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Siting Optimal Locations for the Electric Vehicle Supply Equipment (EVSE): A Case Study of Oxford County, Ontario, Canada

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Summary

As the electric vehicle (EV) gains public traction, the shift into EVs requires vigilant planning to efficiently locate electric vehicle supply equipment (EVSE). This study uses original methodological insights to determine potentially most appropriate EVSE locations for Oxford County residents, commuters, visitors, and through-traffic based on descriptive methods, GIS-based models (Voronoi polygons), and predictive assessments based on a linear model of EV adoption rates assuming 1%, 5%, 10% and 25% adoption of EVs among car owners in and around the Oxford community.

Keywords: Electric Vehicles, Electric Vehicle Supply Equipment, Voronoi Polygons, Adoption Rate

1 Introduction

Vehicle drivers have historically relied on petroleum fuels for long range driving. The low-cost of carbon-based fuels (specifically in jurisdictions without carbon pricing) combined with the ubiquitous access to fueling/gas stations have enabled drivers to travel far distances with relatively little planning (*1,2*).

However, as the electric vehicle (EV) gains public traction, actors and stakeholders are increasingly viewing the emerging technology and its performance in relation to the existing baseline conditions of gas powered vehicles. The shift into EVs requires a reasonable return-on-investment (ROI) plan to justify upfront investment into new electric vehicle supply equipment (EVSE) for a commercialization strategy. Given that it takes longer for an EV to acquire a full battery charge compared to a petroleum-based car with an internal combustion engine, forethought is paramount to facilitate a reasonable fueling experience and hence a wider commercial uptake (*3*).

To date, the deployment of EVSE and its spatial coverage have been largely ad-hoc and sub-optimal. The poor placement of EVSE can influence negatively the public perception towards the value of obtaining an EV (*4*). EV driver behaviour must be considered in future decision-making to ensure a strong ROI from the initial costs of infrastructure and encourage maximum public usage. Additional areas of relevant inquiry include determining (1) the number of charging stations that should be present to achieve supplementary social goals (such as accessibility); (2) the necessary power level requirements (minimal or desired) which impact the required grid-side investments; and (3) open or closed communications standards that digitally network or isolate the charging station visibility, management, and accessibility by drivers (*5*).

Table 1 Types of EVSE

Level of EVSE	Voltage (V)	Time to Full Charge	Type of Plug
L1 EVSE	120-V	8-12 hours	Alternating-current (AC)
L2 EVSE	240-V	4-6 hours	Alternating-current (AC)
L3 EVSE or DC Fast Charger	480-V	30-45 minutes	Direct-current (DC)

Various institutions will prefer different EVSE levels (Table 1 provides more information on different levels of EVSEs) for divergent reasons. Charging profiles at destinations with medium-to-long term visitor dwell time (e.g., hotels, office parks) warrant lower-cost L1 or L 2 EVSE installations, while “short-term” destinations (e.g., fast-food establishments) warrant higher-cost L3 EVSE installations. Some establishments may warrant two different charging strategies – hospitals, for example, might be well-suited for L2 EVSE for visitors, but L1 installations for employees (e.g., nurses, doctors) with a longer “stay” period.

Oxford County is a regional municipality in Ontario, Canada with an area of 2,040 km^2 and a population of 110,862, as reported in the 2016 Census. The County aims to become a fully accessible EV community equipped with ubiquitous charging opportunities in the near future as a part of their Electric Vehicle Accessibility Plan. This initiative is intended to support the uptake of EVs by satisfying the charging needs of local travellers and long-distance intercity traffic travelling on nearby highway routes.

Currently, Oxford County boasts 48 charging stations (of different makes and models) across 22 locations (12 Tesla Superchargers, four L3 chargers, 23 L2 chargers, four home-share L2 chargers, and five L1 chargers). The ownership also varies from the private sector (e.g., hotel owners) and the public sector (support from the Province of Ontario through the Electric Vehicle Charging Ontario (EVCO) 1.0 Program, which launched in 2016). The objective of this study is to assess the current EVSE locations and usage rates, and determine future optimal locations of EVSEs based on the empirical assessment of EVSE usage in the County and in comparable communities.

2 Literature Review

EVSE infrastructure placement in local communities has become a topic loaded with competing ideas regarding the importance of various factors to be considered in decision-making. The most commonly used methodologies include Voronoi Diagrams, Grid Partition, Household Activity Data Analysis, and Charging Patterns Analysis. This section provides examples of utilizing these methodologies in previous studies.

2.1 Distance Considerations in EVSE Placement: Voronoi Diagram Methodology

An early EVSE facility location study in Musashino, Japan (Greater Tokyo Metropolitan Area) implemented a Voronoi diagram methodology (*6*). This methodology is a topological technique that demonstrates the equidistant layout of equipment by accounting for (1) the actual ability of an EVSE owner to install equipment at the existing facilities (e.g., ownership rights, electrical capacity, etc.); and (2) the availability of at least two parking lots as a base minimum for EVSE installation. The method seeks to “fill gaps” in the EVSE network, assuming the optimal locations to situate EVSEs are equidistant from one another to enhance accessibility and visibility.

The study evaluated 33 prospective locations that met the aforementioned requirements with a weighting methodology applied to account for public transportation connections, main road intersections and ramps, multi-entrance availability, and the convenience of the facility access. Their results featured locations including a department store mall and two supermarket areas for priority EVSE installation. A follow-up study built on the Voronoi model was conducted, with an additional consideration given to road intersections in order to account for existing road traffic patterns (*7*). The study aimed at minimizing the users' lost time on route to the charging station as the key objective driving the optimal placement of charging stations. More recent studies reference this methodology while expanding the parameters of EVSE siting (*5,8,9,10*).

2.2 Grid Partition Considerations in EVSE Placement

Other studies proposed a method for locating and sizing EVSE based on "grid partition" variables. Instead of focusing on a concentrated area or cluster of EVSE, researchers used a hypothetical scenario with a proposed partition method to minimize user lost time on route to the charging station, while integrating considerations of traffic density and the charging stations' capacity constraints (*11*). The coverage of each partition and charging station sites were repeatedly amended to develop a feasible output of the charging station area.

Similar to the Voronoi area models, the grid partition approach follows a stochastic methodology to integrate selected variables as defining parameters (e.g., distance to EVSE from a starting point, availability of EVSE during certain hours, desirability of EVSE due to other social factors such as nearby amenities). This methodology facilitates exploratory research in dynamic EV fleet scenarios (*12*, *13*, *14*). For example, a facility location model for electric taxi charging stations in Seoul, South Korea considered key variables including itinerary-interception and queue delay (*15*). This innovative approach to EVSE siting considered the emerging shared mobility economy, which will alter charging needs amongst EV drivers.

2.3 Household Activity Data Considerations in EVSE Placement

The integration of household activity data can strengthen the determination of optimal EVSE site location planning. A study in Seattle, Washington utilized the travel diaries of a sample of survey respondents. A total of 3,700 traffic analysis zones were generated based on the actual travel patterns observed in the survey (*16*). Parking locations (by parcel, then aggregated by traffic analysis zone) and durations of parking periods were determined for all trips away from home and for all minimum 15-minute stops. Parking duration data was used to predict land-use and parking demands to frame individual trip characteristics. The results were digitized to map areas with the highest "demand" potential amongst 80 allocated stations across 900 traffic analysis zones within ten miles of the city's downtown core which could be potentially ideal locations for future EVSE installations.

2.4 Other Optimal EVSE Location Selection Criteria

The results of a prominent study emanating from the U.S. Department of Energy - monitoring the EVSE usage patterns to improve future EVSE deployment - found that an overwhelming majority of charging was done at home and work (*17*). Yet, public charging stations are still anticipated to experience heavy use to facilitate easier intra- and intercity driving. Although these stations do not experience frequent usage at present, the charge provided to the driver remains an essential part of their commute.

The installation of public charging stations proved to be a more expensive endeavor compared to residential or workplace units with large installation cost variance in different regions and venues. The study concludes that the cost and observed usage patterns associated with publicly available EVSEs indicates that chargers should be mostly installed in homes and workplaces with additional public chargers installed *only* at strategic points in the transportation network.

Workplace charging behaviors have also been examined and charging habits were seen to vary based on conditions such as fees and rules for use. Drivers were less likely to plug-in at work if they were required to pay for charging or if they had to move their vehicle after charging was complete. However, EV drivers did show a willingness to use communication tools (e.g., an online message board) to coordinate the use of charging stations with other employees.

3 Methodology

The studies outlined in the Literature Review identify several location siting factors to consider when assessing the optimal EVSE placement in Oxford County. These factors include the expected driving behavioural patterns, EV make and model needs for charging support, and charging location appropriateness (based on both equidistance or solving “gaps” in a local EVSE matrix as well as “convenience” variables such as walking and driving distance and/or nearby amenities). This study map candidate EVSE siting locations based on the following factors:

1. Predicted increases in EV uptake by commuters (of varied types)
2. Current EVSE usage and clustering
3. Gaps in the EVSE network in Oxford County based on distance considerations
4. Gaps in the EVSE network based on locations with amenities and/or workplaces

The specific variables considered to guide Oxford County’s EVSE siting efforts include long-term parking opportunities for L1 and L2 (anticipated characteristics of users), special applications for L2 (considerations for tourists and seasonal/annual events), and freeway interchanges for L3 (nearby off-highway “stop” or “rest” points for 10-30 minute breaks). Both cost and usage of charging stations based on local community needs are advised to be forefront in the decision-making process of siting new EVSE.

An analysis of existing EVSE in Oxford County would be insufficient for predicting how many future EVSE should be integrated into the community in the future, or where they ought to be best situated to prepare for future EV adoption patterns pertaining to usage and charging. Therefore, we have developed a series of predictive and descriptive outcomes to illustrate gaps in Oxford’s EVSE network and identify mechanisms to ensure the efficient clustering of EVSE in high-use or likely high-use areas based on varied types of commuter and/or tourist traffic. The estimation of the predicted number of chargers is followed by an assessment of where such chargers can be optimally located in the near future.

3.1 Data collection

Three communities of potential EVSE users have been identified to guide the data collection process: Oxford residents; transitory and through-way traffic; and visitors. To locate new charging stations in Oxford County, the following data was determined to be necessary:

- Information about existing charging stations (location, make, model, quantity) collected through inquiry to Oxford County and comparing various geospatial mapping tools including EVCO, PlugShare, and AddÉnergie Flo.
- Usage patterns of existing charging stations (e.g., number and length of daily EV charging episodes; power level and electricity demand) collected through AddÉnergie Flo (as the Ministry of Transportation – Ontario (MTO) EVCO information and Tesla’s databases were not available)
- Information about existing EVs in the County provided by the MTO (Green License Plates)
- Locations of main parking areas for short-term stays (1-3 hours) (e.g., shopping malls, cinemas, hospitals, etc.) as well as locations of employer-owned parking areas for long-term stays (more than 8 hours) (e.g., workplaces) determined through Oxford County’s Municipalities Land Use Maps and Business Directory
- Events and attractions attracting outside traffic to Oxford County obtained from Tourism Oxford
- Highway map and traffic flow (annual average daily traffic) obtained from the MTO’s web portal

Several challenges were faced in acquiring appropriate empirical data sets related to localized EV adoption and EVSE usage. Developing a robust localized predictive estimation would be enabled, for example, by obtaining real-time access to relevant charging EVSE system databases. However, restrictions led to a largely predictive methodology based on reasonable but static assumptions regarding potential EV adoption rates in Oxford County.

3.2 Predictive Analysis: Assessing Future EV Adoption Impacts on EVSE Needs in Oxford County

A predictive analysis offers a linear model based on current and anticipated future EV adoption rates, while accounting for integrated traffic flow by defining different types of drivers (Table 2). This predictive analysis assumes two types of EVs as "baseline" vehicle systems – Nissan Leaf 2017 and Chevrolet Bolt 2017 (less expensive than luxury EVs) – to determine the range performance on a daily and annual basis as applied to a variety of potential in-town and out-of-town commuters and drivers. Leaf and Bolt possess a range of 172 km and 383 km, respectively.

The selection of these vehicles allows for a comparative assessment between two similarly priced vehicles with different ranges. When applied to Oxford County and assumed as proportional to all cars in the region, these vehicles have different charging system requirements outside of homes, at workplaces, at common places of extended parking (e.g., shopping malls), and on highways and other road intersections.

3.2.1 Driver Typologies: Type A – Type D EV Owners and Drivers

Table 2 indicates drivers typology used in this study. These types of drivers constitute idealizations meant to capture potential categories of driver types and drive cycle requirements (i.e., range requirements among EV drivers) that would shape future EVSE needs and requirements.

Table 2 EV Owner Typology Characterizations

Type ID	Sub-Category of ID	Characterization
Type A	A1	In-town commuter (principal car)
Type A	A2	Out-of-town commuter
Type A	A3	Out-of-town commuter into town
Type B	-	Family commuter (secondary car)
Type C	-	Tourist commuter (visitors)
Type D	-	Inter-city commuter transiting through Oxford County between city locations (for work or leisure)

3.2.1.1 EV Ownership for Type A1

MTO data indicates that the total number of existing EVs in Oxford County is 163 (2017 figures). Based on the *EV Sales Report in Canada* (3rd quarter 2017) (*18*), tht adoption rate of EVs across Ontario was 0.8% in 2017 (*19*).

To generate a predictive estimation for this feasibility study, we assumed an incremental linear increase in EV volumes (1%, 5%, 10%, 25%) to predict the number of future EVs in Oxford County, assuming 163 EVs (as of 2017) constitutes 0.8% of the total vehicles owned in Oxford County currently (Fig. 1).

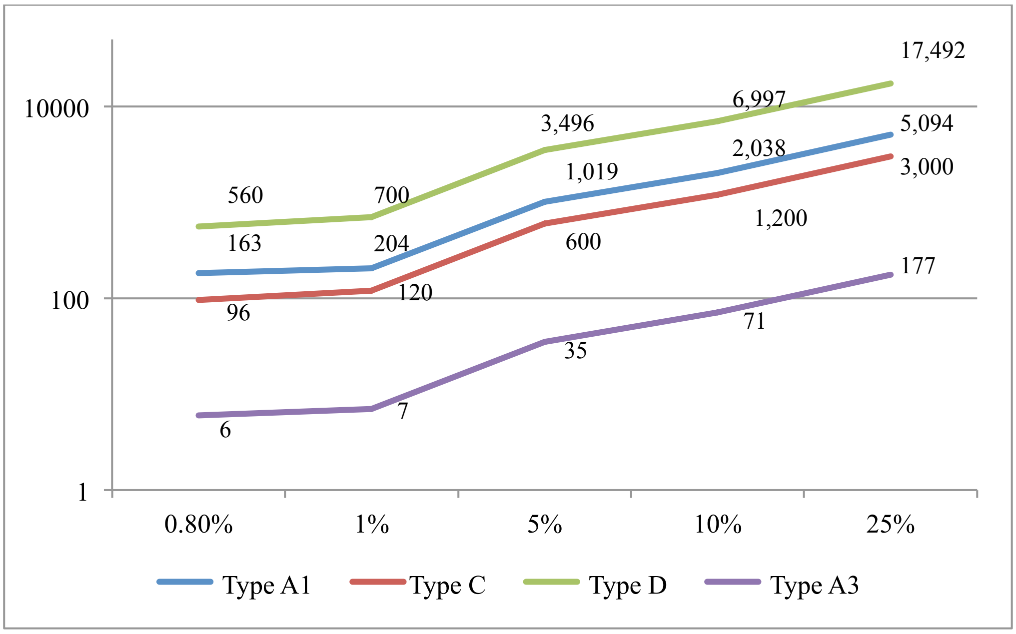

Figure1 Predicted Number of EVs

3.2.1.2 EV Ownership for Type C

Tourist events were explored in order to estimate the level of incoming traffic flow based on annual occurrences. Tourism Oxford advises there are two rural and four urban "high attendance" venues in the County with rural events attracting approximately 4,000 people and urban events attracting 10,000 people per instance. However, data does not indicate the number of event-goers from out-of-town travellers versus in-town visitors. Therefore, we have utilized the general approximation provided by Tourism Oxford that 48,000 tourists visit Oxford County per annum.

To generate reasonable estimates of incoming tourists, it has been assumed four visitors travel in each incoming vehicle (i.e., a standard family unit). This generates a value of approximately 12,000 cars travelling into the County annually, which we utilize as the base value to assess EVSE needs for Type C EV owners. Considering the noted incremental adoption rates, Fig. 1 demonstrates the number of Type C EVs estimated as entering Oxford annually for events and festivals.

3.2.1.3 EV Ownership for Type A3 & D

To assess EVSE requirements among commuters (both in-town and out-of-town), this study has leveraged the Annual Average Daily Traffic (AADT) data associated with the busiest highway routes surrounding Oxford County. The AADT for Oxford County (2017) ranges between 67,151 and 74,200 vehicles with a medium value of 70,675 vehicles commuting through, into, or nearby Oxford County on a daily basis.

Using the linear adoption rates identified above, and assuming 1% of the AADT constitutes vehicles that stop in Oxford County for work/daily commuting purposes, this study estimates the number of cars entering the County as commuter vehicles as approximately 707 per day. Considering the incremental adoption rates notes above, Fig. 1 demonstrates the number of Type A3 EVs that may stop in Oxford County and require charging infrastructure.

In addition, assuming 99% of the AADT constitute inter-city commuters who transit through or across Oxford County to a work location outside of or adjacent to Oxford County another estimated 69,968 vehicles may require a stop-over in Oxford County along highway route intersections.

Considering the identified incremental EV adoption rates, Fig. 1 demonstrates the number of Type D EVs (inter-city commuters) who may require a stopover for charging, as assumed in this model

3.2.2 Vehicle Make and Model Technical Specifications

Table 3 lists the technical and battery pack information for the Leaf and Bolt in this analysis. Working hours are assumed 7 AM to 7 PM.

Table 3 Technical and Battery Pack Information

Element (Unit)	Nissan Leaf 2017	Chevrolet Bolt 2017
Battery Pack (kWh)	30	60
Time to Charge, L1 Charger (Hours)	≈ 20 (1.5 kWh of charging per hour) – 30 (1 kWh of charging per hour)	≈ 40–60
Time to Charge, L2 (Hours)	4.5	9.5
Time to Charge, L3 (Hours)	< 30 minute for 80% charge	< 2 hours
Estimated Range (km)	172	383

3.2.2.1 Usable Battery Range Assumptions

As previously mentioned, the predictive analysis utilizes two electric vehicles (Nissan Leaf, 2017 and Chevy Bolt, 2017) to demonstrate possible charging requirements for Type A-D EV owners/drivers in and around the Oxford County. Table 4 and Table 5 provide the estimated values for the Leaf and Bolt, respectively.

The following assumptions are made regarding the battery range:

- The Nissan Leaf 2017 has an average range of ~172 km (normal ambient conditions) with a buffer/battery state of charge (SOC) loss assumptions of 43 km (with 25% degradation over a ten-year lifecycle) and 51 km (with 30% temporary loss in range due to extreme hot/cold weather conditions). The total usable estimated battery range under all conditions is 78 km.
- The Chevrolet Bolt 2017 has an average range of ~383 km (normal ambient conditions) with buffer/battery SOC loss assumptions of 96 km (with 20% degradation over a ten-year lifecycle) and 114 km (with 30% temporary loss in range due to extreme hot/cold weather conditions). The total usable estimated battery range under all conditions is 173 km.

3.2.3 Future Needs

We conducted a "Lower Bound – Upper Bound" scenario (assessed from the perspective of an EVSE owner/host) to estimate the number of chargers that a regional location must host to fully satisfy the charging needs based on assumptions regarding battery range, home charging, and travel patterns. In this model, the Lower Bound (LB) specifies the minimum number of EVSEs to be installed to serve a local community or a stakeholder sector. The Upper Bound (UB) specifies the maximum number of EVSE to be installed to serve a local community or a stakeholder sector.

For instance to estimate the required number of L2 chargers for Type A1 drivers in the case of owning a Nissan Leaf in an UB scenario, we assumed more than 78 kilometers of travel per day (to and from work and in-between stops, e.g., shopping, and pick ups). Therefore, a top up at work (minimum one hour) is required. The other assumptions include (1) no access to L1 chargers; (2) chargers are smart-enabled that give warning to the drivers to move the vehicle at the end-of-charge period (or face a penalty); and (3) 4-hour charging blocks over a 12-hour workday period, equating to three charging episodes. By dividing the number of EVs by three charging episodes, the required number of L2 chargers could be assessed.

Considering the Upper Bound scenarios, the results of the predictive analysis indicates that to fulfill the present demand, the number of required EVSEs based on the current adoption rate would be as follows:

- L1: 163
- L2: min: 54 – max: 163
- L3: min 12 – max: 47

Therefore, the County needs to supplement its current five L1 chargers, 23 L2 chargers, and four L3 chargers. Assuming an average price of $1,000 CAD for L1, $2,500 CAD for L2, and $60,000 CAD for L3 chargers, Oxford County should invest a minimum of $690,500 CAD – excluding installation costs, which depends on the selected location – to meet the needs of different types of EV drivers. This is the cost of the extra chargers over and above the existing ones.

To situate the best locations for the required chargers, a spatial gap analysis was conducted by deploying the GIS mapping techniques: Voronoi Polygons and Clustering.

3.3 Spatial Gap Analysis

The EVSE station location methodology is separated into two processes reflecting the contrasting geographic factors that influence the locations of high-power and low-power EVSE. Firstly, to ensure appropriate high-power charging accessibility, Voronoi polygons are used to visualize the quality of the existing high-power EVSE network to identify either existing EVSE upgrade candidate sites or new EVSE stations. New EVSE stations should be located to optimally densify the existing network with respect to access to amenities as well as major highways while equalizing distance between adjacent chargers. This process is ideal for locating L2 and L3 chargers for Type B-D users. Locating L1 chargers for Type A users depends less on amenity access and more on proximity to place of work and this controls the second GIS process where clusters of workplaces are used to locate L1 chargers.

Voronoi polygons define the catchment, which is a polygon that includes all locations closest to that particular station. The Voronoi polygon can efficiently allocate resources and municipal assets with respect to proximity to the end-user, which has been used successfully with other EVSE station siting studies (*20*, *21*).

A useful corollary of the Voronoi polygons is that any point on a line separating two polygons associated with two EVSE stations is equidistant from them. New installations designed in this way allow for densification to ensure the high-powered EVSE network is adequately dispersed within populated areas and close to amenities. Yet, the clustering of high-power EVSE installations should be avoided because of the anticipated extra traffic congestion but also negative effects of highly localized charging on the electric grid (*22*).

To provide adequate coverage for users, some locations could be upgraded with the installation of L2 chargers. These locations are denoted by green dots in Fig 2. We recommend new EVSE locations for sites to accommodate a potential increase in EV demand. Such locations should be situated with consideration of existing charging sites in populated areas that lie along the Voronoi polygon boundaries (i.e., equidistant from the nearest two existing EVSEs, and also close to amenities). These locations are denoted by blue dots in Fig. 2.

3.4 Results

The suggested number of required EVSE identified in Table 4 is based on the results of the predictive analysis considering only the current adoption rate of 0.8%. In other words, the number of L1-L3 chargers required at each of these sites is based on an assessment of how many chargers are required to fully serve EV driver needs in and around Oxford County at current EV adoption rates. The existing number of chargers is deducted from the minimum number of required EVSE to reach the final recommendation.

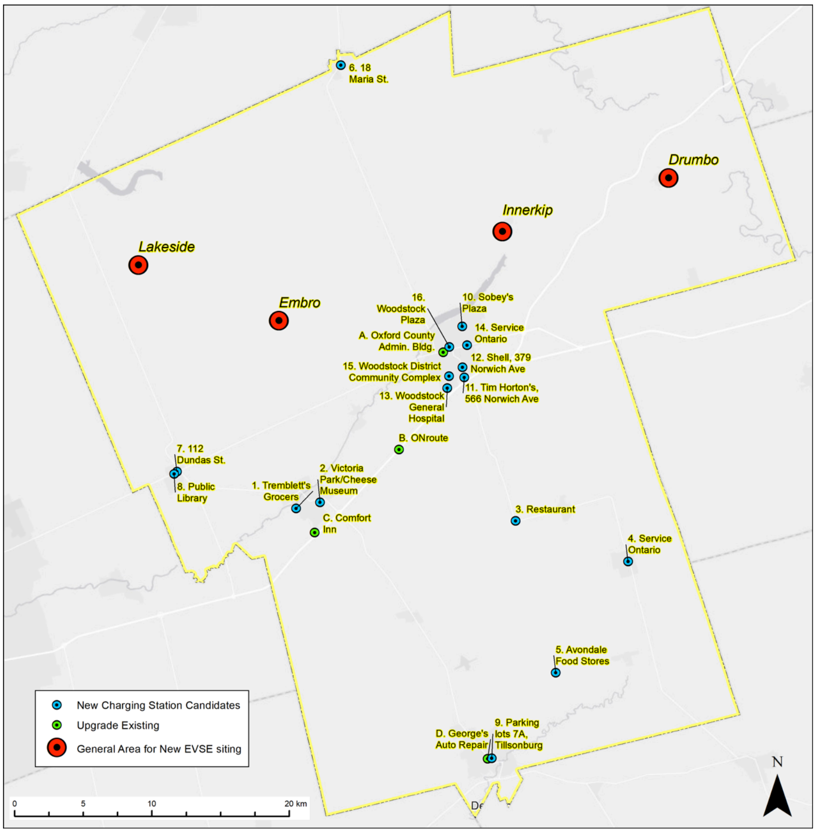

Figure 2 Candidate Location Map for New and Upgraded EVSE

Table 4 Candidate (numbered), Upgraded (lettered), and General ("G") Locations

ID	Locality	Property Description	Ownership	Address	Parking Spaces	Amenities	L1	L2	L3
1	Ingersoll	Free-standing supermarket	Private	306 King St. W.	>20	Large grocery store	-	2	-
2	Ingersoll	Non-commercial sports complex	Private	290 Harris St.	<20	Gas station	-	1	-
3	Norwich	Automotive fuel station	Private	593737 CR-59	<20	Restaurant	-	1	-
4	Norwich	Free-standing supermarket	Private	3 West St. N.	>20	Many	-	2-10	-
5	Springford	Free-standing supermarket	Private	3 West Street N.	<20	Convenience store only	-	1	-
6	Tavistock	Municipal parking	Public	18 Maria St.	<20	Post office, pharmacy, bank	-	1	1
7	Thamesford	Municipal parking	Public	112 Dundas St.	24	Bank, fast-food restaurant,	-	1	-

						family restaurant			
8	Tamesford	Library	Public	165 Dundas St.	>20	Many	-	2	-
9	Tillsonburg	Municipal parking	Public	Intersection of Bridge St. and Lisgar St.	287 (6A) 243 (7A)	Pharmacy, grocery store	-	2	2
10	Woodstock	Shopping Centre	Private	984 Devonshire Ave.	>20	Grocery store, bank, restaurant	-	2-10	-
11	Woodstock	Fast-food restaurant	Private	566 Norwich Ave.	>20	Many (including hotel)	~40	2	-
12	Woodstock	Automotive fuel station	Private	379 Norwich Ave.	>20	Café, restaurants	-	2	-
13	Woodstock	Hospital	Private	310 Juliana Dr.	>20	Hospital, tuck shop	-	2-10	2
14	Woodstock	Service Ontario	Public	925 Dundas St.	>20	Many	-	2-10	-
15	Woodstock	Community Centre	Public	381 Finkle St.	>20	Few, only suitable for L1	~40	-	-
16	Woodstock	Shopping Centre	Private	645 Dundas St.	>20	Fitness gym, grocery store	-	2	-
A	Woodstock	Municipal building	Public	21 Reeve St.	>20	Banks, restaurants, museum	~40	2	-
B	Foldens	Travel plaza	Private	401223 Hwy 401 W.	>20	Travel plaza (fast-food)	-	2	2
C	Ingersoll	Hotel	Private	20 Samnah Cres.	>20	Hotel, restaurants, banks, fast-food restaurants	~40	2	1
D	Tillsonburg	Auto repair	Private	10 Bridge St.	<20	Grocery store, restaurants, banks, Service Ontario	Either 9 or D. 9 is a better location.		

4 Conclusion

The results of this study demonstrate that a large portion of commuter EVSE needs could be addressed through the installation of workplace L1 chargers, which also constitutes the most cost-efficient option for private and public sector workplace hosts, along with strategically placed L2 chargers in parking lots around the region which serve commuter parking purposes specifically. Meanwhile, out-of-town commuter traffic and tourist traffic will require a combination of L2 and L3 clusters of chargers.

Based on our deployed methodology - integrating best practices from GIS-based modelling (Voronoi polygons), charging patterns, and drivers typology - a total of 163 Level 1, 54 Level 2 and 12 Level 3 chargers will need to be placed in suitable parking locations to serve Oxford residents who adopt EVs in the future as well as render Oxford County as the southern Ontario's "charging hub" for transitory drivers.

Given that the majority of EV charging usually occurs at home, it is sensible to target future EVSE installations at densely populated urban areas with condominiums and apartments where the installation of a charging station is out of residents' control and EV adoption may be less likely without an expanded public charging network.

Another opportunity to encourage EV adoption is the workplace charging stations. The workplace charging availability could make EVs viable for people without access to home charging stations

Innovative business models and technology should also increase the availability of charging options for EV owners. Technological innovations such as wireless inductive charging from road to car is already a technically feasible, albeit expensive, but boasts strong merit for vehicles that sit idle such as taxis.

Lastly, 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. To encourage off-peak charging, a business may find that a commercial tariff with a flat rate for electricity is best for its general, nondiscretionary loads, but that Level 2 charging stations installed for customers and employees should have a time-of-use tariff that features a large differential between on- and off-peak rates.

The deployed methodology in this study along with a more detailed and granular data analysis on a community-by-community basis could be performed to support Canada's electrification strategy to meet targets of greenhouse gas (GHG) emissions reduction by 2050 with an eventual stop in the use of fossil fuels by 2100 (Canada's G7 commitment in June 15).

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