in underscoring the fact that Toronto Hydro's investments — if any in this space — need to be based on a strategic plan that recognizes it is not the mandate of transit to care about the grid or manage wider grid concerns, even though the load transit will be drawing is not insignificant, it will not all be during non-peak or surplus power periods, and it will likely be at a variety of high- and low-power levels around the city. The integration of storage devices — if led solely by transit — will be pursued solely to reduce operational costs to e-bus performance overtime and not for the health of the grid.

Demand response, demand management and — utility — systems management to reduce electricity prices over time even as demand goes up in future years due to the electrification of transportation overall is a responsibility of the utility and systems operator; to achieve these goals requires utility investments today.

Importantly, the involvement of Toronto Hydro in this regard would be a signal to other major utilities that strategic thinking in the matrix of transit-utility operations is underway. Canada is a small country. There are few exemplars to follow in innovative design thinking in this regard. Toronto Hydro's leadership in this space would necessarily carry with its national leadership value, not just local costs savings over the long-term.

Other Considerations: Second Life Re-Utilization

A final business case consideration for DERs understood as e-bus batteries and storage devices is that an e-bus "end of life" occurs when battery capacity drops to 75% original state of charge as an average maximum capacity. At that point, the bus cannot deliver the service it is expected to deliver (indeed, this point may arise at higher SOC's as well though 75% is generally used as the cut-off for end-of-life service). While the vehicle chassis and body can be re-used and refurbished by transit, the battery cannot be unless it is sold off as a second-life storage device.

Knowing how to repurpose a used mobile storage device into a stationary storage device for transit or other applications is outside the scope of knowledge expertise within transit today and likely will remain so in the future. Separate businesses may crop up in this space specifically — as repurposing companies. Utilities are, however, well positioned to develop this knowledge and engage in the business practice of repurposing and reselling or re-integrating such devices in the future as part of their asset fleet. Indeed, Hydro Quebec already has research capacity in this regard and is likely the utility that is the furthest ahead in thinking about these lines of business in Canada.

These repurpose packs could serve as a potential low-cost grid support system applied anywhere in the grid — as appropriate or feasible based on design constraints — to enable peak shaving, grid balancing or to support demand response incentive programs to transit clients or household customers of energy.

Lastly, the business case opportunities noted above are bus-centric given CUTRIC's current occupations; however, these opportunities can be replicated across heavy-duty applications such as coach fleets and — especially — truck fleets of varying sizes and fleet models. Further studies are required to assess the feasibility and revenues that could come from these extended business lines.

Light-Duty Vehicles

Utilities face risks if their growth strategy does not include aggressive EV rate adoption alongside renewable energy development. Delivering enough power to the charging infrastructure is one concern, the other concern is about managing the load optimally on the

utility side. If utilities leave it to the users to operate their chargers, major disruption could happen on the grid side therefore it is crucial to implement a long-term vision on how to solve this issue.

There is a strong business case that could potentially generate revenues to Toronto Hydro if demand management is operated digitally.

4. Electric Bus-Related Distributed Energy Resource Considerations for Distribution Rate Base and Rate Design

Heavy-Duty Vehicles

In 2018, the California Transit Association conducted a study to examine electric rate structures that are most economic for electrified transit, especially buses. Different scenarios were presented for two types of route (namely a daytime and a commuter route). The outcomes of this study showed that no single rate design is currently optimal across all electric bus operations. One key conclusion was that a rate with a demand charge can be most economic if smart charging is enabled. Smart charging is defined as the ability to control the sequencing and throttle power. Advances in smart charging technology is required to add further demand charges in electricity rates.

But this finding serves as a wholesome starting point for the development of a strategic initiative by Toronto Hydro that considers the following critical factors:

- Transit systems need to electrify for both environmental and operational cost savings.
- In general, transit systems do not have the capacity on staff to operate and maintain high- or low-powered charging infrastructure and/or energy storage devices (whether battery-based, flywheel, H2 or other).
- Systems planning and systems integration thinking is required to ensure that transit agencies that are propelled into e-bus systems procurement do not proceed in an ad hoc “systems unaware” mode.
- Transit systems will never be responsible for grid management, and therefore a partnership of some form that enables optimization of the DERs that are soon to come under the control of transit agencies are actually integrated in a manner that intends to protect the electricity client over the long-term (both the transit agency, and Torontonians customers of Toronto Hydro, for example).
- There is currently no “right” solution; there are business models being tested in various jurisdictions; as a major utility player in Canada representing the largest city in the country, Toronto Hydro has an ethical duty to act in this space.

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Appendix A — Background on Transportation Electrification

This appendix provides additional background information on the following central elements of transportation electrification: (i) EVSE ownership and tariff models for utilities, (ii) demand-side load issues in the context of EVs; (iii) charging strategies and related considerations for heavy-duty vehicles, and (iv) charging strategies and related considerations for light-duty vehicles.

EVSE Ownership and Tariff Models for Utilities

Ownership Models

Several legislative and regulatory bodies have cited the opinion that utilities should be permitted to build and own make-ready locations (i.e., power supplied to the point where EVSE might be installed) and they should be able to recover those investments through the rate base as an investment in the general social good. Allowing utilities to create make-ready locations would align with long-established principle of line extension, where all customers pay for extending the distribution grid, including new service for rural customers where the cost of providing that service is far greater than that for customers living in densely populated urban environments. Building on this reasoning, the extension of the grid to support EVSE creates a long-term value for the entire network given the shared environmental benefits that EVs create for all customers. This type of reasoning allowed telephone companies to previously build out the pay phone network; each new phone was not necessarily expected to make a profit, but installations were considered necessary to create a functional and accessible network overall (Fitzgerald & Nelder, 2017).

Enabling utilities to own and install, or operate and maintain, EVSE could constitute one of the fastest ways to deploy EVSE across a jurisdiction given that utilities have access to large amounts of low-cost capital and an ability to recover investments over decades. Utility ownership may also serve to regulate electricity markets and avoid overpricing by private sector companies in a completely “private” marketplace. Certainly, regulators should be cautioned against creating a situation in which a utility could leverage its low internal cost of power generation and delivery to undercut private sector competitors on retail charging prices. And monopolistic utility ownership could prevent a competitive and sustainable private sector market in EVSE from arising in the future, and it is possible that utilities may not be as innovative in terms of technology adoption or business modelling compared to the private sector. But, regulators should not ignore the opportunity for utilities to play an investment, ownership, operations or maintenance role in EVSE deployment given their position in the electricity sector, which makes them among the most capacity-ready entities to act in this space in jurisdictions such as Toronto.

Waiting for non-utility driven EVSE investment, ownership and deployment business strategies to emerge will likely slow the growth of EVs across Toronto, given that private businesses are less likely to have large amounts of patient capital to make significant systems-wide investments upfront, and they may wait for guaranteed demand of charging stations and market maturation prior to installation. Also, the chargers might not get installed in optimal places unless planned out from both a transportation and energy systems perspective — something that private companies may struggle to achieve given their lack of knowledge or access to system-wide information that could be relevant to such planning.

The California Public Utilities Commission (CPUC) exemplified this pattern. The CPUC initially thought that competitive benefits from a private market would outweigh the benefits of utility ownership and therefore deployed an exclusive private market model. However, the rate of EVSE installation was found to be too slow to meet state objectives, and an alternative model

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with mixed utility ownership is now being tested. Certainly, there is nothing to prevent a combined solution in Toronto in which Toronto Hydro could play a role in an innovative public-private-partnership for EVSE investment, installation, operations and maintenance combining the financial power of the rate base to deliver operations and maintenance of charging systems as well as make-ready grid extensions, with private capital integrated into contracts with cities for design and build services.

Tariff Models

It is important for utilities to offer appropriate tariffs for EV charging early on before EV penetration is large. Once EV drivers acquire their charging habits it can be hard to break them. It is important that the tariffs are developed appropriately to guide charging towards the valley of system load profiles and away from the peaks. Field studies indicate that optimal tariffs that properly incent EV charging habits rely on time-of-use (TOU) designs with evident pricing signals. Tariffs could also be designed to offer lower rates for lower power Level 1 and Level 2 charging compared to higher power and more infrastructure intensive DCFC systems (Fitzgerald & Nelder, 2017). In Toronto, this would imply the optimization of nighttime non-peak benefits for redistribution into the wider community through EVSEs and EVs as storage devices.

To encourage off-peak charging, businesses may find that a commercial tariff with a flat rate for electricity is the best solution for general, nondiscretionary loads, but that Level 2 charging stations installed for customers and employees should have a TOU tariff that features a large differential between on- and off-peak rates. For this to occur, many utilities require a charging station be connected through a dedicated meter, separated from other loads at the site, although this does incur an additional cost to the business for installation upfront (Fitzgerald & Nelder, 2017).

There are also a number of cost-benefit studies that demonstrate charging EVs can be beneficial to all ratepayers, not just drivers or owners of the vehicles, due to the increase in electron sales utilities benefit from when transportation electrifies ; these new revenues can drive down rates for all ratepayers over time because the fixed costs associated with the grid system are now spread out among new customers (i.e., EV/electrified transportation users) rather than classic industrial and residential users only (McMahon, 2019).

Additional research is required to determine how many more electron sales and revenues Toronto Hydro could and will generate from EV integration, but — as described below — it is likely to be a significant quantity of new sales as EVs are likely to create significant new demand on the grid in the future.

Demand-side Load Issues in the Context of EVs

As the EV market grows (both light- and heavy-duty), the need to manage demand-side load issues is becoming clearer. Utilities have different options to deploy including building/upgrading infrastructure and load shaping solutions. Since electricity distribution infrastructure varies regionally, infrastructure upgrading is an important considering in response to EV load growth.

For instance, in the City of Toronto, the option of upgrading infrastructure could be inevitable due to an aging network. Local transformers, particularly those in older inner city neighbourhoods, were designed with relatively low electrical loads in mind. They convert electricity to the right voltage for use in people's homes. But if there is significant uptake of EVs in a single neighbourhood and if a large number of users draw power from the grid at the same time, they could cause a localized outage depending on the age and condition of the infrastructure. At the very least, it will shorten the lifespan of transformers and require investments in larger ones (Sperling, 2014).

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According to a report prepared by FleetCarma, EV penetration, charging patterns, and the type and size of infrastructure all factor into whether upgrades are a good strategy for a utility. For example, if the majority of a residential service territory has overhead infrastructure at the street front then it may be reasonably possible to upgrade the transformers to be able to better manage EV load. However, if the service territory consists of mostly pad mounts, it is possible that infrastructure upgrades could be an order of magnitude more expensive and load-shaping solutions would be preferred. The report concludes that both load control (power management) and pricing approaches to shaping demand are growing in popularity as an alternative to simply building larger infrastructure. Collecting and analyzing local data and understanding how EV load profiles will differ due to several factors will provide the information necessary to make the optimal selection of building and load shaping solutions. Utilities need to estimate user behaviour to be able to cost-effectively upgrade the grid in a timely manner, along with developing rate plans that are most effective at shifting charging behaviour. This includes understanding charging patterns, household activity data, and impacts on the peak load of the grid and the equipment. It will also be important to analyze the “clustering” phenomenon that occurs when a significant number of EV owners live nearby get connected to the grid, or several electric buses are being charged at the same time or peak-hours.

Heavy-Duty Vehicles

Ontario’s electricity generation and distribution systems have extremely low GHG emissions (less than 40 kg/MWh (ECCC, 2018)) and benefits from sources of nuclear, hydro, solar and wind energy. This makes Ontario an ideal jurisdiction to facilitate the electrification of transit vehicles as part of a long-term strategy to reduce transportation-related GHG emissions.

BEBs are energy efficient urban transportation systems that use electric motors powered by energy stored in rechargeable batteries (Laizāns et al., 2016; Kontou & Miles, 2015). BEBs with zero emission technologies have, in recent years, gained global attention as economically, operationally and environmentally sustainable transportation systems. Appropriate charging and distribution grid infrastructure is required in all jurisdictions considering BEBs as a climate mitigation and adaptation strategy.

Optimized commercial implementation of BEB technology is challenged by a number of factors related to electricity distribution infrastructure and rates including: (i) on route charging times; (ii) coordination with predetermined transit schedules; (iii) limited numbers of re-charging stations; (iv) long charging times for depot-charged vehicles utilizing lower-powered systems; (v) the lack of charging infrastructure (i.e., civil work and grid infrastructure upgrade); and (vi) high-demand charges.

BEBs require upfront installation of high-powered charging systems which typically range from hundreds of thousands of dollars to \$1 million per charger. However, these higher upfront costs can be mitigated over the lifetime of the asset through reduced annual operational costs. Energy storage systems are crucial for EV operation.

Charging Strategies Affecting System Efficiencies and Return-on-Investment (ROI) Calculations for Transit Agencies

BEB charging strategies affect system efficiencies and ROI calculations for transit agencies. There are two main BEB charging strategies in use at present: (i) low-powered or “slow” in-depot charging and (ii) high-powered or “fast” on route (also called “opportunity”) or in-depot charging.

Light-Duty Vehicles

Light-duty EVs that draw power directly from the grid are typically categorized into two groups: (i) battery EVs (often called BEVs), which are vehicles that are 100% powered by electrical power and reliant on stored electrical energy in a rechargeable battery for propulsion, and (ii) plug-in hybrid EVs (often called PHEVs), which vary in terms of the capacity of onboard rechargeable battery packs and rely on both stored electrical energy and petroleum fuel onboard for propulsion.

Charging Strategies Affecting Systems Efficiencies and ROI Calculations for EV Owners

EVs benefit from a multiplicity of charging technologies that influence how, when, and where an EV owner or user chooses to draw power from the grid to charge the vehicle. Within this context, the term EV supply equipment (EVSEs) is often used to refer to the interface between a power source and a vehicle's charging port. The role of EVSE is to transfer electric power to the vehicle safely.

There are three main EV charging strategies: (i) low-powered AC Level 1 charging, which makes use of ordinary household electrical outlets; (ii) higher-powered AC Level 2 charging, which makes use of a charging port that supplies 240V (similar to the type of supply delivered to an electric dryer or electric ovens in homes), and (iii) Level 3 or "DC Fast Charging" or "DCFC", which enables a direct current (DC) connector supporting charging at voltages ranging from 80V to 480V (between 80 A (36 kW) for DC Level 1 and up to 200 A (90 kW)) (SAE, 2010).

To encourage the uptake of EVs and their market economic viability, visibility and access to essential charging infrastructure has been cited as a critical factor to consider from a public policy and private investment perspective (Sierzchula et al., 2014). Often underappreciated in this dialogue is the significant difference between the EV driver and conventional gasoline or diesel vehicle driver fueling/behavioral patterns. Most Canadian households with EVs as primary or secondary vehicles will support home-charging at a Level 1 and/or Level 2 capacity (Axsen & Kurani, 2012). With recent legislation passed in British Columbia (2014) and proposed in Ontario (2017) that mandates condominium developers to install EVSE capabilities in condo buildings, this likelihood is expanding to include condo dwellers as well as detached or semi-detached home owners (Government of Ontario, 2017; Plug in BC, 2014).

Market Share

The electric car market has been growing exponentially in the past few years. For instance, EV sales in Canada have increased 68% year-over-year. However, currently the electric car market only represents one% of new car sales in Canada. Also, even though Ontario EV sales more than doubled in 2017, with year-over-year growth hitting 120%, the EV market share is less than 5% (Schmidt, 2018).

Public and Workplace Charging Systems

Over 90 % of EV charging occurs at home for EV owners with home garages (The Economist, 2017). But expanded public networks are also seen as critical today. In 2017, EV charging stations were being added to 25 Canadian Tire Gas+ locations in Ontario, a first for the company (Newswire, 2017). Similarly, Petro Canada, Shell and other traditional petroleum companies have become active in starting to deploy own EV charging networks at pre-existing gas stations.

An important opportunity to encourage EV adoption also involves workplace charging stations which can be clustered and managed as a fleet of DERs. The U.S. Department of Energy PEV

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studies found that around 30 % of drivers almost exclusively charged up at work, showing that workplace charging availability could make EVs viable for people without access to home charging stations (Francfor et al., 2015). Chargepoint, a California-based company that runs many charging stations worldwide encourages businesses to offer employees free [or discount rate] charging in the office car lot (ibid.). A report published by the U.S. Department of Energy (2016) states that workplace charging accessibility increase the adoption rate by is six times. The study points out to the reasons behind this: (1) With workplace charging, electric-driving employees can nearly double their vehicles' all-electric daily commuting range and feel confident that they can get to where they need to go during and after work; (2) Employees can learn about the benefits of driving electric from their colleagues and may be more likely to consider an EV, knowing they can conveniently charge up at work.

Innovative Solutions

Innovative business models and technology sharing have also emerged to support EVSE distribution. For example, an app called Chargeie (similar to PlugShare in Canada and the U.S.) was recently launched in Britain to allow owners of home chargers to rent them to the public, similar to an Airbnb rental. In Toronto, SWITCH has developed a trial web-based platform that will allow homeowners with EV chargers to rent plug-in time to other EV drivers. Similar to the lodging rental app Airbnb, SWITCH allows users to manage profiles, bookings and transactions through its interface.