- **SAE Combo** is a European/North American standard used by BMW, Chevrolet, Ford and Volkswagen.
- **Supercharger** is a Tesla-only standard. All Tesla vehicles can be purchased with adapters for the other two.

Section 1:Literature Review

Vehicle owners have historically relied on long ranges due to the high energy density associated with petroleum fuels in gasoline and diesel vehicles. The low-cost of carbon-based fuels (especially in jurisdictions that do not price carbon) combined with more than a century of development and now ubiquitous fueling/gas station networks across the developed world has ensured drivers can travel far distances with relatively little planning required to ensuring fuel availability (Delmas *et al.*, 2016; Langer *et al.*, 2017).

The rise of electric vehicles (EVs) – due to a combination of U.S. Corporate Average Fuel Economy Standards (CAFÉ) and European Fuel Standards over the past 15 years, combined with nascent carbon pricing regimes and gasoline/diesel punitive measures intended to reduce emissions from greenhouse gases (GHGs) in the transportation sectors in North America, Europe and Asia today – has resulted in a budding need for new “fueling”, i.e., “charging”, infrastructure.

Municipal, regional and federal governments are therefore struggling against the private market pull of ongoing gasoline and diesel car demand (which protects the status quo in petroleum fueling infrastructure) with public pressures to reduce emissions by encouraging fuel switching and EV adoption whereby EVs are charged from renewable power sources (e.g., hydro, wind and solar power, among other renewables) overtime.

This tug-of-war between the status quo and a necessary low-carbon future of transportation has produced demands for electric vehicle supply equipment (EVSE) – or “charging station” – optimization analyses that assess where, when and to what extent governments and private sector entities should be investing in or be forced to invest in charging system infrastructure to enable EV adoption for both light-duty vehicles (e.g., passenger cars and light trucks) and heavy-duty vehicles (e.g., heavy-duty trucks, buses, shuttles, and coaches).

The financial investments associated with these choices are enormous. Thus, a paradigm shift in transportation and mobility thinking towards a low-carbon future requires the most optimal, strategic and efficient investments into EVSEs as possible. This is a complex process given the current lack of general EV adoption today (EVs still represent less than 1% of all new vehicle purchases in North America, including Canada, today), which means there is precious little descriptive and empirical data demonstrating how human drivers behave when the range of vehicles is limited by the lesser energy density associated with relatively expensive battery technologies compared to relatively cheap petroleum fuels in propulsion applications.

Prospective EV adopters will need to perceive EV technologies as suitable to existing or desired lifestyles, while private sector stakeholders will require a reasonable return-on-investment (ROI) for upfront investments into new vehicle fueling technologies as a push out market shift strategy.

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). Yet, many programs – including Ontario’s own first round of “Electric Vehicle Charging funding, has proceeded with mostly ad hoc installations of EVSEs leading to the concern that trivial or non-optimal implementations of the technology can hinder EV adoption rather than support it by negatively influencing public perception towards the value of EVSE investments and EVs in general.

Often left unacknowledged or underappreciated in this dialogue (including in Canada today) is the significant difference between EV driver and conventional gasoline or diesel vehicle driver fueling/behavioral patterns. As documented and assumed in this report, a majority of households in Canada 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 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).

Therefore, the placement of gasoline or diesel fueling stations today does not constitute a primary variable to consider or utilized when determining where EVSEs *ought* to be placed for optimal usage in the future (given that most home owners do not own gasoline or diesel fueling stations at home, and therefore engage in differing fuelling behaviours compared to EV drivers).

In addition, given that the time necessary for an EV to acquire a full battery charge is significantly longer than the time it requires to fuel a petroleum-based conventional car that relies on an internal combustion engine (ICE) (time-to-charge ranging from 20 minutes with a Level 3 charger to more than 48 hours with a Level 1 charger, depending on battery size and onboard charging capabilities (i.e., the vehicle's on-board AC/DC converter), as well as the specifications of the off board circuit delivering power to the charging station, charging station networks will need to be designed in alignment with long-term stop-over strategies for many EV drivers, rather than solely the quick-stop strategy associated with the design of contemporary gasoline and diesel fueling station networks.

These substantial differences in fueling strategies and EV driver behaviors need to be considered in future decision-making (public and private sector) to ensure the effectiveness of location prediction tools to justify the initial costs of infrastructure (including installation).

The placement of a charging station is worth deep strategic consideration. Jurisdictions invested in the uptake of EVs in the market should concern themselves with placement of the stations in locations that will result in the greatest most efficient (i.e., optimal) usage. Other areas of relevant inquiry include determining the number of charging stations that should be present to achieve supplemental social goals (such as accessibility, as opposed to optimization of usage solely), as well as necessary power requirements (minimal or desired) that impact grid-side investments required, and open or closed communications standards that digitally network or isolate charging station visibility, management and accessibility by drivers (Brooker & Qin, 2015).

Charging profiles for visitors to fast food establishments, for example, might merit higher-cost Level 3 EVSE installations, as opposed to the overnight charging profiles describing the patterns of charging behavior for visitors to hotels – the latter of which might merit lower-cost Level 2 or Level 1 installations. Some establishments might also merit two differing charging strategies – hospitals, for example, might be well-suited to explore higher cost Level 2 chargers for visitors, but lower-cost Level 1 installations for employees (such as nurses and doctors) whose "stay" period might range from 8 to 24 hours. In sum, private or public institutions and organizations that are planning to install EVSEs are best guided to consider the visitation profile, and therefore the charging profile, of EV drivers who visit respective establishments to determine the optimal level of charging required and associated costs for installation and maintenance overtime to optimize user experiences and satisfaction.

Variables that optimize EVSE locational choices: A global review of variables identified as critical in the assessment of EVSE siting locations

One indicator to evaluate EVSE placement is “EV adoption behaviour” which refers to the process in which a jurisdiction may target areas with known higher rates of EV uptake to drive the clustering or initial installation choices for EVSEs. This methodology is based on sociodemographic characteristics associated with “early adopter” EV owner profiles. These characteristics have typically demonstrated that EV owners as “early adopters” are predominantly male, highly educated, and high income earners (ethnic or racial information is not typically available). Problematically, therefore, an EVSE deployment strategy that focuses solely or primarily on the areas within which “early adopters” reside or charge their vehicles will tend to favour privileged sectors of the highly educated male population rather than society at large.

In addition, “early adopter” characteristics may not relate in any causal or systematic fashion to the characteristics defining “average adopters” or typical car drivers in the future – i.e., generalized characteristics defining the overall car driving population. In brief, due to the immense knowledge gaps and informational voids that currently hinder EV adoption predictions globally (i.e., knowledge gaps related to which variables drive forward adoption at the greatest rate, such as carbon prices, road pricing, punitive gasoline taxes, or EV incentives, etc.), analysts and public policy makers are hindered in their ability to accurately assess the state of the EVSE market based on early adoption characteristics primarily. The expansion of consideration to include other key variables extracted from public and private data sources related to mobility patterns and mobility needs, in general, may enable more informed evidence-based EVSE siting choices, therefore.

Useful transportation data sets that document mobility patterns can be assessed alongside EV sales data to inform and shape potential EVSE infrastructure placement choices. Such a holistic and comprehensive methodology would integrate considerations of sociodemographic data that predict the likelihood of EV adoption in given communities (given employment and household income) alongside driving and mobility variables for households (such as the number of commuters in a household, and the number of children or family members accessing extra-curricular or personal matters outside of the home). These sociodemographic household details help to clarify the nature of a community’s daily commute patterns, daily driving range requirements, and potential charging access points (e.g., garages at home, at workplaces, or elsewhere). These data may shape the type of electrified vehicle (i.e., hybrid, plug-in hybrid, or fully battery electric) a household is likely to adopt given charging network options locally in the near-term, mid-term and long-term future. Collecting this type of robust socio-demographic data for Oxford County would require a comprehensive household survey of car owners and potential car owners in the community. Without these data sets currently, CUTRIC has adopted a model that utilitizes general typologies of driver and car owner “types” which span the sociodemographic possibilities for daily and ad hoc drivers into and out of Oxford County.

Several of the assumptions made in the predictive model utilized in this report build upon empirical variables identified in the assessment of EV drivers or potential drivers in other communities globally. In this section, we will review a series of those studies to clarify the assumptions embedded in Section Three of this report. A limited number of studies have attempted to evaluate criticial EVSE placement variables in a comprehensive manner to optimize or potentially streamline decision-making processes among public and private sector investors (i.e., governments, property and retail owners, etc.). This sub-section details examples of studies that have attempted to identify optimal locations for EVSE placement in communities across North America, Europe and Asia.

Currently, there are several competing schools of thought as to how to best approach the issue of EVSE infrastructure placement within local communities; there are also competing views as to which key variables are the most important in such considerations, and which variables should receive the greatest weighting in the decision-making process. The unifying theme across this varied body of research is that EVSE placement decision making, which considers variables other than “early adopter” variables defining current EV drivers, produce better localized dialogue and a greater likelihood of scaled-up, mass adoption of EVs which extends beyond the privileged class of current EV owners, in general.

Distance considerations in EVSE placement in local communities: Voronoi diagram methodology and outputs

One of the initial infrastructural location studies produced in the field of EVSE placement research was an analysis of Musashino, Japan (in the Greater Tokyo Metropolitan area) (Koyanagi & Yokoyama, 2010). To identify the optimal places for implementing charging stations, researchers implemented a Voronoi diagram methodology, which is a topological technique that demonstrates the equi-distant layout of equipment after taking into account the following factors (ibid.):

1. The actual ability of an EVSE owner to install equipment in existing facilities (i.e., ownership rights, electrical capacity, etc.).
2. The availability of at least two parking lots as a base minimum for EVSE installation.

The purpose of this methodology is to fill gaps in an EVSE network; this methodology assumes that it is best to place EVSEs at equi-distances from one another to the extent possible to ensure drivers have access to EVSEs throughout a community and never find themselves too far away from an EVSE to make longer range driving infeasible.

For the 33 prospective locations that met the initial two criteria identified above, researchers used a weighting methodology to account for public transportation connections, main road intersections and ramps, multi-entrance availability, and the convenience of the facilities from a user or customer perspective. This method for selecting refined or idealized sites resulted in three priority locations, as identified through Voronoi and perspective demand measurements. The locations included a department store mall and two supermarket areas in Musashino for EVSE installations as priorities.

A follow-on study built up the Voronoi model designed for Musashino by integrating deeper considerations of traffic flow intersection nodes to represent existing road traffic patterns (Feng *et al.*, 2012). The study calculated the users’ minimum loss of time on the way to the charging station as a variable driving the optimal placement of a charging station. Similar to other similar studies, the coverage of each partition and the locations of charging stations were adjusted repeatedly to locate optimal sites based on time parameters. A limited number of more contemporary studies have also implemented or repeated references to the methodology developed here to further develop the field of EVSE siting (Brooker & Qin, 2015; Mehar *et al.*, 2015; Shareef *et al.*, 2016; Sheppard *et al.*, 2016). These studies suggest that Oxford County could locate optimal locations for EVSE placement by identifying “gaps” in the EVSE network that are equi-distance from one another, roughly, and which constitute accessibility points based on time parameters (i.e., a 10-minute walking distance limit from major sites of employment to EVSEs, or a maximum 20 minute driving distance from other chargers, etc.).

In the outputs prepared below, CUTRIC has assumed, for example, a walking parameter limit of 150 meters from the site of EVSEs. By imposing this distance limitation, the Voronoi method produces a series of parking lot sites that would be “optimal” from the perspective of enabling drivers to park and walk with relative ease to nearby locations for extended stop overs (e.g., workplaces).

Grid partition considerations in EVSE placement in local communities

A separate type of study has been proposed as a method for locating and sizing EVSEs based on "grid partition" variables. Instead of focusing on a concentrated area or cluster of EVSEs, researchers used a hypothetical scenario that could be broadly applied to any urban environment in which they proposed a partition method that would minimize users' loss on route to the charging station, while also integrating considerations of traffic density and the charging station's capacity constraints (Ge *et al.*, 2011). The coverage of each partition and the sites of the charging stations were repeatedly amended to develop a feasible output of the charging station area (ibid.). Similar to the Voronoi area models above, the grid partition approach is a stochastic methodology, which means it integrates a series of randomly selected variables as defining parameter conditions (e.g., distance to EVSE from starting point, availability of EVSE during certain hours, desirability of EVSE due to other social factors such as amenities nearby). This type of methodology has been used to generate exploratory research in differing EV fleet scenarios (Rahman *et al.*, 2016; Wang *et al.*, 2016; Mohsenzadeh *et al.*, 2017). For example, a facility location model for electric taxi charging stations in Seoul, South Korea considered the placement of EVSEs assuming key variables dividing the jurisdiction ought to include itinerary-interception and queue delay; this approach was adopted as an innovative approach suggesting EVSE locations on the basis that an emerging shared mobility economy will alter charging needs among drivers and users of shared EVs (Jung *et al.*, 2014).

In the outputs prepared below, CUTRIC has adopted a stochastic approach in some respective, integrating the random parameter of a 150 metre walking limit for employees as well as a ranking of "rich" versus "poor" amenities nearby to proposed EVSE locations. These paramters have helped to identify "optimal" charging locations across Oxford based on the needs of drivers rather than the driving ranges of cars, or other technical car-related needs.

Household activity data considerations in EVSE placement in local communities

Household activity data have also been used to determine optimal EVSE site location planning in some jurisdictions. A study in Seattle, Washington followed respondents over two consecutive weekdays in which the respondents had to keep a travel diary. Diary documentation collected thereafter resulted in 3,700 traffic analysis zones generated based on people's actual travel patterns (Chen *et al.*, 2013) (ibid.). Parking locations (by parcel, then aggregated by traffic analysis zones) and durations of parking periods were determined for all trips away from home and for all stops that were at least 15 minutes in duration (as research assumed a 15-minute stop over period as a base minimum justifying a potential EVSE installation in the future). Parking duration information was used to formulate demands for land-use and parking to frame individual trip characteristics (ibid.).

The outcome of this study resulted in a computer-generated map with areas demonstrating the highest "demand" potential for charging stations for the 80 allocated stations across 900 traffic analysis zones within 10 miles of the city's downtown core (ibid.).

A similar study could be completed in the Oxford County jurisdictions. It would require a survey-based methodology in which residents are asked to keep travel logs and diaries over an extended period of time to generate evidence of mobility, traffic and transportation patterns. Such a study is outside the scope of the present Report, but it is certainly worth considering as a future empirical exercise in the County if officials require additional evidence to justify publicly-funded EVSE installations in the future.

EVSE usage in small communities: Key outcomes to consider in making EVSE placement choices

Electric vehicle uptake in some urban communities (including Toronto) has grown exponentially over the past 36 months. In addition, new makes and models by various automotive manufacturers are being released on a near quarterly basis as of late-2017, which has resulted in more consumer choice in battery technologies, range performance, and vehicle characteristics overall.

The following sub-section provides a few examples of the EVSE deployment in small communities similar to Oxford County. The purpose of this section is to explore the costs associated with chargers and other installation considerations that drive municipal siting criteria.

Tompkins County: An example of installation cost considerations in EVSE siting choices

Tompkins County is located in the state of New York and has a population of approximately 105,000 residents (United States Census Bureau, 2016). Installation costs for an EVSE at different sites around Tompkins County were found to vary from $2,000 to $12,500 USD depending on site-specific characteristics and installation variables (Energetics, 2017).

Charging stations can either be mounted on a concrete base for a free-standing pedestal unit or mounted onto an existing structure for a wall unit. The material the charging station is installed upon will affect cost (e.g., pavement, concrete sidewalk, dirt) based on the ease for which the EVSE conduit can be built. Increased distances between the charging station location and electric box will increase the costs through additional construction requirements. The state of the electrical service or panel must also be assessed and upgraded to support EVSE's where necessary (ibid.).

Tompkins County also installed preventative measures against accidental vehicular damage when installing EVSEs. Existing structures could be utilized, such as curbs, or charging stations could be mounted at an elevated spot on the wall. In some cases, Tompkins County opted to install either a tire stop (costing approximately $350 USD per space) or bollards ($1,000 USD each) in front of the charging station to protect it (ibid.).

Advertisement and signage to users should also be considered when installing EVSEs. Adequate signage is necessary to regulate how charging stations are used, by clearly marking the spot as an EV-only parking spot, advertising who sponsors the station. Businesses could use this to their advantage to attract EV customers to demonstrate sustainability objectives, and to create awareness for non-EV drivers. Signage of this nature was found to add up to an additional $500 to the total station cost (ibid.).

Most commercial charging station models can be networked, which means the station utilizes cellular communications to report and track real-time data from the charging station. Networked stations cost more to purchase due to additional cellular communication modules which allow for the sending and receiving of information. This feature adds $1,000 USD to the installation cost to verify the site has sufficient cellular signal and the activation and verification of proper communication (ibid.).

Following installation, EVSEs require ongoing expenses, which include network fees, electricity, and maintenance. Networking fees cover the required cellular data plan and services to maintain the networking features, and are approximately $300 USD per charging port per year. Additional transaction fees for billing EV drivers are not included in the $300 USD estimation. Ongoing station maintenance costs are unique to each location and usage patterns, but if properly cared for (e.g., coiling the cord, occasionally wiping it clean, and clearing and snow or debris accumulated around the base) only minor repairs should be required costing less than $1,000 USD over the 10-year lifespan of the station (ibid.).

Preliminary monitoring data from installed EVSEs in Tompkins County showed that on average, one charge event dispended about $1.00 USD of electricity to an EV, which equals to approximately 7.7 kWh at an electricity rate of $0.13 USD per kWh. In the state of New York, 700 charging ports are monitored by the New York State Energy Research and Development Authority, and findings conclude there is an average of 2.5 charging events per week per port. This frequency translates into approximately 150 charging events per year, costing each site $150 USD in electricity (ibid.).

The Tompkins County study estimates total costs for the installation of Level 2 charging stations for the first year at different sites with varying characteristics and found costs ranging between $11,250 and $23,400 USD (ibid.). Given the variance in the costs, it becomes evident that optimal EVSE installation is not only dependent upon broader criteria, but is also very dependent upon placement at a given location based on existing infrastructures.

San Joaquin Valley: An example of ad hoc EV driver needs in EVSE siting criteria and considerations

The San Joaquin Valley Air Pollution Control District and the San Joaquin Valley Plug-in Electric Vehicle Coordinating Council (PEVCC) have identified optimal locations for public EVSEs in ten Valley cities based on three different siting categories: fast charging infrastructure, public access charging, and workplace charging (San Joaquin Valley Air Pollution Control District, 2014).

To determine optimal locations for fast charging, sites had to be located within a half-mile of a highway exit, easily accessible, well-lit, offering facilities and shelters for drivers while charging along with a “destination” point. The types of destinations chosen based on those criteria were supermarkets, department stores, shopping malls, restaurants and short-term parking spots at airports. The locations should also be equipped with transformers with a capacity to support fast chargers alongside existing parking availability (ibid.).

Public access charging sites were chosen in urban areas and destinations where drivers could park their vehicle for more than one hour. This assessment included locations that attract out-of-town visitors (e.g., art galleries, zoos, museums and amusement parks) and places where community members often visit (e.g., libraries, universities and parks). After assessing travel survey data, the following places were determined to attract drivers to travel “medium-to-long” distances from their home, and remain parked for at least one hour, which was deemed to be generally sufficient time to charge an EV using a Level 2 charger to complete a return trip home (ibid.). Examples of locations that involve a service or entertainment worthy of an extended (i.e., one hour or more) wait time may include:

- Airport
- Amusement park
- Aquarium
- Art gallery
- Campground
- Hospital
- Library
- Local government office
- Lodging
- Movie theater
- Casino
- Dentist’s office
- Department or big-box store
- Doctor’s office
- Grocery store or supermarket
- Restaurant
- Shopping mall
- Stadium
- Train station
- University

- Museum
- Park
- Zoo

Workplace charging stations were sited by assessing the number of employees within travel analysis zones, where zones with more employees were assumed to contain higher numbers of current or future EV drivers at the workplace (ibid.).

Uppsala: An application of GIS modelling in predicting optimal EVSE siting locations

A thesis study conducted in the City of Uppsala, Sweden, used GIS mapping to determine optimal EVSE locations for three cases: slow charging stations, fast charging stations and charging alongside roads. Slow charging stations were assumed to provide public charging within city regions while cars were parked for elongated periods. Demand for this type of charging would be in pre-existing parking lots close to where residents live or work. Input data to ArcGIS include road grids, parking areas, and residential statistics (Lindblad, 2012).

Fast charging stations are assumed to have the highest suitability when located close to heavily trafficked roads. The input data for this case included road grids, electric grids (to assess capacities to support fast charging), suitable stops, and traffic density. Medium to fast charging systems were sited based on their ability extend EV range alongside roads and key highway routes and roads. The input data for this case included road grids, electric grids, suitable stops, and popular EV model ranges (ibid.).

Another example of GIS site suitability analysis emanates from the Los Angeles County GIS analysis. The study identified the most efficient placement of Level 3 stations included government offices, public libraries, and public parks within a half-mile radius of a highway. This siting criterion enabled easy travel from one end of the county to the other and an ability to ease range anxiety for interregional and intraregional commutes (Shengji Jin, 2016).

Optimal locations for Level 2 chargers at public libraries and parks have been derived from demographics related to EV owners indicating a majority of EV owners are middle-aged, possess a bachelor's degree or higher, and have a relatively high household income. Therefore, public libraries and parks within neighborhoods of residents fitting this demographic profile were chosen as ideal for Level 2 charger installation (ibid.).

Lastly, Level 2 chargers have been recommended for installation at Los Angeles County government offices since workplaces are the second more frequently utilized charging location (after home charging). The study recommended the Los Angeles County government could purchase and install chargers at all government offices as an exemplary workplace initiative (ibid.).

Other U.S. examples of optimal EVSE location selection criteria

Prominent studies emanating from the U.S. Department of Energy, as well as plug-in electric vehicle (PEV) infrastructure studies and demonstrations, include "The EV Project" and the "ChargePoint America Project" which, combined, form the largest PEV infrastructure demonstration in the world. The two projects installed 17,000 EVSEs between 2011-2013, in 22 regions across the U.S., comprised of both Level 2 and Level 3 EVSEs. The projects were not only created to install EVSEs, but to also monitor their usage patterns and develop lessons learned that could be applied to future deployment of PEVs and charging infrastructure (Francfor *et al*., 2015). The following is a summary of main findings, which inspired CUTRIC's descriptive analysis.

Optimal location considerations

The study concluded that an overwhelming majority of charging was done at home and work, with about half of the project participants exclusively charging their EVs at home. Even though the vast majority of charging occurs at residential or workplace EVSEs, it does not mean that public charging stations are not necessary or desirable. Some fast charging stations experienced heavy use and allowed for intra and inter-city driving. Although these stations did not experience frequent usage, the charging provided to the driver was very important to that driver's commute (Francfor *et al*., 2015).

A small number of Level 2 chargers drew consistently high usages and were located in areas where cars were parked for a while, including shopping malls, airports, commuter lots, and downtown parking lots of garages with easy access to a variety of venues. Conversely, some Level 2 EVSEs installed in locations perceived as optimal had surprisingly low usage. It was therefore very difficult to pinpoint exact criteria for optimal placement of EVSEs across regions and seemed to be more dependent upon community-specific factors (ibid.)

The stated results indicate that a ubiquitous charging network (similar to ubiquitous gasoline and diesel fueling stations) are not required in the future to support wide-spread EV adoption and/or optimized long-range driving.

The studies demonstrated charging episodes and infrastructure will be clustered at homes, workplaces, and in public "hot spots". Installation of public charging stations were found to be more expensive than residential or workplace units with large installation cost variance in different regions and venues. The report authors conclude the cost and usage patterns associated with publicly available EVSEs underscore the fact the bulk of chargers should be installed at homes and workplaces with additional public chargers installed *only* at strategic points in the transportation network (ibid.).

Installation costs assessment

The installation costs for a public Level 2 charger ranged from $600 to $12,660 USD, with an average cost of $3,108 USD. The costs were primarily dependent on the distance between the facility's electric panel and the charging station, and these costs varied regionally due to labour rates. Workplace charger installations averaged $2,223 USD per unit, which is 28 per cent less than the average public Level 2 charger cost. This difference in cost was attributed to increased flexibility at workplaces to choose optimal locations for the charging station and the type of equipment needed. However, employers found that once all of the optimal charging station installation sites were taken, prices increased quite a bit for less ideal spots (Francfor *et al*., 2015).

Installation costs for Level 3 chargers were between $8,500 to over $50,000 USD, with an average cost of $22,626 USD. Many of the DCFC installations required additional electrical services to support the 60-kW power rating and requirement for 480-volt outputs, creating significant increases to the installation costs (ibid.).

Charging patterns assessments

The study also monitored whether EV owners typically used Level 2 or Level 3 chargers when charging away from their home, and it was found that drivers of the Chevy Volt used Level 2 chargers half the time and Level 1 charging the other half of the time (either from a dedicated charging station or a standard 120-volt outlet). For Nissan Leaf owners, only eight per cent of charging events away from home were done using Level 3 chargers, and the rest were done with Level 1 or 2 chargers (Francfor *et al*., 2015).

Workplace charging behaviors were also 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. There was also an observed common courtesy and willingness from employees to follow practices such as plugging in a neighboring EV for charging after unplugging their own fully charged EV. These behaviors led to high charging station usage in certain workplaces and allowed for a large number of employees to regularly charge their vehicles (ibid.).

Summary

The studies documented above have helped CUTRIC identify several location siting variables to invoke when assessing optimal EVSE placement in Oxford County based on driving behavioural patterns (expected), EV make and model needs for charging support, and charging location appropriateness based on equi-distance or "gap" filling in an EVSE matrix locally and based on ad hoc parameters such a walking and driving distance and/or amenities nearby.

The placement of electric vehicle supply equipment (EVSE) across the Level 1 to Level 3 system spectrum requires a comprehensive consideration of all of these variables – to the extent possible, with the data sources currently available – in Oxford County. As more data become available over time, this analysis can be reiterated to refine the locational optimization of EVSEs not yet installed in the community.

In the next sections of this Report, we document the predictive and descriptive outcomes associated with mapping EVSE siting locations based on the following factors:

1. Predicted increases in EV uptake by commuters (varied types) and tourists
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 serving amenities and/or workplaces